Dental and Medical Problems

QUARTERLY ISSN 1644-387X (PRINT) ISSN 2300-9020 (ONLINE) www.dmp.umed.wroc.pl

2018, Vol. 55, No. 4 (October–December)

Ministry of Science and Higher Education – 11 pts.
Index Copernicus (ICV) – 109.28 pts.

Wroclaw Medical University

Dental and Medical Problems

ISSN 1644-387X (PRINT) ISSN 2300-9020 (ONLINE) www.dmp.umed.wroc.pl

QUARTERLY
2018, Vol. 55, No. 4
(October–December)

"Dental and Medical Problems" is a peer-reviewed open access journal published by Wroclaw Medical University and Polish Dental Society. Journal publishes articles from different fields of dentistry and other medical, biological, deontological and historical articles, which were deemed important to dentistry by the Editorial Board – original papers (clinical and experimental), reviews, clinical cases, and letters to the Editorial Board.

Address of Editorial Office
Marcinkowskiego 2–6
50-368 Wrocław, Poland
Tel.: +48 71 784 11 33
E-mail: dental@umed.wroc.pl

Publisher
Wroclaw Medical University
Wybrzeże L. Pasteura 1
50-367 Wrocław, Poland

Polish Dental Society
ul. Krakowska 26
50-425 Wrocław, Poland

Online edition is the original version of the journal

Editorial Policy

During the review process, the Editorial Board conforms to the "Uniform Requirements for Manuscripts Submitted to Biomedical Journals: Writing and Editing for Biomedical Publication" approved by the International Committee of Medical Journal Editors (http://www.icmje.org/). Experimental studies must include a statement that the experimental protocol and informed consent procedure were in compliance with the Helsinki Convention and were approved by the ethics committee.

Indexed in: MEDLINE, Scopus, GFMER, Index Copernicus, Ministry od Science and Higher Education, CiteFactor, WorldCat, Directory of Research Journal Indexing.

This publication has been co-financed by the Ministry of Science and Higher Education.

Typographic design: Monika Kolęda, Piotr Gil
Cover: Monika Kolęda
DTP: Wroclaw Medical University Press
Printing and binding: EXDRUK

Dental
and Medical Problems

QUARTERLY 2018, Vol. 55, No. 4 (October–December)

ISSN 1644-387X (PRINT)
ISSN 2300-9020 (ONLINE)
www.dmp.umed.wroc.pl

Contents

Clinical cases

Dental
and Medical Problems

Kwartalnik, 2018, tom 55, nr 4 (październik–grudzień)

ISSN 1644-387X (PRINT)
ISSN 2300-9020 (ONLINE)
www.dmp.umed.wroc.pl

Spis treści

Prace kazuistyczne

Acknowledgements

We would like to express our gratitude to all reviewers who devoted their time and expertise to evaluate manuscripts in "Dental and Medical Problems." We sincerely appreciate all your hard work and dedication. It is due to your contribution that we can achieve the standard of excellence.

Editors

Reviewers in 2018:

Akira Aoki, Teresa Bachanek, Wojciech Bednarz, Einar Berg, Marek Bochnia, Marek Bolanowski, Maria Chomyszyn-Gajewska, Ewa Czochrowska, Beata Dejak, Elżbieta Dembowska, Marzena Dominiak, Barbara Dorocka-Bobkowska, Omar El-Moway, Katarzyna Emerich, Thomas Gedrange, Hanna Gerber, Ludmiła Halczy-Kowalik, David Herrera, Michał Jeleń, Urszula Kaczmarek, Milan Kaminek, Beata Kawala, Andrzej Kiejna, Kazimierz Kobus, Tomasz Konopka, Marcin Kos, Jolanta Kostrzewa-Janicka, Jan Kowalski, Marcin Kozakiewicz, Tadeusz F. Krzemiński, Natalia Lewkowicz, Mariusz Lipski, Monika Łukomska-Szymańska, Piotr Majewski, Irena Makulska, Agnieszka Mielczarek, Marcin Mikulewicz, Justyna Opydo-Szymaczek, Halina Pawlicka, Lidia Postek-Stefańska, Małgorzata Radwan-Oczko, Monique-Marie Rousset-Caron, Ingrid Różyło-Kalinowska, Teresa Sierpińska, Krzysztof Simon, Jerzy Sokalski, Jerzy Sokołowski, Adam Szeląg, Danuta Waszkiel, Andrzej Wojtowicz, Piotr Wójcicki, Grażyna Wyszyńska-Pawelec, Anna Zalewska, Marek Ziętek

Comparative evaluation of the early effects of the low-level laser therapy versus intra-articular steroids on temporomandibular joint acute osteoarthritis in rats: A histochemical, molecular and imaging evaluation

Ocena porównawcza wczesnej reakcji na laser małej mocy w odniesieniu do dostawowego podawania steroidów w ostrym zapaleniu stawów skroniowo-żuchwowych u szczurów – badanie histochemiczne, molekularne i obrazowe

Nermeen AbuBakr[A–F], Zeinab Salem[B–F], Zoba Ali[A,B,D–F], Manal El Assaly[A,C–F]

Department of Oral Biology, Faculty of Dentistry, Cairo University, Egypt

A – research concept and design; B – collection and/or assembly of data; C – data analysis and interpretation;
D – writing the article; E – critical revision of the article; F – final approval of the article

Dental and Medical Problems, ISSN 1644-387X (print), ISSN 2300-9020 (online) *Dent Med Probl.* 2018;55(4):359–366

Address for correspondence
Nermeen AbuBakr
E-mail: nermeen.abubakr@dentistry.cu.edu.eg

Funding sources
None declared

Conflict of interest
None declared

Acknowledgements
The authors would like to thank Dr. Ahmed Abdalsamad, Assistant Professor at the Department of Oral and Maxillofacial Radiology, Faculty of Dentistry at Cairo University, Egypt, for his help and technical support.

Received on August 8, 2018
Reviewed on September 14, 2018
Accepted on September 25, 2018

Published online on December 31, 2018

Cite as
AbuBakr N, Salem Z, Ali Z, El Asaaly M. Comparative evaluation of the early effects of the low-level laser therapy versus intra-articular steroids on temporomandibular joint acute osteoarthritis in rats: A histochemical, molecular and imaging evaluation. *Dent Med Probl.* 2018;55(4):359–366. doi:10.17219/dmp/96290

DOI
10.17219/dmp/96290

Abstract

Background. Osteoarthritis (OA) is a serious degenerative joint disease. It is one of the main causes of disability in the world. Current treatment modalities have numerous side effects. Subsequently, health experts are looking for alternative therapies.

Objectives. The aim of the study was to evaluate the early effects of low-level laser therapy (LLLT) vs intra-articular (IA) corticosteroids (CS) on acute temporomandibular joint osteoarthritis (TMJOA).

Material and methods. Sixty rats were divided into 3 groups: group 1– untreated OA; group 2 – OA treated with CS; and group 3 – OA treated with LLL. Half of the animals in each group were sacrificed at 1 and 4 weeks post treatment. The temporomandibular joint was dissected and evaluated histochemically, using quantitative real-time polymerase chain reaction (qRT-PCR), and radiographically.

Results. Histochemically, Safranin-O staining revealed an obvious reduction in proteoglycans in the untreated osteoarthritic group. However, both of the treated groups showed a moderate increase in glycosaminoglycan (GAG) staining. As for the qRT-PCR results, caspase-3 showed the highest mean value in the untreated OA group, followed by the CS group, while the lowest mean value was recorded in the LLL group. Radiographically, the condyle showed erosion, flattening, osteophyte formation, and sclerosis in the untreated group, but there was great improvement in both of the treated groups.

Conclusions. Both laser and cortisone showed reparative and formative effects, as evidenced by the increases in the proteoglycan content. However, LLL was superior in its anti-apoptotic effects. Cone beam computed tomography (CBCT) is a valuable tool in assessing osseous abnormalities.

Key words: osteoarthritis, temporomandibular joint, glucocorticoids, low-level laser therapy, caspase-3

Słowa kluczowe: zapalenie stawów, staw skroniowo-żuchwowy, glikokortykosteroidy, terapia laserem małej mocy, kaspaza-3

Introduction

Osteoarthritis (OA) is a degenerative disease that commonly affects the temporomandibular joint (TMJ). It is identified by the disintegration of the articular cartilage and the underlying subchondral bone. Progressive disintegration of TMJ limits basic daily activities, such as talking and chewing. It also causes discomfort, joint pain, limitation in mandibular movements, and stiffness. This eventually leads to the deterioration of the patient quality of life.[1]

Degradation in cartilage collagens and proteoglycans leads to fibrillation and fissures in the superficial layer of the cartilage. This spreads to deeper layers and finally expands to form erosion.[2] Apoptotic cell death of chondrocytes has been detected in the osteoarthritic cartilage. This is associated with matrix degeneration and calcification.[3]

Temporomandibular joint osteoarthritis (TMJOA) can be diagnosed both clinically and radiographically. The clinical symptoms are mainly tenderness and pain. The radiographic signs include cortical bone erosion, flattening of joint compartments and bony changes, such as sclerosis and osteophyte formation.[4]

It was proven in the 1940s that corticosteroids (CS) had strong anti-inflammatory properties. Both natural and synthetic steroids have become the most commonly used anti-inflammatory medications worldwide.[5] However, repeated intra-articular (IA) CS injections cause pain, blushing of the skin, swelling at the injection site, and an increased risk of infection.[6] The available forms of IA drug delivery usually necessitate repeated injections, which generates high costs and affects the patient quality of life.[7]

Due to its non-invasiveness and the advantage of provoking nearly no adverse effects, low-level laser therapy (LLLT) has been broadly used to alleviate pain in many musculoskeletal disorders.[8] It is considered a promising therapeutic intervention, mostly because of its stimulatory effects on tissue metabolism and the ability to regulate the inflammatory process after injury. Other effects include better cellular oxygenation, the release of neurotransmitters associated with pain modulation, and the release of anti-inflammatory and endogenous mediators.[9]

The PubMed and Google Scholar search results from 2008 to 2018 showed that the assessments of the therapeutic effects of LLLT on OA in previous clinical studies were focused mainly on monitoring the improvement in mandibular movements and pain reduction. Previous studies assessed the late effects of LLLT and CS on chronic joint disorders. No radiographic studies have been performed to assess the improvement in bony structures after LLLT. Previous comparisons were made between laser and systemic CS.

The aim of the study was to use an experimental animal model to accurately estimate the early effects of LLLT vs local injections of CS on acute TMJOA. This was assessed histochemically, on a molecular basis and radiographically.

Material and methods

Ethical statement

All the experiments were conducted in the animal house at the Faculty of Medicine at Cairo University, Egypt, in accordance with the recommendations and with the approval of the Ethics Committee on Animal Experimentation of the Faculty of Dentistry at Cairo University (approval No.16/9/15).

Animals

Sixty healthy adult female albino rats, approx. 3–6 months old and weighing about 180–200 grams were used in this study. The animals were housed in a sterile, controlled environment (temperature 23 ±5°C; 12-hour dark/light cycles). They were fed with a standard pellet diet and tap water ad libitum. They were kept individually in stainless steel cages. The animals were randomly distributed into 3 groups of 20 animals each, as shown in Table 1.

Induction of osteoarthritis

To induce OA in the TMJ of the rats, a single IA injection of 2 mg/joint of monosodium iodoacetate – MIA (Sigma-Aldrich Chemical Co., St. Louis, USA) dissolved in 50 µL sterile 0.9% saline was administered into the right TMJ of each rat.[10]

Confirmation of osteoarthritis induction

After 7 days, blood samples were collected once from all the animals. We used the orbital sinus blood sample collection method as one of the general commonly accepted methods of blood collection, approved by the Ethics Com-

Table 1. Experimental groups

Study design	Group 1 (OA)	Group 2 (CS)	Group 3 (LLL)
Number of rats	20	20	20
OA induction	IA injection of 2 mg of MIA		
Treatment	no treatment	IA injection of dexamethasone	LLLT
Date of sacrifice	1 and 4 weeks after OA confirmation	1 and 4 weeks after dexamethasone administration	1 and 4 weeks after LLLT

CS – corticosteroid; IA – intra-articular; LLL – low-level laser; LLLT – low-level laser therapy; MIA – monosodium iodoacetate; OA – osteoarthritis.

mittee on Animal Experimentation. It yields a moderate to large volume of blood. It is rapid and sterile samples can be obtained. It was performed by inserting a heparinized capillary tube gently but firmly at the medial canthus of the eye into the retro-orbital plexus for the biochemical estimation of C-reactive protein (CRP). The normal CRP value reported in previous studies was 300–600 µg/mL. The animals presenting CRP levels above normal were included in our study.[11] In our experiment, the mean CRP value ± standard deviation (SD) in the rats was 722.8 ±0.57 µg/mL.

Dexamethasone administration

Seven days after the induction of OA, the animals in group 2 were sedated and given a single IA injection of 1.2 mg/kg dexamethasone (Amriya Pharmaceutical Industries, Alexandria, Egypt).[12]

Laser application

For laser irradiation, an Epic™ 10 indium gallium arsenide phosphide (InGaAsP) system laser (Biolase, Irvine, USA) was used. The rats in group 3 received mild chloroform sedation and the tissue over the TMJ region, 5–10 mm posterior to the lateral eye canthus, was irradiated. Seven sessions of 60 s of low-level laser (LLL) were performed every other day during a 2-week period. The physical parameters shown in Table 2 were selected in accordance with a study performed by Khozeimeh et al.[13] The laser was applied at 3 points: the capsule, the retrodiscal area and the condylar neck.[14]

Animal sacrifice and tissue preparation

The animals were sacrificed by intraperitoneal injections of 500 mg/kg sodium pentobarbital, as approved by the Ethics Committee on Animal Experimentation.[15] The temporomandibular joint was then dissected. The tissues were preserved in 10% neutral buffered formalin for 24 h, then dehydrated in ascending grades of ethyl alcohol, immersed in xylene, and embedded in paraffin wax. Sections about 3–4-micrometer-thick were prepared.

Table 2. The parameters of the laser device

Characteristics	Explanation
Laser type	InGaAsP diode laser
Brand	Biolase
Model number	Epic 10
Wavelength	940 nm
Operation mode	continuous wave
Power output	0.2 W
Spot size	300 µm
Energy	4 J
Irradiation time	20 s/point

InGaAsP – indium gallium arsenide phosphide.

Investigation techniques

Histochemical examination (Safranin-O staining)

Safranin-O, used in the articular cartilage staining, binds to glycosaminoglycans (GAGs) and shows an orange-red color. The intensity of the staining demonstrates the proteoglycan content in the cartilage tissue – a deep red color represents a normal cartilage, while orange and faint red colors represent a loss of proteoglycans.

Quantitative real-time polymerase chain reaction for caspase-3 expression

The mRNA expression level was quantified by quantitative real-time polymerase chain reaction (qRT-PCR). From each sample 1000 ng of the total RNA was used for complementary DNA (cDNA) synthesis by reverse transcription, using a high-capacity cDNA reverse transcriptase kit (Applied Biosystems, Foster City, USA). Complementary DNA was subsequently amplified with a Syber Green I PCR Master Kit (Fermentas, Waltham, USA) in a 48-well plate, using a Step One instrument (Applied Biosystems) as follows: 10 min at 95°C for the enzyme activation, followed by 40 cycles of 15 s at 95°C, 20 s at 55°C and 30 s at 72°C for the amplification step. Changes in the expression of each target gene were normalized in regard to the mean critical threshold (CT) values of the glyceraldehyde-3-phosphate dehydrogenase – *GAPDH* housekeeping gene, using the ΔΔCt method. We used 1 µM of both of the primers specific for each target gene. The primer sequences and annealing temperatures specific for each gene are presented in Table 3.

Cone beam computed tomography examination

The head of a rat, stored in a plastic container filled with formalin, was placed on the ProMax® 3D Mid CBCT machine (Planmeca Oy, Helsinki, Finland), located at the Department of Oral and Maxillofacial Radiology, Faculty of Dentistry at Cairo University, with the use of laser guiding beams. The rat's head was imaged using the following parameters: 90 kVp, 10 mA, field of view (FOV) of 4 cm × 5 cm, and resolution of a voxel size of 100 µm, at an exposure time of 12 s. The CBCT images were

Table 3. Primer sequences and annealing temperatures specific for each gene

Target gene	Primer sequence: 5′–3′	Gene bank accession number
Caspase-3	forward: TGACAGCCAGTGAGACTTGG reverse: GACTCTAGACGGCATCCAGC	NM004346.3
GAPDH	forward: CACCCTGTTGCTGTAGCCATATTC reverse: GACATCAAGAAGGTGGTGAAGCAG	XR598347.1

GAPDH – glyceraldehyde-3-phosphate dehydrogenase.

acquired in the Digital Imaging and Communications in Medicine (DICOM) format and assessed using a Romexis Viewer v. 4.6.2.R (Planmeca Oy). On the axial image, the long axis of the sagittal image was aligned to pass along the long axis of the condyle in an anteroposterior direction, so the sagittal image became a true sectional image aligned with the direction of the condyle. Sagittal images of 1-millimeter thickness were used to assess various bony changes affecting the condyle (Fig. 1).

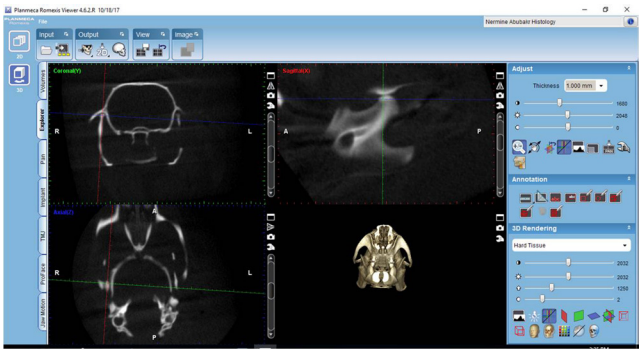

Fig. 1. A photomicrograph showing the method by which the condyle was imaged using cone beam computed tomography (CBCT)

Statistical analysis

Values were presented as mean and SD. Data was checked for normality, using the Kolmogorov–Smirnov test of normality. The results indicated that most of the data was normally distributed (parametric data); therefore, the one-way analysis of variance (ANOVA) test was used to compare between the groups. This was followed by Tukey's post hoc test when the difference was found to be significant. The unpaired *t*-test was used to compare the same treatment group on the 2 observation dates. The significance level was set at $p < 0.05$. The statistical analysis was performed using the SPSS v. 16.0 software for Windows (IBM Corp., Armonk, USA).

Results

Histochemical results (Safranin-O staining)

Group 1 (untreated osteoarthritis)

At 1 week: Safranin-O staining showed a moderate reduction in GAG staining, presented as a faint red color, distributed along the fibrocartilage layer of the temporal bone, disc and condyle. Some areas of a generalized loss in GAG staining, presented as an orange color, were observed in the cartilage layer of the condyle (Fig. 2A).

At 4 weeks: Safranin-O staining showed an obvious reduction and a generalized loss in proteoglycan staining, presented as an orange color and distributed along the fibrocartilage layer of the temporal bone, disc and condyle (Fig. 2B).

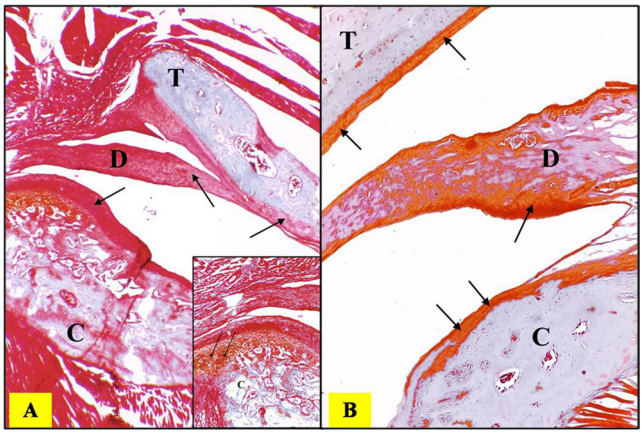

Fig. 2. A photomicrograph of the sagittal section of the temporomandibular joint (TMJ) from the untreated osteoarthritis (OA) group: A – 1 week, showing a moderate reduction in glycosaminoglycan (GAG) staining, presented as a faint red color (arrows) (Safranin-O, ×40); inset – an obvious reduction in GAG staining, seen as an orange color (arrows) (Safranin-O, ×100); B – 4 weeks, showing an obvious reduction in GAG staining, presented as an orange color (arrows) (Safranin-O, ×100)

C – the condyle; D – the disc; T – the temporal bone.

Group 2 (intra-articular corticosteroids)

At 1 week: Safranin-O staining of the cartilaginous extracellular matrix appeared fairly homogenous, with moderate GAG staining, presented as a red color along the fibrocartilage layer of the temporal bone, disc and condyle (Fig. 3A).

At 4 weeks: Safranin-O staining showed a moderate increase in GAG staining, appearing as a red color in the fibrocartilage layer of the temporal bone, disc and condyle (Fig. 3B).

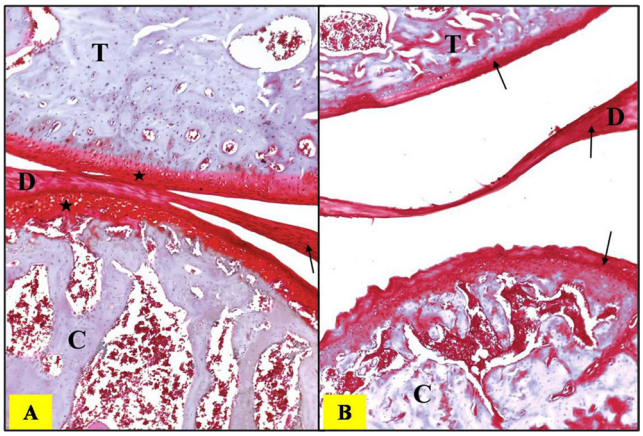

Fig. 3. A photomicrograph of the sagittal section of TMJ from the corticosteroid (CS) group: A – 1 week, showing moderate and homogenous staining, presented as a red color (asterisks and arrow); B – 4 weeks, showing a moderate increase in GAG staining, presented as a red color (arrows) (Safranin-O, ×100)

Group 3 (low-level laser therapy)

At 1 week: Safranin-O staining showed a uniform moderate increase in GAG staining, presented as a red color seen in the fibrocartilage layer of the temporal bone, disc

and condyle. Areas of weak staining, appearing as an orange color, were observed in the condylar head, just beneath the fibrous covering (Fig. 4A).

At 4 weeks: Safranin-O staining of the cartilaginous GAG was intense and homogenous, presenting as a deep red color along the fibrocartilage layer of the temporal bone, disc and condyle, indicating intact aggrecan content (Fig. 4B).

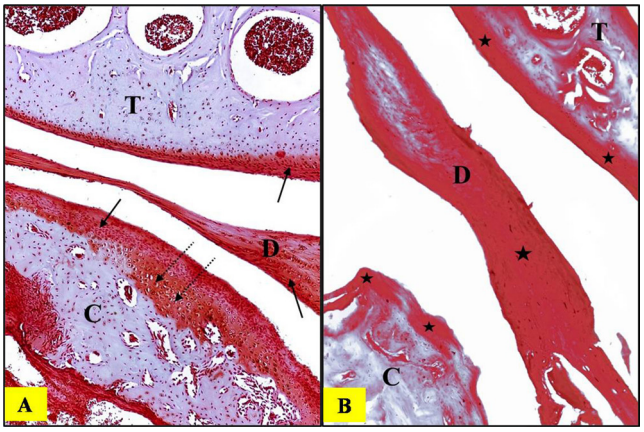

Fig. 4. A photomicrograph of the sagittal section of TMJ from the low-level laser (LLL) group: A – 1 week, showing a moderate increase in GAG staining, presented as a red color (arrows); areas of weak staining appearing as an orange color (dotted arrows) were observed; B – 4 weeks, showing an intense increase in GAG staining, presented as a deep red color (asterisks) (Safranin-O, ×100)

Quantitative real-time polymerase chain reaction results (caspase-3)

At both 1 and 4 weeks, the highest mean value was recorded in the untreated OA group, followed by the CS group; the lowest value was recorded in the LLL group. The ANOVA test revealed that the differences between the 3 groups were highly statistically significant (p = 0.001) at week 1; at week 4, the differences were extremely statistically significant (p < 0.0001). Tukey's post hoc test revealed no significant difference between the CS and LLL groups (Tables 4,5).

Cone beam computed tomography examination results

The sagittal images obtained by CBCT revealed erosion, flattening in the articular surface of the condylar head and osteophyte formation in the untreated OA group at week 1 (Fig. 5A). At week 4, sclerosis was observed in the condylar head (Fig. 5B). In the CS group, at week 1, erosion was observed in the condylar head (Fig. 5C); at week 4, minimal sclerosis was observed (Fig. 5D). As for the LLL group, at week 1, minimal erosion was observed in the condylar head (Fig. 5E); at week 4, minimal sclerosis was observed (Fig. 5F).

Table 4. Caspase-3 relative quantitation at 1 week (ANOVA test)

Groups		Mean	SD
1 week	OA1	3.37[a]	0.17
	CS1	2.71[b]	0.45
	LLL1	2.37[b]	0.17
F-value		14.573	
p-value		0.001*	

SD – standard deviation; * statistical significance (p < 0.05); Tukey's post hoc test – means sharing the same superscript letter are not significantly different.

Table 5. Caspase-3 relative quantitation at 4 weeks (ANOVA test)

Groups		Mean	SD
4 weeks	OA4	3.63[a]	0.24
	CS4	2.64[b]	0.35
	LLL4	2.27[b]	0.13
F-value		37.948	
p-value		<0.0001*	

* statistical significance (p < 0.05); Tukey's post hoc test – means sharing the same superscript letter are not significantly different.

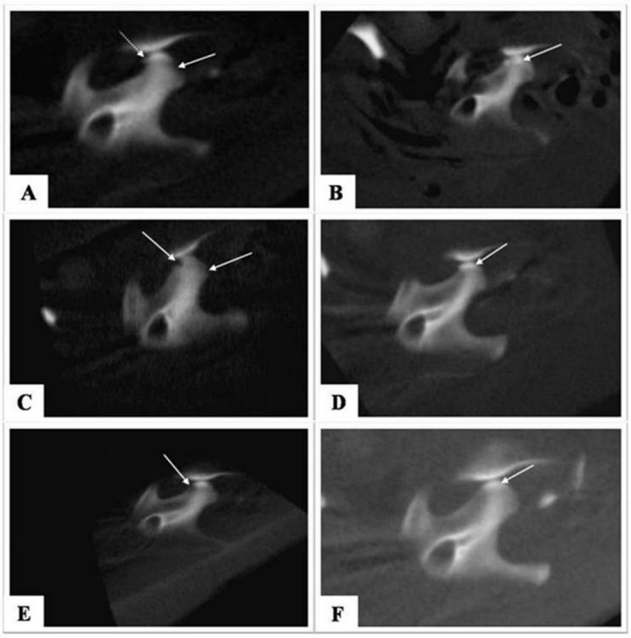

Fig. 5. The sagittal section of the condyle: A – the untreated OA group, 1 week, showing erosion and flattening in the condylar head (arrow) and osteophytes (dotted arrow); B – the untreated OA group, 4 weeks, showing sclerosis in the condylar head (arrow); C: the CS group, 1 week, showing erosion in the condylar head (arrows); D – the CS group, 4 weeks, showing minimal sclerosis (arrow); E – the LLL group, 1 week, showing minimal erosion in the condylar head (arrow); F – the LLL group, 4 weeks, showing minimal sclerosis in the condylar head (arrow)

Discussion

Due to the expanding predominance of OA and the absence of cure, it is becoming an increasing burden for countries worldwide. Therefore, enhancements in the prevention and treatment of the disease are urgently

needed. Human clinical studies have many limitations. The unexpected and slow course of the disease and the late appearance of clinical symptoms in human patients prevents precise investigation of the structural changes and molecular events within the joint. In our study, we used an in vivo preclinical animal model to accurately evaluate the early effects of LLLT vs CS on acute TMJOA – histochemically, on a molecular basis and radiographically. Without the use of animal models, the limitations inherent to clinical trials would hinder the ongoing progress in learning about and treating the disease.[16]

In the current study, we used MIA to induce OA. The IA injection of MIA resulted in the disorganization of the articular cartilage by hindering the activity of *GAPDH* in chondrocytes. This eventually led to the disruption of glycolysis and cell death. These chondrocytes have nearly identical histopathology as compared to human OA. The MIA-induced OA animal model almost exactly mimics the pain and structural changes accompanying the disease in human patients.[17]

We started treatment 7 days after the confirmation of OA. Guzman et al. observed extensive chondrocyte degeneration and the collapse of the cartilaginous matrix with a marked loss of chondrocyte by 5 or 7 days.[17]

The confirmation of OA induction in our study was performed through a biochemical analysis of CRP. Several studies have proven the presence of a relationship between CRP and OA, in which the elevated values of acute phase proteins, especially CRP, were correlated with the disease. C-reactive protein is widely accepted as a clinical measure of disease activity. Its use as a marker of arthritic disease has been supported in many studies. Connolly et al. reported that the CRP values were significantly higher in arthritic rats than in normal controls,[11] which concurred with the results obtained in our study.

In our experiment, dexamethasone was used as a standard, traditional way to treat OA. Corticosteroids are gold standard anti-inflammatory agents. Their effects are mediated through binding to the glucocorticoid receptor, which translocates from the cytoplasm to the nucleus and binds to glucocorticoid response elements. This regulates the transcription of certain genes, thus reducing pro-inflammatory cytokine synthesis.[18]

Low-level laser therapy is a treatment modality that has been used as alternative to the traditional CS treatment. It has an extensive variety of effects at the molecular, cellular and tissular levels. Within the cell, LLLT increases the adenosine triphosphate (ATP) production in the mitochondria, modulates reactive oxygen species (ROS) and induces transcription factors. These transcription factors synthesize proteins that trigger more downstream effects, such as increased cell proliferation, migration and tissue oxygenation, and the modulation of the levels of cytokines, growth factors and inflammatory mediators.[19]

The articular cartilage is made of chondrocytes and extracellular matrix, consisting mainly of proline, hydroxyproline, phenylalanine, GAGs, and proteoglycans. Using Safranin-O, a detailed cartilage histology is shown. The concentration and intensity of the red staining of the articular cartilage measures the GAG content.[20]

Our histochemical results coincide with those of Wang et al., who observed cartilage degeneration following the IA injection of MIA, detectable as a loss of Safranin-O staining, indicating a reduction in GAGs in the cartilage and a reduction in chondrocytes.[10]

Our findings are also in agreement with a study by Lu et al., in which the CS treatment had a protective effect on the articular cartilage in models of OA.[21]

Gottlieb et al. evaluated the influence of LLLT on the proteoglycan content in the arthritically changed cartilage in animals and found that the changes in the irradiated joints were less severe, and that LLLT accelerated the metabolic rate in the hyaline cartilage and increased proteoglycan synthesis.[22] This was compatible with the findings of our study.

Regarding the qRT- PCR results, the apoptotic marker caspase-3 showed the highest value in the untreated osteoarthritic group. This is consistent with a study of discectomy-induced TMJOA conducted by Kourí-Flores et al., who demonstrated that gene expression of the death receptor family and immuno-histochemical staining of caspase-3 revealed the caspase-dependency of the apoptotic process was.[23]

This is also in agreement with Chagin et al., who observed chondrocyte apoptosis on day 1 after the MIA injection. Condylar apoptosis reached a peak on day 3, resulting in the hypocellular changes in the cartilage and disc. They found that chondrocyte apoptosis in the early stages was an essential initiator of cartilage disintegration.[24]

In our study, the caspase-3 values decreased in both of the treated groups. These findings coincide with Lee et al. who reported that dexamethasone had an anti-apoptotic effect on gentamicin-induced ototoxicity.[25] The protective mechanism involved hindering the mitochondrial apoptosis pathway and the down-regulation of the pro-apoptotic protein Bax.[25]

Our results are also in agreement with Lin et al., who demonstrated that LLLT improved the cartilage structure, prevented articular cartilage disintegration and noticeably reduced the expression of caspase-3 in a surgery-induced OA model in rabbits.[26]

In our study, we used CBCT to evaluate bony changes in TMJ. Since the early 1980s, computed tomography (CT) has been one of the most preferred modalities of imaging for assessing the osseous changes in the condyle, temporal bone, and other articulating and non-articulating surfaces in TMJ. The accuracy of CT in detecting osseous changes is as high as 87%. The images were obtained in the sagittal plane, which is desirable for the assessment of osteophytes, erosion, flattening, and sclerosis.[27]

In our study, in the untreated osteoarthritic group, the condyle revealed erosion, flattening of the articular surface of the condylar head and osteophyte formation at

1 week. At 4 weeks, sclerosis was observed. This concurs with a study conducted by Wang et al., in which erosion was observed at 1 and 2 weeks after OA induction.[10] However, osteophytes were observed at 4 weeks and sclerosis at 8 weeks.[10] This was attributed to the fact that MIA-induced arthritis progressed in a dose-dependent manner. The higher the dose, the greater and faster the destruction. In our study, OA was induced by the IA injection of 2 mg/joint of MIA, while in the study by Wang et al., a lower dose (0.5 mg/joint) was used. The temporal bone presented with nearly no changes compared to the condyle. This resembles the radiographical evaluation performed by Mani and Sivasubramanian, who reported that the condylar bony changes were greater than the temporal bone changes.[28]

In our study there was a great improvement in both the CS- and LLL-treated groups. These findings are in accordance with Ringold et al., who found that patients receiving IA CS therapy showed improvement in CT images in a follow-up analysis.[29] No radiographic studies were performed to assess improvement in bony structure after LLLT. However, its effectiveness in improving mandibular movements and in reducing pain have been proven clinically in many studies.[30]

More animal studies are required to determine the ideal physical parameters of LLLT, such as duration, energy doses and frequency. Also, recent investigatory methods must be used to assess the therapeutic effects of LLL in treating OA with a long-term follow-up. In addition, more experiments are needed to study the combined early effect of both glucocorticoids and LLL in treating acute OA.

Conclusions

From our study, it was concluded that using the present laser parameters, LLLT was as effective as dexamethasone in its formative effects, as indicated by an increase in proteoglycan synthesis. However, LLLT was superior in its anti-apoptotic effects. An in-depth radiological evaluation is important to assess disease activity, and to help plan the treatment modality and monitor the therapeutic response.

References

1. Kim JH, Ok SM, Heo JY, et al. The clinical and radiographic features of patients with temporomandibular joint osteoarthritis: Comparison of adolescents and middle-old aged Koreans. *J Oral Med Pain*. 2014;39:2–9.
2. Breedveld FC. Osteoarthritis – the impact of a serious disease. *Rheumatol*. 2004;43(Suppl 1):i4–8.
3. Galanti C, Musumeci G, Valentino J, Giunta S, Castorina S. A role for apoptosis in temporomandibular joint disc degeneration. A contemporary review. *Ital J Anat Embryol*. 2013;118:151–158.
4. Cho BH, Jung YH. Intra- and interobserver agreement of computed tomography in assessment of the mandibular condyle. *Korean J Oral Maxillofac Radiol*. 2007;37:191–195.
5. Clark AR, Belvisi MG. Maps and legends: The quest for dissociated ligands of the glucocorticoid receptor. *Pharmacol Ther*. 2012;134:54–67.
6. Stephens MB, Beutler AI, O'Connor FG. Musculoskeletal injections: A review of the evidence. *Am Fam Physician*. 2008;78:971–976.
7. Mountziaris PM, Kramer PR, Mikos AG. Emerging intra-articular drug delivery systems for the temporomandibular joint. *Methods*. 2009;47:134–140.
8. Huang Z, Ma J, Chen J, Shen B, Pei F, Kraus VB. The effectiveness of low-level laser therapy for nonspecific chronic low back pain: A systematic review and meta-analysis. *Arthritis Res Ther*. 2015;17:360.
9. Herman JH, Khosla RC. In vitro effects of Nd:YAG laser radiation on cartilage metabolism. *J Rheumatol*. 1988;15:1818–1826.
10. Wang XD, Kou XX, He DQ, et al. Progression of cartilage degradation, bone resorption and pain in rat temporomandibular joint osteoarthritis induced by injection of iodoacetate. *PLoS ONE*. 2012;7:e45036.
11. Connolly KM, Stecher VJ, Pruden DJ. Effect of auranofin on plasma fibronectin, C reactive protein, and albumin levels in arthritic rats. *Ann Rheum Dis*. 1988;47:515–521.
12. El-Hakim IE, Abdel-Hamid IS, Bader A. Temporomandibular joint (TMJ) response to intra-articular dexamethasone injection following mechanical arthropathy: A histological study in rats. *Int J Oral Maxillofac Surg*. 2005;34:305–310.
13. Khozeimeh F, Moghareabed A, Allameh M, Baradaran S. Comparative evaluation of low-level laser and systemic steroid therapy in adjuvant-enhanced arthritis of rat temporomandibular joint: A histological study. *Dent Res J*. 2015;12:215–223.
14. Mazzetto MO, Carrasco TG, Bidinelo EF, Pizzo RC, Mazzetto RG. Low intensity laser application in temporomandibular disorders: A phase I double-blind study. *Cranio*. 2007;25:186-192.
15. Steven L, Wendy U, Raymond A, et al. *AVMA Guidelines for the Euthanasia of Animals: 2013 Edition*. Schaumburg (IL): American Veterinary Medical Association; 2013.
16. Lampropoulou-Adamidou K, Lelovas P, Karadimas EV, et al. Useful animal models for the research of osteoarthritis. *Europ J Orthop Surg Traumatol*. 2014;24:263–271.
17. Guzman RE, Evans MG, Bove S, Morenko B, Kilgore K. Mono-iodoacetate-induced histologic changes in subchondral bone and articular cartilage of rat femorotibial joints: An animal model of osteoarthritis. *Toxicol Pathol*. 2003;31:138–139.
18. Clark AR. MAP kinase phosphatase 1: A novel mediator of biological effects of glucocorticoids? *J Endocrinol*. 2003;178:5–12.
19. Karu TI, Kolyakov SF. Exact action spectra for cellular responses relevant to phototherapy. *Photomed Laser Surg*. 2005;23:355–361.
20. Flahiff CM, Narmoneva DA, Huebner JL, Kraus VB, Guilak F, Setton LA. Osmotic loading to determine the intrinsic material properties of guinea pig knee cartilage. *J Biomech*. 2002;35:1285–1290.
21. Lu YC, Evans CH, Grodzinsky AJ. Effects of short-term glucocorticoid treatment on changes in cartilage matrix degradation and chondrocyte gene expression induced by mechanical injury and inflammatory cytokines. *Arthritis Res Ther*. 2011;13:R142.
22. Gottlieb T, Jörgensen B, Rohde E, Müller G, Scheller EE. The influence of irradiation with low-level diode laser on the proteoglycan content in arthritically changed cartilage in rabbits. *Med Laser Applicat*. 2006;21:53–59.
23. Kourí-Flores JB, Abbud-Lozoya KA, Roja-Morales L. Kinetics of the ultrastructural changes in apoptotic chondrocytes from an osteoarthrosis rat model: A window of comparison to the cellular mechanism of apoptosis in human chondrocytes. *Ultrastruct Pathol*. 2002;26:33–40.
24. Chagin AS, Karimian E, Zaman F, Takigawa M, Chrysis D, Sävendahl L. Tamoxifen induces permanent growth arrest through selective induction of apoptosis in growth plate chondrocytes in cultured rat metatarsal bones. *Bone*. 2007;40:1415–1424.
25. Lee JH, Oh SH, Kim TH, Go YY, Song JJ. Anti-apoptotic effect of dexamethasone in an ototoxicity model. *Biomater Res*. 2017;21:4.
26. Lin HD, He CQ, Luo QL, Zhang JL, Zeng DX. The effect of low-level laser to apoptosis of chondrocyte and caspases expression, including caspase-8 and caspase-3 in rabbit surgery-induced model of knee osteoarthritis. *Rheumatol Int*. 2012;32:759–766.

27. Westesson PL. Reliability and validity of imaging diagnosis of temporomandibular joint disorder. *Adv Dent Res*. 1993;7:137–151.
28. Mani FM, Sivasubramanian SS. A study of temporomandibular joint osteoarthritis using computed tomographic imaging. *Biomed J*. 2016;39:201–206.
29. Ringold S, Torgerson TR, Egbert MA, Wallace CA. Intraarticular corticosteroid injections of the temporomandibular joint in juvenile idiopathic arthritis. *J Rheumatol*. 2008;35:1157–1164.
30. Mazzetto MO, Hotta TH, Pizzo RC. Measurements of jaw movements and TMJ pain intensity in patients treated with GaAlAs laser. *Braz Dent J*. 2010;21:356–360.

Mandibular angle augmentation using solid silicone implants

Zwiększenie kąta żuchwy przy użyciu stałych implantów silikonowych

Badr Al-Jandan[1,A–F], Hesham Fathi Marei[1,2,C–F]

[1] Department of Biomedical Dental Sciences, College of Dentistry, Imam Abdulrahman Bin Faisal University, Dammam, Saudi Arabia
[2] Department of Oral and Maxillofacial Surgery, Faculty of Dentistry, Suez Canal University, Ismailia, Egypt

A – research concept and design; B – collection and/or assembly of data; C – data analysis and interpretation;
D – writing the article; E – critical revision of the article; F – final approval of the article

Dental and Medical Problems, ISSN 1644-387X (print), ISSN 2300-9020 (online) *Dent Med Probl.* 2018;55(4):367–370

Address for correspondence
Hesham F. Marei
E-mail: hesham.marei@yahoo.com

Funding sources
None declared

Conflict of interest
None declared

Acknowledgements
The author would like to thank the hospital staff who assisted during the surgeries.

Received on September 9, 2018
Reviewed on October 8, 2018
Accepted on November 2, 2018

Published online on December 27, 2018

Abstract

Background. The demand for facial esthetics has increased dramatically to overcome the ongoing aging process and/or improve facial appearance.

Objectives. The aim of this study was to evaluate the outcomes of using bilateral silicone implants for mandibular angle augmentation.

Material and methods. The study involved a prospective analysis of the outcomes of the mandibular angle region augmentation with bilateral silicone implants in 58 patients (2 males and 56 females) within 1 year. All the data was collected either from patients' interviews or their records, after receiving the ethical approval from the relevant hospital. The collected patients' data was analyzed based on 3 main outcomes: occurrence of implant displacement, presence of postoperative infection and patient satisfaction. Only the patients who completed a follow-up of 6 months postoperatively were included in this study.

Results. A total of 58 patients received bilateral silicone implants at the mandibular angle with a total of 116 implants, out of which 96 were found intact, with no evidence of complications. The total number of implants that were infected was 5 (4.3%), 16 implants were found displaced (13.8%) and only 3 patients of those without complications were dissatisfied with the final facial appearance (6%).

Conclusions. Using solid silicone implants in the augmentation of the mandibular angle resulted in low postoperative infection and displacement rates, as well as in high patient satisfaction.

Key words: reconstructive surgery, solid silicone implants, mandibular angle augmentation

Słowa kluczowe: chirurgia plastyczna, stałe implanty silikonowe, zwiększenie kąta żuchwy

Cite as
Al-Jandan B, Marei HF. Mandibular angle augmentation using solid silicone implants [published online as ahead of print on December 27, 2018]. *Dent Med Probl.* 2018;55(4):367–370. doi:10.17219/dmp/99531

DOI
10.17219/dmp/99531

Introduction

The demand for facial esthetics has increased dramatically to overcome the ongoing aging process and/or improve facial appearance.[1] With aging, changes occur in the face – the mandibular angle becomes greater in edentulous people as compared to the dentate ones,[2] which may lead to the sagging of the mandibular jowl area.

In the literature, there is a lack of cephalometric and clinical examination standards to evaluate the ideal mandibular angle length and projections. However, some of the favorable radiographic and clinical features of the ideal mandibular angle are as follows: the angle of the jaw should be long and low in profile, <105° when measuring the slope of the lower border and the ascending ramus on a lateral cephalometric radiograph. Clinically, frontal examination should show an equal bigonial and bitemporal distance in order to have the mandibular angle well-defined and easily noticeable from the neckline.[3,4]

The mandibular angle is an essential part of the skeletal framework; therefore, its correction plays an important role in maintaining and improving facial esthetics.[4] Multiple techniques and approaches have been described in the literature to address the sagging of the mandibular jowl area, with variable success rates. These techniques involve the injection of temporary fillers or the surgical placement of permanent alloplastic materials, such as polytetrafluoroethylene (PTFE) and solid silicone implants. Temporary fillers approved by the Food and Drug Administration (FDA) include collagen, hyaluronic acid, calcium hydroxyapatite, and polylactic acid. In the case of hyaluronic acid, the results are reversible with hyaluronidase. Although both PTFE and silicone implant materials are considered as inert permanent alloplastic materials, each one carries its indications, risks and benefits.[5–7]

Solid silicone (dimethylsiloxane, $SiO(CH_3)_2$) implants are easy to handle, have increased flexibility, can be sculpted,[8] and thus can be placed at the lateral mandibular ramus using small incisions. It has improved bone adaptability, which makes it easier to stabilize with titanium (Ti) screws. In contrast, a PTFE implant is rigid and stiff, and does not bend. Therefore, placing it in the bone requires larger incisions. Moreover, due to the stiff nature of PTFE, it is difficult to passively adapt it at the lateral mandibular ramus, so there are problems with stabilizing it.[9] Furthermore, the surface porosity of PTFE enables the soft tissue growth into the implant, which makes the implant difficult to remove, if indicated in the future. On the other hand, silicone implants create a capsule around them, which makes their removal easier, if needed.[9]

The surgical placement of silicone implants involves general complications, such as infection, seroma and hematoma. Moreover, in the cases of non-stabilized silicone implants, implant displacement and bone resorption were reported.[10,11] Currently, there is no consensus regarding the stabilization of implants and the required fixation devices (Ti screws vs non-resorbable sutures). It might be due to the fact that there are multiple specialists (maxillofacial, plastic, and head and neck) with a diverse training background referring to such a service. Maxillofacial surgeons tend to use screws for stabilization, whereas plastic surgeons commonly use sutures for stabilization, as indicated by previous studies.[9,12]

Since there is a deficit of studies that have analyzed the performance of silicone implants in the mandibular angle region, the aim of this study was to evaluate the outcomes of mandibular angle augmentation with the use of a silicone implant through a prospective evaluation of patients in regard to implant displacement, infection and patient satisfaction.

Material and methods

The study involved a prospective analysis of the records of 58 consecutive patients (2 males and 56 females), who had received bilateral silicone implants at the mandibular angle region within 1 year in 2 different hospitals. All the data was collected either from patients' interviews or from a specific data sheet that had been designed for this study. The data was collected after receiving the ethical approval from the relevant hospital. The inclusion criteria were as follows:

- the patient had been diagnosed with ill-defined mandibular angles and a narrow face;
- silicone implants were placed at the mandibular angle;
- the patient was medically fit;
- the patient was followed up for at least 6 months after the surgery.

All the patients received the surgical procedure by the same surgeon and the same surgical protocols were followed. All the procedures were performed under general anesthesia with nasoendotracheal intubation. Approximately 10 mL of 2% lidocaine with 1:100,000 epinephrine was injected along the incision site. A 1.5-centimeter incision was made 1 cm lateral to the external oblique ridge of the mandible. Next, subperiosteal dissection was performed to expose the lateral ramus of the mandible and superiorly to the level of the sigmoid notch. The entire lateral and inferior surface of the mandibular ramus was then exposed. A curved freer elevator instrument was used to disrupt the pterygo-masseteric sling at the inferior border of the mandible and to allow the silicone angle implant (Hanson Medical Inc., Kingston, USA) to be adapted easily below the inferior border and behind the posterior border of the mandible. The silicone implant was stabilized using 2 monocortical screws of 2 × 7 mm (Fig. 1). The wound was then irrigated with antibiotic solution (Gentamicin®, 40 mg in 100 mL solution) and closed with 2 layers using 4/0 Vicryl® sutures (Ethicon, Inc., Bridgewater, USA).

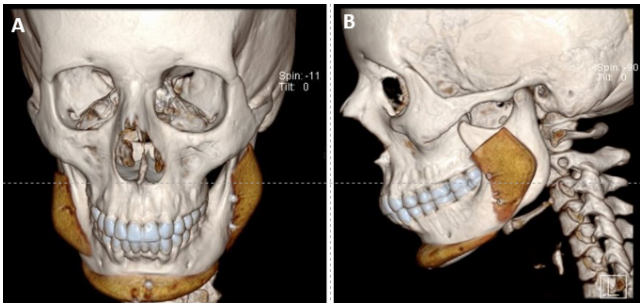

Fig. 1. Three-dimensional cone beam computed tomogram showing a solid silicone implant placed at the mandibular angle
A – frontal view; B – lateral view.

All the patients were administered Augmentin® (1 g twice daily for 1 week), Ibuprofen® (600 mg 4 times daily for 1 week) and chlorohexidine mouthwash for 2 weeks. The patients were reviewed according to the following protocol:
– the 1st follow up: 1–2 weeks;
– the 2nd follow-up: 3–4 weeks;
– the 3rd follow-up: 2–3 months;
– and the last follow-up: 6 months postoperatively.

During the follow-up visits, patients were evaluated by a second examiner (maxillofacial surgeon) for the following parameters:
– infection, which was demonstrated by fluctuation and pus discharge from the incision line;
– displacement of the silicone implant, which was established on the basis of facial asymmetry that was noticed by the patient and/or reported during examination by the surgeon;
– and satisfaction, which was reported by the patients as either 'yes' or 'no' after 6 months. Patient satisfaction was mainly based on the fulfillment of their expectations about the proposed treatment.

Results

In this study, a total of 58 patients (2 males and 56 females) received bilateral implant placement at the mandibular angle (Fig. 2) with a total of 116 implants, out of which 96 were found intact, with no evidence of complications.

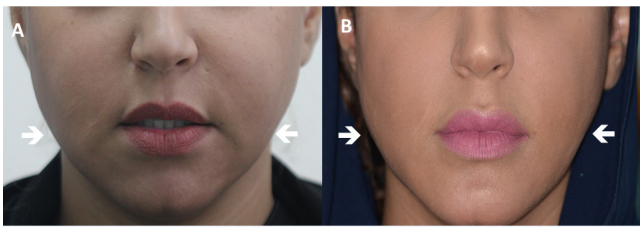

Fig. 2. A – preoperative frontal view; B – postoperative frontal view after submental liposuction, mandibular angle and chin augmentation using a solid silicone implant

Five implants in 3 different patients were infected; 4 of them had to be removed and 1 resolved after antimicrobial therapy and daily local wound care. The overall incidence of infection was 4.3%.

The total number of displaced implants was 16 in 8 patients, of which half required removal only and the other half required removal and replacement by another implant. The overall incidence of displacement was 13.8%.

In regard to patient satisfaction, only 3 patients out of those without complications (n = 50) were dissatisfied with the final outcome, with an overall satisfaction rate of 94%. Dissatisfied patients had intact mandibular angle implants with adequate facial symmetry, but still found that their expectations were not met.

Discussion

The current study investigated data of 58 patients who received 116 silicone implants by 1 surgeon following the same surgical protocol within 1 year with at least 6 months of follow-up. In an earlier study, it was reported that one of the complications associated with silicone implants was underlying passive bone remodeling and this claim was supported by the presentation of 4 cases of bone resorption after alloplastic chin augmentation (in 2 of them, silicone implants were used).[13] The probable reason of such a complication might be the fact that the implants were not stabilized with screws, which could lead to continuous micro-movement, and consequently to bone resorption.[10] In contrast, our study involved the stabilization of all the implants utilizing monocortical fixation screws, which was recommended previously.[9] Passive bone remodeling is a common process that occurs at the early stages after solid silicone implants have been placed, when the body attempts to confine the implants into the facial skeleton. However, this process might be continuous if the implants are not stabilized.[10] Absolute fixation of solid implants via a transoral approach requires the placement of at least 1 screw at each corner of the implant, which is clinically unachievable in such a way. However, this can be achieved via a transcutaneous approach, which may in turn carry unfavorable cosmetic outcomes. In addition, it makes the elective removal process quite complex if the patient is unsatisfied.

Ridwan-Pramana et al. placed 27 PTFE implants at the mandibular angle region and reported that 3 patients presented with infection (27%) and 2 patients remained unsatisfied with the outcome (18.2%).[5] By contrast, in our study, which had a 3 times bigger sample size, only 3 patients developed infection (4.3%) and only 3 patients were dissatisfied (6%). This is most likely due to the fact that the rigid and non-fixable nature of PTFE implants makes it difficult to place them and achieve good adaptation, whereas silicone implants are flexible,[8] and therefore can be properly adapted, leading to better patient satisfaction.

Previously, a review of 24 PTFE implants placed at the mandibular angle reported no infection from any implant and 1 implant (4.16%) got displaced.[13] Aynehchi et al. reported no displacement or infection in 105 patients who underwent the placement of silicone implants transorally via a vertical concise incision at the chin region with no fixation, over at least 1-year follow-up period.[14] Moreover, Gui et al. reported on 150 porous polyethylene implants (Medpore®) placed in the chin transorally and fixated with a screw. They observed no displacement during a follow-up from 6 months to 6 years.[15] In contrast to the abovementioned studies, the displacement rate in our study was 13.8%. The different rate of displacement could be due to the fact that the displacement of a facial implant is site-dependent and may vary according to the surrounding soft tissue, musculature and masticatory forces in this area.[16] Since there are high masticatory forces in the angle as compared to the chin region, the implant displacement rate in our study was higher than the reported displacement rate in the chin region.

Our study is not without limitations. It involved 58 patients who received only 1 type of facial implants and were followed up for a limited time. The literature would benefit from controlled studies comparing silicone implants with 2 or more types of facial implants at different facial regions. Within the limitation of this study, we found that bilateral silicone implants, when placed through concise transoral incisions and stabilized with 2 monocortical Ti screws, are an appropriate material that can augment the mandibular angle region with minimal complications and high patient satisfaction.

Conclusions

Low incidence of postoperative infections and a low displacement rate, along with high patient satisfaction were observed in the augmentation of bilateral mandibular angles with solid silicone implants.

References

1. D'souza R, Kini A, D'souza H, Shetty N, Shetty O. Enhancing facial aesthetics with muscle retraining exercises – a review. *J Clin Diagn Res*. 2014;8:9–11.
2. Engstrom C, Hollender L, Lindqvist S. Jaw morphology in edentulous individuals: A radiographic cephalometric study. *J Oral Rehabil*. 1985;12:451–460.
3. Ousterhout DK. Mandibular angle augmentation and reduction. *Clin Plast Surg*. 1991;18:153–161.
4. Aiache AE. Mandibular angle implants. *Aesthetic Plast Surg*. 1992;16:349–354.
5. Ridwan-Pramana A, Wolff J, Raziei A, Ashton-James CE, Forouzanfar T. Porous polyethylene implants in facial reconstruction: Outcome and complications. *J Craniomaxillofac Surg*. 2015;43:1330–1334.
6. Binder WJ, Azizzadeh B. Malar and submalar augmentation. *Facial Plast Surg Clin North Am*. 2008;16:11–32.
7. Constantinides MS, Galli SK, Miller PJ, Adamson PA. Malar, submalar, and midfacial implants. *Facial Plast Surg*. 2000;16:35–44.
8. Anger J, Alcalde RF, de Campos JR. The use of soft silicone solid implant molded intraoperatively for pectus excavatum surgical repair. *Einstein (São Paulo)*. 2014;12:186–190.
9. Niamtu J III. *Cosmetic Facial Surgery*. 1st ed. London, UK: Elsevier; 2011:369–433.
10. Polo M. Bone resorption under chin implants: The orthodontist's role in its diagnosis and management. *Am J Orthod Dentofacial Orthop*. 2017;151:201–208.
11. Hasson O, Levi G, Conley R. Late infections associated with alloplastic facial implants. *J Oral Maxillofac Surg*. 2007;65:321–323.
12. Terino EO, Edwards MC. Customizing jawlines: The art of alloplastic premandible contouring. *Facial Plast Surg Clin North Am*. 2008;16:99–122.
13. Yaremchuck MJ. Facial skeletal reconstruction using porous polyethylene implants. *Plast Reconstr Surg*. 2003;111:1818–1827.
14. Aynehchi BB, Burstein DH, Parhiscar A, Erlich MA. Vertical incision intraoral silicone chin augmentation. *Otolaryngol Head Neck Surg*. 2012;146:553–559.
15. Gui L, Huang L, Zhang Z. Genioplasty and chin augmentation with Medpore implants: A report of 650 cases. *Aesthetic Plast Surg*. 2008;32:220–226.
16. Carboni A, Cerulli G, Perugini M, Renzi G, Becelli R. Long-term follow-up of 105 porous polyethylene implants used to correct facial deformity. *Eur J Plast Surg*. 2002;25:310–314.

Volumetric upper airway changes following a new technique for Surgically-Assisted Maxillary Expansion (SAME)

Zmiany objętościowe górnych dróg oddechowych po zastosowaniu nowej techniki wspomaganego chirurgicznie poszerzania szczęki

Shadi Yazigi[1,A–F], Mazen Zenati[2,A–F], Rania Hadad[3,A–F]

[1] Department of Oral and Maxillofacial Surgery, Faculty of Dental Medicine, Damascus University, Syria
[2] Department of Oral and Maxillofacial Surgery, Faculty of Dentistry, Syrian Private University, Damascus, Syria
[3] Department of Orthodontics and Dentofacial Orthopedics, Faculty of Dental Medicine, Damascus University, Syria

A – research concept and design; B – collection and/or assembly of data; C – data analysis and interpretation;
D – writing the article; E – critical revision of the article; F – final approval of the article

Dental and Medical Problems, ISSN 1644-387X (print), ISSN 2300-9020 (online) *Dent Med Probl.* 2018;55(4):371–378

Address for correspondence
Shadi Yazigi
E-mail: shadiyazigi@gmail.com

Funding sources
None declared

Conflict of interest
None declared

Received on September 16, 2018
Reviewed on October 7, 2018
Accepted on October 23, 2018

Published online on December 31, 2018

Cite as
Yazigi S, Zenati M, Hadad R. Volumetric upper airway changes following a new technique for Surgically-Assisted Maxillary Expansion (SAME). *Dent Med Probl.* 2018;55(4):371–378. doi:10.17219/dmp/99158

DOI
10.17219/dmp/99158

Abstract

Background. Skeletal maxillary constriction (SMC) is one of the common skeletal discrepancies which are associated with alterations in the respiratory function. Today, many surgical techniques are used to expand the maxilla in adult patients with no consensus about the optimal technique.

Objectives. The present study aimed to investigate the changes of the upper airway volume resulting from the use of a new, minimally invasive surgically-assisted maxillary expansion (SAME) technique, and compare the results with the conventional SAME technique.

Material and methods. A prospective study was conducted between September 2015 and July 2018. A total of 28 adult patients (11 males, 17 females; mean age: 19.1 ±2.7 years) with SMC underwent SAME. The sample was divided according to the applied surgical technique into 2 groups: the conventional osteotomy SAME (CO-SAME) group consisted of 13 patients (18.7 ±2.2 years) and the selective osteotomy SAME (SO-SAME) group consisted of 15 patients (19.4 ±3.2 years). Cone beam computed tomography (CBCT) scans were initially obtained preoperatively (T1) and 3 months post expansion (T2). The upper airway was divided into 2 segments: retropalatal and retroglossal. The volume of each segment and the total airway volume (TAV) were assessed using the OnDemand3D® software.

Results. The total upper airway volume showed a significant increase after both CO-SAME and SO-SAME (1.29 ±0.26 cc and 1.21 ±0.19 cc, respectively), with significant increases in retropalatal and retroglossal airway volumes (RPAV and RGAV) after both CO-SAME and SO-SAME (RPAV – 0.73 ±0.10 cc and 0.83 ±0.10 cc, and RGAV – 0.56 ±0.23 cc and 0.38 ±0.23 cc, respectively). No significant differences were observed in the maxillary width (MW), TAV or RGAV between the 2 SAME techniques, whereas the increase in RPAV in the SO-SAME group was significantly greater than that of the CO-SAME group.

Conclusions. The new, minimally invasive SAME technique was an effective procedure to increase MW and the upper airway volume.

Key words: skeletal maxillary constriction, surgically-assisted maxillary expansion (SAME), upper airway volume

Słowa kluczowe: szkieletowe zwężenie szczęki, wspomagane chirurgiczne poszerzanie szczęki, objetość górnych dróg oddechowych

Introduction

Skeletal maxillary constriction (SMC) is a frequent component of malocclusions in non-syndromic patients.[1] Clinical features of SMC include a narrow palate, unilateral or bilateral posterior cross bite, dental crowding, and difficulty in nasal breathing.[2–4]

Several approaches are available to treat SMC, including rapid maxillary expansion (RME) and slow maxillary expansion (SME), which are successful in correcting this discrepancy in children aged up to 13–15 years, but they are inefficient after the ossification of the mid-palatal suture occurs. Surgically-assisted maxillary expansion (SAME) is indicated in patients who have already achieved maturity of the mid-palatal suture.[1–3]

Since the early 20th century, the SAME techniques have been developed with different osteotomies. Osteotomies of the zygomatic buttresses, the separation of the pterygomaxillary junction, the separation of the mid-palatal suture, or a combination of these procedures represent the most common techniques, as they involve the most common areas that resist maxillary expansion.[3]

Despite the effectiveness of SAME as a treatment for SMC, the literature provides no consensus about the minimum of osteotomies required for effective expansion.[3] Nevertheless, most authors agree that there is a need for a zygomatic buttress osteotomy.[3,5] However, the tendency is toward minimally invasive surgery.[6]

The relationship between SMC and respiratory problems, such as obstructive sleep apnea, has received increasing attention in the recent literature.[4,7,8] The volume of air passing through the nose and the nasopharynx is limited by the shape and diameter of the latter.[9] Some authors observed SMC in patients who presented with constricted nasopharyngeal dimensions and altered the respiratory function.[9]

Maxillary expansion procedures widen the nasal floor and reduce the resistance to airflow, with a positive influence on the respiratory function.[7] Angell first proposed RME as a treatment for respiratory disturbances in the 19th century.[acc.10]

Today, various studies show nasal respiratory improvement after SAME and RME, and these have used a lot of methodologies to evaluate nasal airflow, such as acoustic rhinometry,[11] rhinomanometry,[11,12] and tomography evaluation.[13–15]

There are few studies in the literature that show the effect of SAME on the upper airway and compare the influence of different SAME techniques on the upper airway dimensions.[7,16,17] Therefore, the aim of this study was to show the effects of a new, minimally invasive SAME technique on the upper airway dimensions, and compare the results with the conventional SAME technique using cone beam computed tomography (CBCT).

Material and methods

Study design

A prospective study was conducted between September 2015 and July 2018 at the Department of Oral and Maxillofacial Surgery and the Department of Orthodontics and Dentofacial Orthopedics, Faculty of Dental Medicine of Damascus University, Syria.

The study protocol was approved by the Ethics Committee of Damascus University at the Ministry of Higher Education of Syria (protocol No. 51). Written informed consent was obtained from each participant and/or their legal representative, as appropriate.

Sample size estimation

The sample size was calculated using the Minitab® v. 16.2.1 software (Minitab, Inc., State College, USA) in accordance to a study by Günbay et al.,[18] who observed an increase in the maxillary width (MW) (5.25 ±1.46 mm) after SAME, which is the most important variable that confirms maxillary expansion. The following assumptions were used: the statistical test was the sample *t*-test with a statistical power of 90% and a significance level of 0.05. The sample size of at least 26 patients was necessary (13 patients for each group). Taking into consideration sample attrition, additional 2 patients were added to each group, which made the total sample size of 30 patients (15 patients for each group).

Ultimately, we eliminated 2 patients because of the inability to follow up throughout the observation period. Eventually, data from 28 patients were used for the statistical analysis.

Patient selection

Patients were selected from the Department of Orthodontics and Dentofacial Orthopedics at Damascus University. The study sample included 28 adult patients: 17 women (60.7%) and 11 men (39.3%) aged 17–28 years (19.1 ±2.7 years). The inclusion criteria were as follows: adult normal healthy patient – according to the American Society of Anesthesiologists (ASA) classification,[19] SMC > 5 mm – according to the Ricketts analysis,[5] and age >16 years.[5] The exclusion criteria were as follows: systemic disease, syndromes, maxillofacial deformities, previous maxillofacial trauma, previous orthodontic treatment, and/or previous maxillofacial surgery.

According to the surgical protocol that was undertaken, the patients were divided into 2 groups: the conventional osteotomy SAME technique (CO-SAME) group, which included 13 patients (9 females, 4 males; mean age: 18.7 ±2.2 years), and the selective osteotomy SAME technique (SO-SAME) group, which included 15 patients (8 females, 7 males; mean age: 19.4 ±3.2 years) .

Surgical interventions

All surgical procedures were done under local anesthesia, 2% lidocaine with 1/80,000 epinephrine (Kwang Myung Pharm Co., Ltd., Seoul, South Korea), and all osteotomies were accomplished with a piezo-surgical device (Implant Center; SATELEC, ACTEON Equipment, Mérignac, France) at the voltage of 100-115-230V 50/60 Hz and ultrasonic frequency of 28–36 kHz.

In the CO-SAME group, the osteotomy technique protocol followed the methods reported by Bierenbroodspot et al.[20] Briefly, a bilateral LeFort-1 osteotomy extended from the piriform rims anteriorly, through the zygomatic buttress, to the tuberosity area posteriorly, 5 mm above the apices of the maxillary teeth with 2 para midline palatal osteotomies (Fig. 1,2).

In the SO-SAME group, the osteotomy technique protocol followed the methods reported by de Freitas et al.,[21] involving bilateral zygomatic buttress osteotomies (Fig. 3). The first author of the present study added bilateral nasal buttress osteotomies (Fig. 3) and modified a palatal osteotomy by adding a V-shaped midline osteotomy (Fig. 4) to ensure a complete mid-palatal suture separation and a full disjunction between the maxilla and the nasal septum.

The hyrax® tooth-borne expanders (DENTAURUM GmbH & Co., Ispringen, Germany) were used for all the patients. After a latency period of 3 days, the patients started activating the expander twice a day as follows: 2 turns in the morning and 2 turns in the evening, corresponding to an expansion rate of 0.88 mm per day, until adequate expansion was achieved. At the end of the active expansion phase, the hyrax screw was stabilized for 3 months with a stainless-steel ligature wire and a flowable composite.

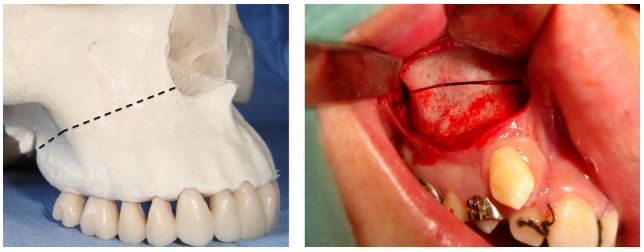

Fig. 1. LeFort-1 osteotomy 5 mm above the apices of the maxillary teeth

Fig. 2. Two para midline palatal osteotomies

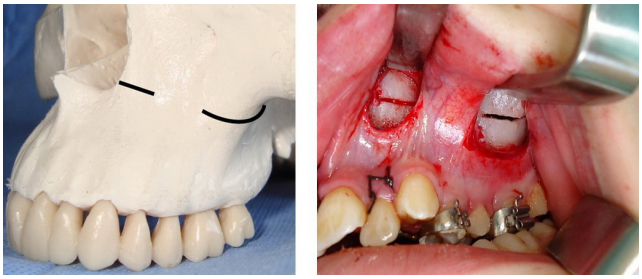

Fig. 3. Zygomatic and nasal buttress osteotomies

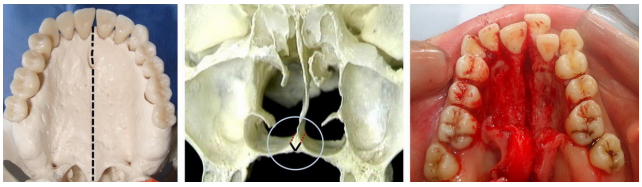

Fig. 4. V-shaped midline osteotomy

Outcome measures

Cone beam computed tomography scans were done for all the patients before the operation (T1) and 3 months after expansion (T2), and all CBCT scans were performed using the same device (SCANORA®; SOREDEX, Tuusula, Finland) with 85 kV, 15 mA and the exposure time of 2.25 s. The field of view (FOV) was 13.5 × 17 cm and the voxel size was 0.3 mm. All the Digital Imaging and Communications in Medicine (DICOM) data was processed with the OnDemand3D® software, the 1.0.8.0408 edition (Cybermed, Inc., Tustin, USA).

Each patient was seated in a chair with their Frankfort horizontal plane parallel to the floor and asked to hold their breath after the end of expiration, without swallowing. This patient position ensures a static pharyngeal airway size, which can be recorded consistently in all CBCT scans.

For more accuracy, measurements were performed after all CBCT images were oriented to the midsagittal view (the horizontal axis passing through the anterior and posterior nasal spine – ANS and PNS) (Fig. 5) and to the axial view (the vertical axis passing through ANS and PNS) (Fig. 6).

The maxillary width was calculated and compared pre- and post-expansion. To calculate MW, all CBCT images were standardized at the level of the first molar furcation on the axial dimension (Fig. 7). The deepest points in the concavity of the posterior maxilla were identified on the right and left sides. The maxillary width was measured along the line connecting these 2 points (Fig. 8).

The upper airway volume was defined as the airway volume between the 2 planes: the superior plane, defined on the midsagittal slice as the horizontal line extending from PNS to the basion (called the P-plane), and the inferior plane, defined as the horizontal line passing through the most superior point of the epiglottis and parallel to the P-plane (called the EP-plane).

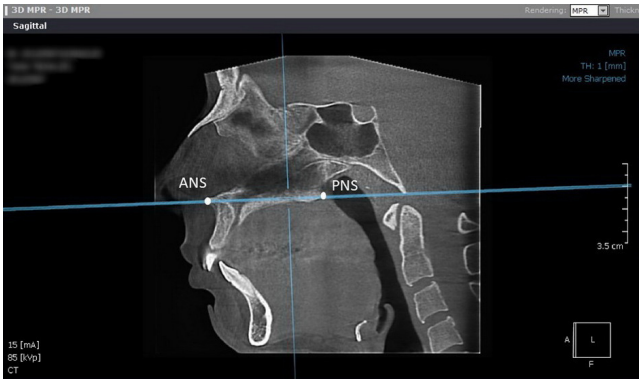

Fig. 5. Horizontal axis passing through the anterior (ANS) and posterior nasal spine (PNS)

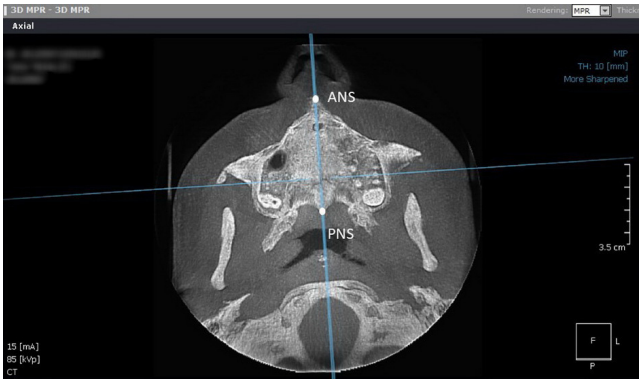

Fig. 6. Vertical axis passing through ANS and PNS

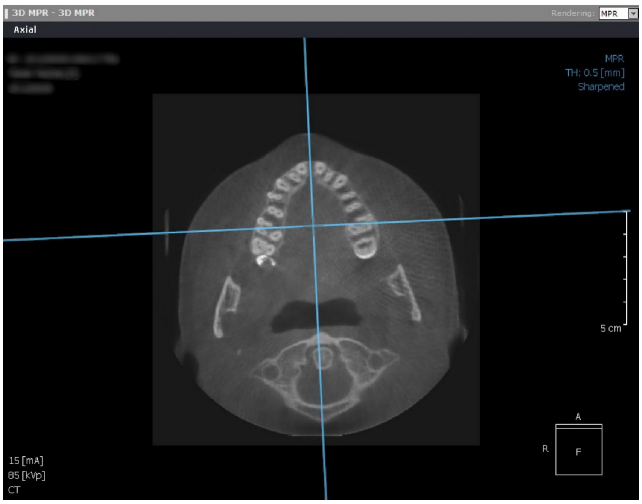

Fig. 7. Horizontal axis passing through the first molar furcation on both sides

The upper airway was divided into 2 segments to further evaluate the effects of SAME. The superior segment or retropalatal airway was limited superiorly by the P-plane and inferiorly by a horizontal plane passing through the most posteroinferior point of the soft palate and parallel to the P-plane (called the SP-plane). The inferior segment or retroglossal airway was extended from the SP-plane to the EP-plane (Fig. 9).

As a first step, we calculated total airway volume (TAV) using the OnDemand3D software. Then in the next step, we calculated retropalatal airway volume (RPAV), then we subtracted RPAV from TAV to obtain retroglossal airway volume (RGAV) (Fig. 10,11).

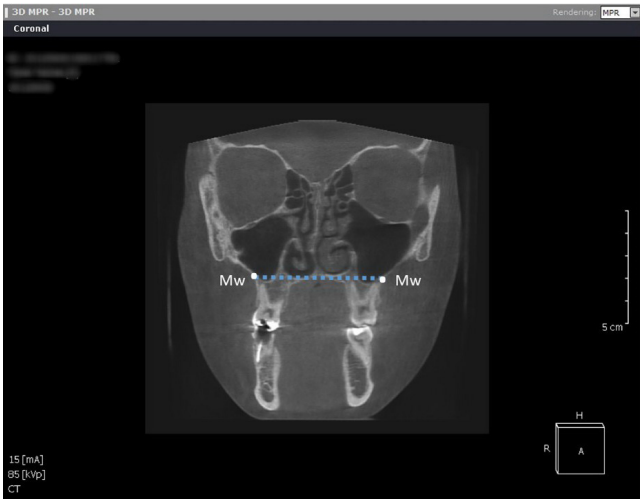

Fig. 8. Linear measurement of the maxillary width (MW)

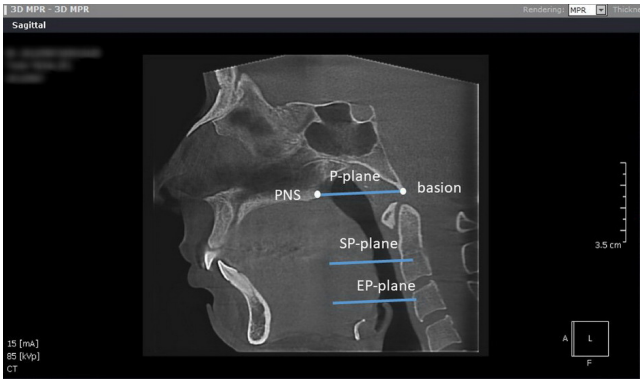

Fig. 9. Total upper airway, retropalatal and retroglossal borders

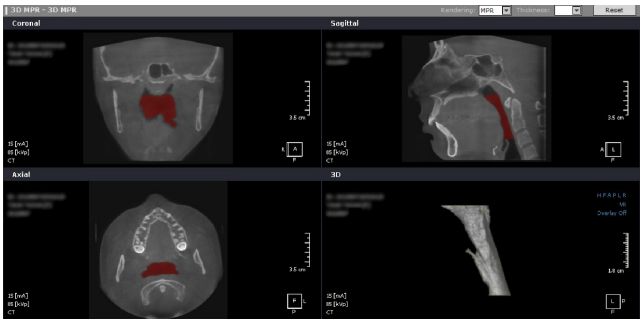

Fig. 10. Total upper airway volume (TAV)

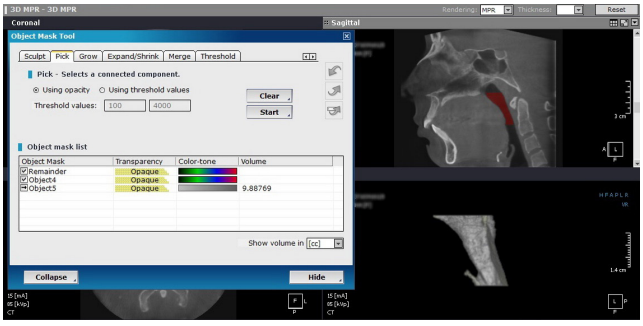

Fig. 11. Retropalatal airway volume (RPAV)

Reliability of measurements

Ten CBCT images were randomly chosen from the sample. The landmarks were identified, and MW, TAV and RPAV were calculated. All 10 CBCT images were traced again 4 weeks later. The error of the measurements was calculated by means of the intraclass correlation coefficient (ICC) for single measurements; this is an expression of intra-observer reliability. An ICC value >0.75 indicates excellent reliability. The ICC values were between 0.992 and 1 (Table 1).

Statistical analyses

The SPSS v. 13.0 software for Windows (IBM Corp., Armonk, USA) was used for statistical analyses. According to the Kolmogorov–Smirnov test, the data was normally distributed. Descriptive statistical methods (mean, standard deviation – SD) and pre-/post-expansion data were compared using the sample *t*-test. The results were evaluated at the significance level of $p < 0.05$ and a 95% confidence interval (CI).

Results

Statistically significant differences between the 2 periods (T1 and T2) were observed for each of the values – TAV, RPAV and RGAV in the CO-SAME group (1.29 ±0.26 cc, 0.73 ±0.10 cc and 0.56 ±0.23 cc, respectively), and also in the SO-SAME group (1.21 ±0.19 cc, 0.83 ±0.10 cc and 0.38 ±0.23 cc, respectively) (Table 2).

The retropalatal airway volume was significantly greater than RGAV after both CO-SAME and SO-SAME (Table 3). There were no significant differences in MW ($p = 0.790$), TAV ($p = 0.315$) and RGAV ($p = 0.052$) between the 2 techniques, whereas RPAV in the SO-SAME group was significantly greater than that of the CO-SAME group ($p = 0.015$) (Table 4).

Table 1. The intraclass correlation coefficient (ICC) values between the values in 2 readings

Second variable	Studied variable	First variable (values in the 1st reading)	Reproducibility
		ICC value	
Values in the 2nd reading	MW [mm]	0.998	Excellent
	RPAV [cc]	0.992	Excellent
	RGAV [cc]	1.000	Excellent
	TAV [cc]	0.997	Excellent

ICC – intraclass correlation coefficient; MW – maxillary width; RPAV – retropalatal airway volume; RGAV – retroglossal airway volume; TAV – total airway volume.

Table 2. Paired sample Student's *t*-test results between the 2 studied periods (before expansion, after 3 months) according to the studied technique

Studied variable	Studied technique	Studied period	N	Mean	SD	Min	Max	Mean difference	*t*-value	*p*-value
MW [mm]	SO-SAME	before expansion	15	52.89	2.67	49.70	57.70	4.09	36.329	0.000*
		after 3 months	15	56.98	2.69	53.40	61.30			
	CO-SAME	before expansion	13	52.15	2.01	49.10	55.60	4.05	42.227	0.000*
		after 3 months	13	56.19	1.94	53.00	59.80			
RPAV [cc]	SO-SAME	before expansion	15	9.07	0.78	7.85	10.23	0.83	32.903	0.000*
		after 3 months	15	9.90	0.79	8.83	11.22			
	CO-SAME	before expansion	13	9.57	1.14	7.98	11.46	0.73	26.426	0.000*
		after 3 months	13	10.30	1.14	8.51	12.13			
RGAV [cc]	SO-SAME	before expansion	15	6.14	0.95	4.68	7.46	0.38	6.445	0.000*
		after 3 months	15	6.52	0.96	4.90	7.89			
	CO-SAME	before expansion	13	5.87	1.19	4.13	8.88	0.56	8.611	0.000*
		after 3 months	13	6.43	1.14	4.93	9.21			
TAV [cc]	SO-SAME	before expansion	15	15.22	1.49	12.84	17.52	1.21	24.016	0.000*
		after 3 months	15	16.42	1.50	13.74	18.62			
	CO-SAME	before expansion	13	15.44	1.97	12.88	20.11	1.29	18.197	0.000*
		after 3 months	13	16.74	1.99	13.73	21.16			

N – number of patients; SD – standard deviation; SO-SAME – selective osteotomy surgically-assisted maxillary expansion; CO-SAME – conventional osteotomy surgically-assisted maxillary expansion; * statistically significant.

Table 3. Paired sample Student's *t*-test between the RPAV and RGAV variation according to the studied technique

Studied technique	Studied variable [cc]	N	Mean	SD	Min	Max	Mean difference	*t*-value	*p*-value
SO-SAME	RPAV variation	15	0.83	0.10	0.65	1.03	0.45	6.087	0.000*
	RGAV variation	15	0.38	0.23	–0.08	0.72			
CO-SAME	RPAV variation	13	0.73	0.10	0.53	0.91	0.17	2.493	0.028*
	RGAV variation	13	0.56	0.23	0.12	0.84			

* statistically significant.

Table 4. Independent Student's *t*-test results between the SO-SAME technique group and the CO-SAME technique group according to the studied variable

Studied variable	Studied technique	N	Mean	SD	Min	Max	Mean difference	*t*-value	*p*-value
MW variation [mm]	SO-SAME	15	4.09	0.44	3.60	5.20	0.04	0.270	0.790
	CO-SAME	13	4.05	0.35	3.30	4.70			
RPAV variation [cc]	SO-SAME	15	0.83	0.10	0.65	1.03	0.10	2.606	0.015*
	CO-SAME	13	0.73	0.10	0.53	0.91			
RGAV variation [cc]	SO-SAME	15	0.38	0.23	–0.08	0.72	–0.18	–2.034	0.052
	CO-SAME	13	0.56	0.23	0.12	0.84			
TAV variation [cc]	SO-SAME	15	1.21	0.19	0.90	1.54	–0.09	–1.025	0.315
	CO-SAME	13	1.29	0.26	0.85	1.76			

* statistically significant.

Discussion

Skeletal maxillary constriction is a pathological condition that may be associated with other types of dentoskeletal alterations and can cause functional implications, including respiratory problems.[7] The anatomic proximity of the pharynx to the oral cavity suggests that any change in the intraoral volume changes the oropharyngeal dimensions.[8] The SAME technique, which offers the maxillary bony segment expansion, might also be effective in increasing the nasopharyngeal dimensions.[10]

Cone beam computed tomography is considered to be a reliable and accurate method for measuring the pharyngeal volume[22] and OnDemand3D is considered to be reliable software to measure the airway volume.[23]

There is inconsistent data in the literature about the maxillary expansion (RME and SAME) effects on the upper airway. Pangrazio-Kulbersh et al. evaluated the effect of RME on the airway volume and concluded that the airway volume did not significantly change after expansion.[14] El and Palomo reported that RME significantly increased the nasal passage airway volume without any significant change in the oropharyngeal airway volume.[15] Zhao et al. declared that there was no evidence supporting the hypothesis that RME could increase the oropharyngeal airway volume.[24] Fastuca et al. stated that RME significantly increased TAV.[25] Iwasaki et al. observed that RME not only reduced the nasal obstruction, but also raised the tongue and enlarged the pharyngeal airway volume.[26] Buck et al. presented a systematic review on the effects of surgically-assisted rapid maxillary expansion (SARME) on the upper airway volume and concluded that the effects of SARME on the respiratory function still needed to be evaluated,[27] and that was the aim of the present study.

In the present study, MW increased significantly after the application of either of the 2 SAME surgical techniques, in the SO-SAME and CO-SAME groups (4.09 ±0.44 mm and 4.05 ±0.35 mm, respectively), and there was no significant difference between the 2 techniques (p = 0.79). This is in accordance with Sygouros et al. and indicates the skeletal effects of the 2 SAME techniques on 2 maxillary bony segments.[28]

In the present study, RPAV, RGAV and TAV significantly increased after 3 months in the SO-SAME group (0.83 ±0.10 cc, 0.38 ±0.23 cc and 1.21 ±0.19 cc, respectively) and in the CO-SAME group (0.73 ±0.10 cc, 0.56 ±0.23 cc and 1.29 ±0.26 cc, respectively). These changes might be explained by the effect of SAME on the posterior part of the maxilla and subsequently on the palatal muscles, as well as by the anterior displacement of the maxilla and the change in the tongue position.

These results do not correlate with those of Pereira-Filho et al., who evaluated the effect of SARME on the upper airway volume and stated that there were no significant differences in TAV measured preoperatively and 6 months after expansion.[7] This disagreement might result from the different surgical techniques applied by Pereira-Filho et al., which did not comprise a palatal osteotomy.[7]

The results of this study correlate with those of Rômulo de Medeiros et al., who applied 2 surgical techniques of SARME, with and without a pterygomaxillary disjunction.[17] They assessed the volumetric changes of the nasopharynx and the oropharynx preoperatively, after the

activation period and at 6 months after expansion. They declared that there was a significant increase in the nasopharynx and oropharynx volume immediately after the hyrax screw stabilization. Furthermore, these results are in accordance with the observations made by Vinha et al., who stated that SARME promoted the pharyngeal enlargement, especially in the lower levels of the pharynx.[29]

On the other hand, contrary results are presented by Kurt et al., who compared the effect of SARME on the nasopharyngeal airway using lateral and posteroanterior cephalograms.[10] They concluded that no significant difference was found in the nasopharyngeal airway after SARME. This disagreement might be due to the different surgical techniques and different method of X-ray assessment.

The present study showed that the change in RPAV was greater than that in RGAV in both groups. It may result from a direct effect of both the SAME techniques on the bony segments of the maxilla, especially on the posterior part of the maxilla, where the soft palate muscles attach. The change in the position of these muscles may affect the retropalatal airway. In addition, the SAME technique improves nasal breathing, and this may reduce the thickness of the retropalatal airway respiratory mucosa.

Similar results were presented by Sadeghian et al., who concluded that the average increases in RPAV and TAV were statistically significant, while the change in RGAV was not significant.[30] The change in RGAV may have resulted from the effect of the SAME technique on the tongue position, and that agrees with Akay et al., who concluded that the transpalatal distraction caused changes in the tongue height, the nasopharyngeal airway dimensions and the minimal oropharyngeal distance behind the tongue base.[31]

The results of the present study show that the changes in RPAV associated with the SO-SAME technique were greater than those related to the CO-SAME technique ($p = 0.015$), and that may be explained by the difference in the pattern of palatal osteotomy between the 2 techniques. This confirms the results obtained by Rômulo de Medeiros et al.[17], who found that the difference in the surgical techniques of SARME resulted in different effects on the upper airway volume.

Conclusions

Both the CO-SAME and the SO-SAME techniques increased RPAV, RGAV and TAV. The SO-SAME technique increased RPAV to a greater extent than the CO-SAME technique. Both the SAME techniques increased RPAV to a greater extent than RGAV.

The new SAME technique with a minimally invasive surgery is an effective way to increase MW and the upper airway volume. However, additional studies with longer follow-up periods may be needed to thoroughly evaluate the effectiveness of the abovementioned technique.

References

1. Daif ET. Segment tilting associated with surgically assisted rapid maxillary expansion. *Int J Oral Maxillofac Surg*. 2014;43:311–315.
2. Kayalar E, Schauseil M, Kuvat SV, Emekli U, Firatli S. Comparison of tooth-borne and hybrid devices in surgically assisted rapid maxillary expansion: A randomized clinical cone-beam computed tomography study. *J Craniomaxillofac Surg*. 2016;44:285–293.
3. Oliveira TF, Pereira-Filho VA, Gabrielli MA, Goncales ES, Santos-Pinto A. Effects of lateral osteotomy on surgically assisted rapid maxillary expansion. *Int J Oral Maxillofac Surg*. 2016;45:490–496.
4. Menegat F, Monnazzi MS, Silva BN, de Moraes M, Gabrielli MA, Pereira-Filho VA. Assessment of nasal obstruction symptoms using the NOSE scale after surgically assisted rapid maxillary expansion. *Int J Oral Maxillofac Surg*. 2015;44:1346–1350.
5. Betts NJ. Surgically assisted maxillary expansion. *Atlas Oral Maxillofac Surg Clin North Am*. 2016;24:67–77.
6. Koudstaal MJ, Poort LJ, van der Wal KG, Wolvius EB, Prahl-Andersen B, Schulten AJ. Surgically assisted rapid maxillary expansion (SARME): A review of the literature. *Int J Oral Maxillofac Surg*. 2005;34:709–714.
7. Pereira-Filho VA, Monnazzi MS, Gabrielli MA, et al. Volumetric upper airway assessment in patients with transverse maxillary deficiency after surgically assisted rapid maxillary expansion. *Int J Oral Maxillofac Surg*. 2014;43:581–586.
8. Vinha PP, Faria AC, Xavier SP, Christino M, de Mello-Filho FV. Enlargement of the pharynx resulting from surgically assisted rapid maxillary expansion. *J Oral Maxillofac Surg*. 2016;74:369–379.
9. Gungor AY, Turkkahraman H. Effects of airway problems on maxillary growth: A review. *Europ J Dent*. 2009;3:250–254.
10. Kurt G, Altug-Atac AT, Atac MS, Karasu HA. Changes in nasopharyngeal airway following orthopedic and surgically assisted rapid maxillary expansion. *J Craniofac Surg*. 2010;21:312–317.
11. Zambon CE, Ceccheti MM, Utumi ER, et al. Orthodontic measurements and nasal respiratory function after surgically assisted rapid maxillary expansion: An acoustic rhinometry and rhinomanometry study. *Int J Oral Maxillofac Surg*. 2012;41:1120–1126.
12. Magnusson A, Bjerklin K, Nilsson P, Jonsson F, Marcusson A. Nasal cavity size, airway resistance, and subjective sensation after surgically assisted rapid maxillary expansion: A prospective longitudinal study. *Am J Orthod Dentofacial Orthop*. 2011;140:641–651.
13. Deeb W, Hansen L, Hotan T, Hietschold V, Harzer W, Tausche E. Changes in nasal volume after surgically assisted bone-borne rapid maxillary expansion. *Am J Orthod Dentofacial Orthop*. 2010;137:782–789.
14. Pangrazio-Kulbersh V, Wine P, Haughey M, Pajtas B, Kaczynski R. Cone beam computed tomography evaluation of changes in the naso-maxillary complex associated with two types of maxillary expanders. *Angle Orthod*. 2012;82:448–457.
15. El H, Palomo JM. Three-dimensional evaluation of upper airway following rapid maxillary expansion: A CBCT study. *Angle Orthod*. 2014;84:265–273.
16. Nada RM, van Loon B, Schols JG, et al. Volumetric changes of the nose and nasal airway 2 years after tooth-borne and bone-borne surgically assisted rapid maxillary expansion. *Europ J Oral Sci*. 2013;121:450–456.
17. Rômulo de Medeiros J, Ferraro Bezerra M, Gurgel Costa FW, Pinheiro Bezerra T, de Araújo Alencar CR, Studart Soares EC. Does pterygomaxillary disjunction in surgically assisted rapid maxillary expansion influence upper airway volume? A prospective study using dolphin imaging 3D. *Int Oral Maxillofac Surg*. 2017;46:1094–1101.
18. Günbay T, Akay MC, Günbay S, Aras A, Koyuncu BO, Sezer B. Transpalatal distraction using bone-borne distractor: Clinical observations and dental and skeletal changes. *J Oral Maxillofac Surg*. 2008;66:2503–2514.
19. Stronczek MJ. Determining the appropriate oral surgery anesthesia modality, setting, and team. *Oral and Maxillofac Surg Clin North Am*. 2013;25:357-366.
20. Bierenbroodspot F, Wering PC, Kuijpers-Jagtman AM, Stoelinga PJ. Surgically assisted rapid maxillary expansion: A retrospective study [in Dutch]. *Ned Tijdschr Tandheelkd*. 2002; 109(8):299–302.
21. de Freitas RR, Goncalves AJ, Moniz NJ, Maciel FA. Surgically assisted maxillary expansion in adults: Prospective study. *Int J Oral Maxillofac Surg*. 2008;37:797–804.

22. Tsolakis IA, Venkat D, Hans MG, Alonso A, Palomo JM. When static meets dynamic: Comparing cone-beam computed tomography and acoustic reflection for upper airway analysis. *Am J Orthod Dentofacial Orthop*. 2016;150:643–650.
23. Chen H, van Eijnatten M, Wolff J, et al. Reliability and accuracy of three imaging software packages used for 3D analysis of the upper airway on cone beam computed tomography images. *Dentomaxillofac Radiol*. 2017;46:20170043.
24. Zhao Y, Nguyen M, Gohl E, Mah JK, Sameshima G, Enciso R. Oropharyngeal airway changes after rapid palatal expansion evaluated with cone-beam computed tomography. *Am J Orthod Dentofacial Orthop*. 2010;137(Suppl 4):S71–78.
25. Fastuca R, Meneghel M, Zecca PA, et al. Multimodal airway evaluation in growing patients after rapid maxillary expansion. *Europ J Paediatr Dent*. 2015;16:129–134.
26. Iwasaki T, Saitoh I, Takemoto Y, et al. Tongue posture improvement and pharyngeal airway enlargement as secondary effects of rapid maxillary expansion: A cone-beam computed tomography study. *Am J Orthod Dentofacial Orthop*. 2013;143:235–245.
27. Buck LM, Dalci O, Darendeliler MA, Papadopoulou AK. Effect of surgically assisted rapid maxillary expansion on upper airway volume: A systematic review. *J Oral Maxillofac Surg*. 2016;74:1025–1043.
28. Sygouros A, Motro M, Ugurlu F, Acar A. Surgically assisted rapid maxillary expansion: Cone-beam computed tomography evaluation of different surgical techniques and their effects on the maxillary dentoskeletal complex. *Am J Orthod Dentofacial Orthop*. 2014;146:748–757.
29. Vinha PP, Eckeli AL, Faria AC, Xavier SP, de Mello-Filho FV. Effects of surgically assisted rapid maxillary expansion on obstructive sleep apnea and daytime sleepiness. *Sleep Breath*. 2016;20:501–508.
30. Sadeghian S, Ghafari R, Feizbakhsh M, Dadgar S. Dimensional changes of upper airway after rapid maxillary expansion evaluated with cone beam computed tomography. *Orthodont Waves*. 2016;75:10–17.
31. Akay MC, Aras I, Günbay T, Aras A. Does transpalatal distraction affect pharyngeal airway dimensions and related soft tissues? *J Oral Maxillofac Surg*. 2014;72:1559–1564.

Remineralization of artificial carious lesions using a novel fluoride incorporated bioactive glass dentifrice

Remineralizacja preparowanych in vitro ubytków próchnicowych środkiem zawierającym nowe bioaktywne szkło wzbogacone fluorkami

Abdulmajeed Mohammed Alhussain[1,A–D,F], Abdulhakeem Ali Alhaddad[1,A–D,F], Mahdi Mohammed Ghazwi[1,A–D,F], Imran Farooq[2,A–F]

[1] Dental Intern, College of Dentistry, Imam Abdulrahman Bin Faisal University, Dammam, Saudi Arabia
[2] Department of Biomedical Dental Sciences, College of Dentistry, Imam Abdulrahman Bin Faisal University, Dammam, Saudi Arabia

A – research concept and design; B – collection and/or assembly of data; C – data analysis and interpretation;
D – writing the article; E – critical revision of the article; F – final approval of the article

Dental and Medical Problems, ISSN 1644-387X (print), ISSN 2300-9020 (online) *Dent Med Probl.* 2018;55(4):379–382

Address for correspondence
Imran Farooq
E-mail: drimranfarooq@gmail.com

Funding sources
None declared

Conflict of interest
None declared

Received on June 13, 2018
Reviewed on September 17, 2018
Accepted on October 4, 2018

Published online on November 23, 2018

Cite as
Alhussain A, Alhaddad A, Ghazwi M, Farooq I. Remineralization of artificial carious lesions using novel fluoride-incorporated bioactive glass dentifrice [published online as ahead of print on November 23, 2018]. *Dent Med Probl.* 2018;55(4):379–382. doi:10.17219/dmp/97311

DOI
10.17219/dmp/97311

Abstract

Background. Remineralization potential of dentifrices with novel compositions that can restore minerals back into incipient carious lesions has not been extensively studied so far.

Objectives. The aim of this study was to assess the efficacy of a dentifrice based on novel fluoride incorporated bioactive glass in remineralizing artificial carious lesions in human enamel, and compare it with a standard fluoride-containing dentifrice.

Material and methods. Twenty-four human extracted teeth were sectioned at the cementoenamel junction to obtain enamel blocks. These blocks (n = 24) were randomly divided into 3 groups, with each group containing 8 specimens: group 1 (negative control group; distilled water), group 2 (positive control group; fluoride toothpaste) and group 3 (test group; BioMin™ F toothpaste). Artificial carious lesions were produced in the enamel surfaces by exposing them to a demineralization solution (6% citric acid, pH 2.2) for 96 h. After demineralization, the specimens were brushed with manual toothbrushes in a toothbrush simulation machine (each sample received 800 strokes). For brushing the specimens from group 1, 20 mL of distilled water was used, for group 2 – 20 mL of slurry of toothpaste mixed with artificial saliva, and for group 3 – 20 mL of slurry of toothpaste (BioMin F) mixed with artificial saliva. The micro-hardness data (VHN – Vickers hardness number) was collected at baseline (sound enamel), post-demineralization and post-remineralization.

Results. The biggest difference between the post-remineralization and post-demineralization values was observed in group 3 (mean VHN = 118.73), followed by group 2 (mean VHN = 60.54) and group 1 (mean VHN = 47.44). All the groups revealed significant differences ($p < 0.05$) when the post-demineralization and post-remineralization values were compared to baseline values within each group.

Conclusions. The BioMin F group outperformed the other 2 groups in terms of remineralizing the demineralized enamel structure.

Key words: enamel, remineralization, fluoride bioactive glass

Słowa kluczowe: szkliwo, remineralizacja, bioaktywne szkło wzbogacone fluorkami

Introduction

Dental caries initiates with demineralization of the tooth structure caused by the acids produced by the cariogenic bacteria residing in dental plaque, after they ferment dietary carbohydrates.[1] In the past, dental caries was considered as an irreversible infectious bacterial disease, but recently, it has been established that caries is a complex multifactorial disease, which occurs when the equilibrium between demineralization and remineralization is disturbed.[2] A decrease in pH can cause a net loss of minerals from the tooth surface, also known as demineralization, whereas the process of restoring lost mineral ions to the tooth structure (which usually occurs at high pH) and strengthening the lattice network is known as remineralization.[3]

The most effective method described in the literature for the removal of plaque is mechanical tooth brushing with toothpaste.[4] In 1969 there was a revolution in tissue engineering, when Prof. Larry Hench introduced bioactive glass (BG) (sodium calcium phosphosilicate glass), as it was the first material that exhibited exceptional bone bonding ability.[5,6] The use of BG in dentistry has been encouraged recently due to its compositional resemblance to bone and dental enamel.[7] The other reason for its recent extensive use is that it forms hydroxylapatite (HAP), which repairs the structure of bone and enamel, and also makes them resilient.[8] The traditional BG composition (Bioglass®) is deficient in fluoride.[7] Fluoride is an essential ion that helps in the formation of fluorapatite (FAP), which is more resistant to caries and acid encounters as compared to HAP.[9] Recently, a new toothpaste consisting of fluoride incorporated BG has been introduced, and claims have been made that it causes sustained release of calcium, phosphate and fluoride ions, thus resulting in enhanced remineralization of the tooth structure.[10]

Therefore, the aim of this study was to assess the efficacy of a dentifrice based on novel fluoride incorporated BG in remineralizing artificial carious lesions in human enamel, and compare it with a standard fluoride-containing dentifrice.

Materials and methods

Ethical approval (Ref. No. 2018001) was obtained from the Scientific Research Unit of the institution (College of Dentistry, Imam Abdulrahman Bin Faisal University, Dammam, Saudi Arabia) and all the ethical protocols were strictly followed.

Twenty-four extracted human teeth were obtained from the Department of Oral Surgery of the College of Dentistry at Imam Abdulrahman Bin Faisal University, Dammam, Saudi Arabia. Teeth which were free from caries, obvious white spot lesions, restorations, or other defects were included in this study. All the teeth were sectioned at the cementoenamel junction using a water-cooled diamond saw (Isomet® 5000 Linear Precision Saw; Buehler Ltd., Lake Bluff, USA) and their roots were discarded. The crowns of all the teeth were then embedded in self-cure acrylic resin in such a manner that the buccal/labial surface of tooth enamel was exposed. The enamel surfaces to be treated were then polished with 600-grit wet silicon-carbide paper. An enamel window of approx. 4 × 4 mm was created on the exposed enamel surface by a nail varnish to ensure that the analysis would be performed only in that particular area.

Artificial saliva preparation and grouping of specimens

Artificial saliva (AS) was prepared by mixing NaCl (0.400 g), KCl (0.400 g), $NaH_2PO_4 \cdot H_2O$ (0.690 g), $CaCl_2 \cdot H_2O$ (0.795 g), and $Na_2S \cdot 9H_2O$ (0.005 g) in 1000 mL of deionized water, as proposed by Fusayama et al.[11] The pH of freshly prepared AS was 5.5, which was adjusted by adding 1 M of sodium hydroxide (NaOH) until neutral pH of 7.0 was achieved. The enamel blocks (n = 24) were randomly divided into 3 groups, with each group containing 8 specimens: group 1 (negative control group; distilled water), group 2 (positive control group; fluoride toothpaste) and group 3 (test group; BioMin™ F toothpaste (BioMin Technologies Ltd., London, UK)). The details of active and other ingredients of the tested toothpastes are shown in Table 1.

Artificial carious lesions

Artificial carious lesions were produced in the enamel surfaces by exposing them to a demineralization solution (6% citric acid, pH = 2.2) for 96 h, as described earlier by Wang et al.[12] The demineralizing solution was changed every day during this 96-hour period. The specimens were then washed with distilled water and air-dried for a day.

Remineralization procedure

The specimens were brushed with manual toothbrushes from the same manufacturer (TRISA AG, Triengen, Switzerland). For brushing specimens from group 1, 20 mL of distilled water was used, for group 2 – 20 mL of slurry of toothpaste (Colgate®; Colgate-Palmolive Arabia Ltd., Dammam, Saudi Arabia) mixed with AS in a ratio of 1:3, and for group 3 – 20 mL of slurry of toothpaste (BioMin F) mixed with AS. The brushing experiments were carried out inside a toothbrush simulation machine (toothbrush simulator, model ZM-3.8; SD Mechatronik GmbH, Feldkirchen-

Table 1. Composition of the tested toothpastes

Toothpaste	Manufacturer	Composition	Active ingredient
Colgate	Colgate-Palmolive Arabia Ltd., Dammam, Saudi Arabia	dicalcium phosphate dihydrate, sodium lauryl sulfate, sodium saccharin, tetrasodium pyrophosphate, cellulose gum, glycerin, water, flavor	sodium monofluorophosphate 1.1% w/w fluoride content: 1450 ppm F
BioMin F	BioMin Technologies Ltd., London, UK	fluoro calcium silicate, sodium lauryl sulfate, titanium dioxide, acesulfame potassium, carbomer, polyethylene glycol 400 (PEG 400), glycerin, silica, flavor, fluoride <600 ppm	BioMin F (fluoro calcium phosphosilicate) fluoride content: <600 ppm F

Westerham, Germany), under a continuous loading of 250 g, with 100 strokes/min for 4 days (each sample received 800 strokes, which is equivalent to 2 weeks of in vivo brushing). After every brushing cycle, all the specimens were thoroughly washed with distilled water. After the 4th day of brushing, the specimens were washed with distilled water and left to air-dry, prior to the surface micro-hardness analysis.

Surface micro-hardness analysis

Eight specimens from each group were used to evaluate the changes in the surface micro-hardness values. The Vickers surface hardness was measured using a digital micro-hardness tester (FM-ARS 9000; Future-Tech Corp, Kawasaki, Japan). Five indents were made on the polished surface of each specimen using a Vickers diamond indenter under a load of 100 g, applied for 10 s. An average of 5 indents was used for the analysis. The micro-hardness data (VHN – Vickers hardness number) was collected at baseline (sound enamel), post-demineralization and post-remineralization.

Statistical analysis

The results were analyzed statistically using the Kruskal–Wallis test, which was applied to compare the 3 groups. For comparison within each group of the post-demineralization and post-remineralization vs baseline values, the Wilcoxon signed-rank test was used. A p-value ≤0.05 was considered statistically significant.

Results

The surface micro-hardness analysis was performed by means of a Vickers tester (Fig. 1). The biggest difference between the post-remineralization and post-demineralization values was observed in group 3 (mean VHN = 118.73), followed by group 2 (mean VHN = 60.54) and group 1 (mean VHN = 47.44) (Table 2). For all the groups, 800 strokes were not enough to restore the structure completely back to the baseline values; still, the BioMin F group outperformed the other 2 groups in terms of remineralizing the demineralized enamel structure. All the groups revealed significant differences ($p < 0.05$) when the post-demineralization and post-remineralization values were compared to baseline values within each group (Table 2).

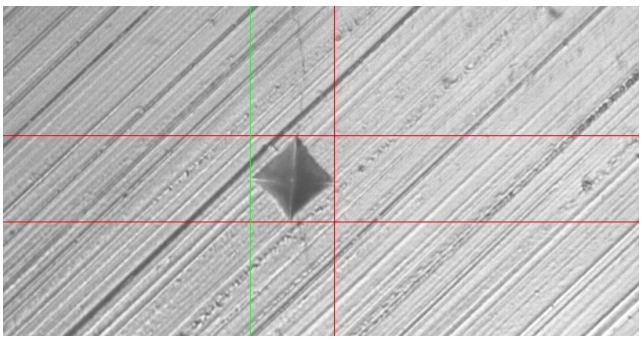

Fig. 1. Vickers indentation performed to assess the micro-hardness of the enamel surface

Table 2. Mean micro-hardness values (VHN – Vickers hardness number) for the 3 tested groups at baseline, post-demineralization and post-remineralization

Analysis time	Group 1 (distilled water)	Group 2 (fluoride toothpaste)	Group 3 (BioMin F toothpaste)	p-value
Baseline	569.98 ±29.41	482.04 ±66.13	497.56 ±71.28	0.015
Post-demin	122.75 ±56.03[a]	209.50 ±151.22[a]	164.93 ±171.20[a]	0.456
Post-remin	170.19 ±73.69[a]	270.04 ±136.67[a]	283.66 ±161.55[a]	0.184
Difference (post-remin – post-demin)	47.44	60.54	118.73	–
p-value	0.002	0.005	0.002	–

Data presented as mean ± standard deviation (SD); post-demin – post-demineralization; post-remin – post-remineralization; [a] significant difference of mean of the post-demin and post-remin values as compared to the baseline value within each group.

Discussion

In this study, the BioMin F toothpaste showed more remineralizing capability as compared to the fluoride-based toothpaste and distilled water, according to the surface micro-hardness analysis. The better remineralization potential of BioMin F could be ascribed to the difference in its composition with regard to a standard fluoride toothpaste. Conventionally, BG is composed of calcium sodium phosphosilicate and contains no fluoride.[7] The presence of fluoride in toothpastes ensures enhanced remineralization and helps in the prevention of caries, as shown by the previous literature.[13,14] The BioMin F toothpaste contains high-phosphate BG with fluoride within its BG composition.[10] When BG is placed in the oral cavity, ionic exchange reactions take place and the glass begins to dissolve, releasing calcium (Ca^{2+}) and phosphate (PO_4^{3-}) ions,[15] resulting in the formation of FAP, which is more acid-resistant and is quite desirable for various dental applications. On the other hand, fluoride from a regular toothpaste can be washed quickly by the salivary flow and the amount of FAP thus formed is also questionable.[16] The high phosphate content of a BG toothpaste is also useful, as it helps to maintain the network connectivity of the glass and ensures the formation of FAP, as shown previously by Brauer et al.[17]

The literature lacks studies which have analyzed and compared the remineralization potential of BG toothpastes and fluoride toothpastes. A recent in vitro study reported more tubule occlusion on dentin specimens achieved by BioMin F as compared to Novamin™ (Sensodyne Repair®, Group Pharmaceuticals Ltd., Mumbai, India) and a standard fluoride toothpaste.[18] Our results also demonstrated a better performance of BioMin F toothpaste, but in terms of enamel remineralization. To achieve the maximum benefit of fluoride, it should be deposited and released slowly.[19] Farooq et al. previously developed the composition of fluoride-containing BG that formed apatite in Tris buffer solution within 6 h, which was much faster than in the case of 45S5 (Bioglass; 24 h).[20] Therefore, the superior remineralization potential of BioMin F could be attributed to the presence of fluoride, in addition to BG, in its composition.

One limitation of our study is its in vitro nature. Actual in vivo conditions could be different and may offer more dynamic challenges to the tested materials. To the best of the authors' knowledge, this study is the first to compare the remineralization potential of BioMin F and fluoride in a head-to-head trial. This study could prove useful and serve as a basis for future quantitative and clinical studies, which can be performed to analyze the effects of these dentifrices under more vigorous in vivo conditions.'

Conclusions

The BioMin F group outperformed the other 2 groups in terms of remineralizing the demineralized enamel structure. Future in vivo studies are recommended to evaluate its clinical efficacy.

References

1. Featherstone JD. Dental caries: A dynamic process. *Aust Dent J*. 2008;53:286–291.
2. Kawasaki K, Ruben J, Tsuda H, Huysmans MC, Takagi O. Relationship between mineral distributions in dentine lesions and subsequent remineralization in vitro. *Caries Res*. 2000;34:395–403.
3. González-Cabezas C. The chemistry of caries: Remineralization and demineralization events with direct clinical relevance. *Dent Clin North Am*. 2010;54:469–478.
4. Collins WJN, Walsh TF, Figures KH. *A Handbook for Dental Hygienists*. 4th ed. Oxford, UK: Butterworth-Heinemann. 1998:272–273.
5. Jones JR. Review of bioactive glass: From Hench to hybrids. *Acta Biomater*. 2013;9:4457–4486.
6. Krishnan V, Lakshmi T. Bioglass: A novel biocompatible innovation. *J Adv Pharm Technol Res*. 2013;4:78–83.
7. Farooq I, Imran Z, Farooq U, Leghari A, Ali H. Bioactive glass: A material for the future. *World J Dent*. 2012;3:199–201.
8. Pradeep K, Rao PK. Remineralizing agents in the non-invasive treatment of early carious lesions. *Int J Dent Case Rep*. 2011;1:73–84.
9. Mohammed RN, Lynch RJ, Anderson P. Effects of fluoride concentration on enamel demineralization kinetics in vitro. *J Dent*. 2014;42:613–618.
10. https://www.biomin.co.uk/products/biomintm-f-toothpaste. Accessed May 10, 2018.
11. Fusayama T, Katayori T, Nomoto S. Corrosion of gold and amalgam placed in contact with each other. *J Dent Res*. 1963;42:1183–1197.
12. Wang Y, Mei L, Gong L, et al. Remineralization of early enamel caries lesions using different bioactive elements containing toothpastes: An in vitro study. *Technol Health Care*. 2016;24:701–711.
13. Somaraj V, Shenoy RP, Shenoy Panchmal G, Kumar V, Jodalli PS, Sonde L. Effect of herbal and fluoride mouth rinses on *Streptococcus mutans* and dental caries among 12–15-year-old school children: A randomized controlled trial. *Int J Dent*. 2017;2017:5654373.
14. Clark MB, Slayton RL; Section on Oral Health. Fluoride use in caries prevention in the primary care setting. *Pediatrics*. 2014;134:626–633.
15. Khalid MD, Khurshid Z, Zafar MS, Farooq I, Khan RS, Najmi A. Bioactive glasses and their applications in dentistry. *J Pak Dent Assoc*. 2017;26:32–38.
16. Aasenden R, Brudevold F, Richardson B. Clearance of fluoride from the mouth after topical treatment or the use of a fluoride mouthrinse. *Arch Oral Biol*. 1968;13:625–636.
17. Brauer DS, Karpukhina N, O'Donnell MD, Law RV, Hill RG. Fluoride-containing bioactive glasses: Effect of glass design and structure on degradation, pH and apatite formation in simulated body fluid. *Acta Biomater*. 2010;6:3275–3282.
18. Shaikh K, Pereira R, Gillam DG, Phad S. Comparative evaluation of desensitizing dentifrices containing BioMin®, Novamin® and fluoride on dentinal tubule occlusion before and after a citric acid challenge – a scanning electron microscope in-vitro study. *J Odontol*. 2018;2:1000105.
19. ten Cate JM. Current concepts on the theories of the mechanism of action of fluoride. *Acta Odontol Scand*. 1999;57:325–329.
20. Farooq I, Tylkowski M, Müller S, Janicki T, Brauer DS, Hill RG. Influence of sodium content on the properties of bioactive glasses for use in air abrasion. *Biomed Mater*. 2013;8:065008.

Gingival microleakage of class II bulk-fill composite resin restorations

Mikroprzeciek dziąsłowy wypełnień klasy II z żywic kompozytowych typu bulk-fill

Haytham Behery[1,A–F], Omar El-Mowafy[1,A,C–F], Wafa El-Badrawy[1,A,E,F], Sameh Nabih[2,A,E,F], Belal Saleh[2,A,E,F]

[1] Department of Restorative Dentistry, Faculty of Dentistry, University of Toronto, Canada
[2] Department of Operative Dentistry, Faculty of Dental Medicine, Al-Azhar University, Cairo, Egypt

A – research concept and design; B – collection and/or assembly of data; C – data analysis and interpretation;
D – writing the article; E – critical revision of the article; F – final approval of the article

Dental and Medical Problems, ISSN 1644-387X (print), ISSN 2300-9020 (online) *Dent Med Probl.* 2018;55(4):383–388

Address for correspondence
Haytham Behery
E-mail: behery@live.com

Funding sources
None declared

Conflict of interest
None declared

Received on July 4, 2018
Reviewed on September 16, 2018
Accepted on October 29, 2018

Published online on December 31, 2018

Cite as
Behery H, El-Mowafy O, El-Badrawy W, Nabih S, Saleh B. Gingival microleakage of class II bulk-fill composite resin restorations. *Dent Med Probl.* 2018;55(4):383–388. doi:10.17219/dmp/99264

DOI
10.17219/dmp/99264

Abstract

Background. Bulk-fill composites were developed to simplify composite placement and minimize polymerization shrinkage stresses, which can improve gingival marginal adaptation in deep class II cavities.

Objectives. The objective of this study was to compare the gingival microleakage of class II cavities restored with bulk-fill composites to that of incrementally restored ones with a conventional composite at 2 storage periods.

Material and methods. Forty freshly extracted intact molars were employed. Two standardized class II slot cavities, 3-millimeter-wide buccolingually, with the gingival floor 0.5 mm below the cementoenamel junction (CEJ) and the axial wall depth of 1.3 mm were prepared in each tooth (80 cavity preparations). The prepared teeth were divided equally into 3 bulk-fill groups (Tetric EvoCeram® Bulk Fill, X-tra Fil® and QuiXX®) and 1 control group (TPH Spectra® HV). Each group was subdivided into 2 equal subgroups (n = 10) according to the storage period in distilled water (24 h and 6 months). The Adper® Single Bond Plus adhesive was used with all the restorative materials. The cavities in the experimental groups were restored with 4-millimeter bulk-fill composites in 1 increment, while the cavities in the control group were restored with 2 increments of the thickness of 2 mm. The polymerization light was applied from the occlusal surfaces. The teeth were then immersed in 2% procion red dye solution, sectioned and examined under a stereomicroscope to determine the extent of dye penetration. The data was statistically analyzed using the Kruskal–Wallis test and the Mann–Whitney *U* test.

Results. The Kruskal–Wallis test revealed no significant differences in the mean microleakage scores among all the groups after 24-hour and 6-month storage ($p = 0.945$ and $p = 0.928$, respectively). The Mann–Whitney *U* test revealed an increase in the mean microleakage scores in all the groups after 6-month storage; however, the scores were not significantly different from the means obtained after 24 h ($p = 0.259$ for Tetric EvoCeram Bulk Fill; $p = 0.205$ for X-tra Fil; $p = 0.166$ for QuiXX; $p = 0.155$ for TPH Spectra HV).

Conclusions. Gingival microleakage of bulk-fill composites in class II cavities was not significantly different from that of incrementally restored ones with a conventional composite. The increase in the mean gingival microleakage of the specimens stored for 6 months was not statistically significantly different in comparison to the values obtained after the 24-hour storage period for each composite.

Key words: composite resin, microleakage, bulk-fill, dental restorations

Słowa kluczowe: żywica kompozytowa, mikroprzeciek, bulk-fill, wypełnienia dentystyczne

Introduction

Polymerization shrinkage of composite resins and the accompanying shrinkage stress build-up represent the major drawbacks in using direct composite resin restoratives. This is due to the fact that the forces connected with the shrinkage stress may disrupt the bond to the cavity walls, leading to micro-gaps, which can result in the passage of the saliva and oral fluids along the tooth restoration interface (i.e., microleakage). Microleakage is a commonly encountered problem with posterior composite restorations, especially at gingival margins placed apically to the cementoenamel junction (CEJ), as in deep class II cavities.[1] It represents a matter of concern, as it can lead to staining at the margins of restorations and recurrent caries with subsequent pulp pathology. Other problems related to direct composite restorations are the limited depth of the cure, technique sensitivity and time-consuming placement procedure. Dentists have always sought a fast and reliable restoration technique that would allow for a reduction of the number of composite layers placed, thus reducing the effort and time consumed in such a routine procedure. Bulk-fill composite resins seem to fulfill this desire.

Several developments in the field of composite restoration techniques have been made, such as optimizing the polymerization light intensity,[2] the application of a flowable resin as a liner[3] and the incremental placement.[4] These innovations have been introduced to minimize the shrinkage stress, and improve the marginal integrity and the durability of composite restorations.[5]

Bulk-fill composites were developed in an attempt to simplify and expedite the composite placement technique.[5] According to their manufacturers, they have a higher depth of polymerization, which could eliminate the need for layering. They are also claimed to generate low polymerization shrinkage stresses,[6,7] owing to the use of modified resin-filler technologies,[8,9] that minimize the volumetric shrinkage and/or modify the visco-elastic behavior of bulk-fill composites by decreasing their elastic moduli and increasing their flow capacity. The reduction in shrinkage stresses of bulk-fill composites, if true, can result in improving the marginal integrity and the durability of the bond of composite restoration to the tooth structure.[10,11]

This study was conducted to assess the gingival microleakage of class II slot cavity preparations restored with 3 types of bulk-fill composite resins in comparison to those incrementally restored with a conventional composite resin at 2 different storage periods (24 h and 6 months). The research null hypotheses were the following:

– there is no significant difference in the gingival microleakage between the tested bulk-fill composites and the conventional composite;
– there is no significant difference in the gingival microleakage of each of the 4 tested composites at 2 different storage periods (24 h and 6 months).

Material and methods

Forty freshly extracted intact human molars were employed. The teeth were sterilized with gamma irradiation, thoroughly rinsed and scaled to remove any plaque, calculus or attached periodontal tissues. The teeth were then stored in distilled water in a refrigerator. The teeth were mounted vertically in acrylic resin bases 2 mm apical to CEJ. Class II slot cavities were prepared on both proximal sides of each molar, using carbide bur No. 56 (Great White® Series; SS White Burs, Inc., Lakewood, USA) in a water-cooled high-speed handpiece. A total of 80 slot cavities were prepared, each with the dimensions: the width of 3 mm buccolingually, the axial depth of 1.3 mm and the gingival floor located 0.5 mm below CEJ. A new bur was used for every 4 cavity preparations. The dimensions of each cavity were verified with a digital caliper (Mastercraft, Toronto, Canada).

The prepared teeth were divided into 4 groups (10 molars each, with 20 class II slot cavities) and assigned to 4 composite resins groups – 3 bulk-fill: Tetric EvoCeram® Bulk Fill (Ivoclar Vivadent, Amherst, USA), X-tra Fil® (VOCO America, Inc., Indian Land, USA), and QuiXX® (Dentsply Caulk, Milford, USA); and 1 control: TPH Spectra® HV (Dentsply Caulk) (Table 1). Each group was subdivided into 2 equal subgroups (n = 10) according to the storage period in distilled water (24 h and 6 months).

A Tofflemire metal matrix retainer/band was secured around each prepared tooth to establish the proper proximal anatomic contour. The metal matrix band was supported externally with a low-fusing compound to maintain its adaptation to the cavity margins.[1] For all groups, the same etch-and-rinse adhesive system was used (Scotchbond® Etchant and Adper® Single Bond Plus; 3M ESPE, St. Paul, USA). The restorative procedure was performed according to the manufacturer's instructions.

The 3 bulk-fill composites were applied in a single increment of 4 mm in thickness, while the conventional composite (TPH Spectra HV) was applied in 2 horizontal increments, each 2-millimeter-thick. An LED light polymerization unit (Demi® LED Light Curing System; Kerr Corporation, Orange, USA) was used for the polymerization of all the composites. Each bulk-fill composite restoration was subjected to 20 s of irradiation, while in the case of the TPH Spectra HV restoration, each increment was subjected to 20 s of irradiation. The irradiance of the light polymerization unit was periodically checked with checkMARC (BlueLight Analytics, Inc., Halifax, Canada). The irradiance was found to be 1,120 mW/cm² on average. The specimens were stored in distilled water at 37°C for the aforementioned storage periods.

Two coats of nail varnish were applied on the tooth surfaces, except for 1 mm from the restoration margins. Afterward, the teeth were immersed in 2% procion red dye solution (Imperial Chemical Industries, London, England) for 24 h at 37°C, and then rinsed under running water

Table 1. Materials used in the study

Material	Product description	Main components of the restorative material	Manufacturer
Tetric EvoCeram Bulk Fill	light-cured, methacrylate-based bulk-fill composite resin	monomer matrix of dimethacrylates, fillers (barium glass, ytterbium trifluoride, mixed oxide, prepolymer)	Ivoclar Vivadent, Amherst, USA
X-tra Fil	light cured, methacrylate-based bulk-fill composite resin	Bis-GMA, UDMA, TEGDMA, fillers (barium-boron-alumino-silicate glass)	Voco America, Inc., Indian Land, USA
QuiXX	light cured, methacrylate-based bulk-fill composite resin	UDMA,TEGDMA, di- and tri-methacrylate resins, carboxylic acid-modified dimethacrylate, fillers (strontium-alumino-sodium-fluoro-silicate glass)	Dentsply Caulk, Milford, USA
TPH Spectra HV	light cured, methacrylate-based composite resin	urethane-modified Bis-GMA resin, TEGDMA, fillers (silanated barium, aluminoborosilicate glass, silanated barium-boron-fluoro-alumino-silicate glass, silicon dioxide)	Dentsply Caulk
Scotchbond Etchant	35% phosphoric acid gel		3M ESPE, St. Paul, USA
Adper Single Bond Plus	two step etch-and-rinse adhesive system		3M ESPE

Bis-GMA – bisphenol A glycidyl dimethacrylate; TEGDMA – triethylene glycol dimethacrylate; UDMA – urethane dimethacrylate.

for 5 min. Each tooth was sectioned mesio-distally into 2 halves with a microslicing machine (IsoMet; Buelher, Lake Buff, USA).[1,12] The half with the deepest dye penetration was used to represent the tooth.[1,12] The extent of dye penetration was determined by an examination with a stereomicroscope (Wild M3Z Stereo Microscope; Leica Microsystems (Schweitz) AG, Heerbrugg, Switzerland) at a magnification ×10, according to a 5-point scale:

– 0: no dye penetration;
– 1: dye penetration limited to the outer half of the gingival floor;
– 2: dye penetration extended along the entire gingival floor (i.e., beyond the outer half of the gingival floor);
– 3: dye penetration extended along the gingival wall and up to half of the axial wall;
– 4: dye penetration extended along the gingival floor and the entire axial wall.

In addition, a digital camera (Canon PowerShot S 120; Canon, Inc., Tokyo, Japan) was used to capture photographic images for each selected section (Fig. 1,2).

The data was tabulated and statistically analyzed. The means and standard deviations (SDs) were calculated and statistically analyzed using the non-parametric Kruskal–Wallis test and the Mann–Whitney *U* test. The significance level was set at 0.05. The statistical analysis was performed with SPSS v. 20 for Windows (IBM Corp., Armonk, USA).

Fig. 1. Photographs of a representative specimen from each group stored for 24 h (from left to right: Tetric EvoCeram Bulk Fill, X-tra Fil, QuiXX, and TPH Spectra HV)

Fig. 2. Photographs of a representative specimen from each group stored for 6 months (from left to right: Tetric EvoCeram Bulk Fill, X-tra Fil, QuiXX, and TPH Spectra HV)

Results

The mean, standard deviation, median, and range values of the gingival microleakage scores for all the 4 groups are recorded in Table 2 and Fig. 3,4.

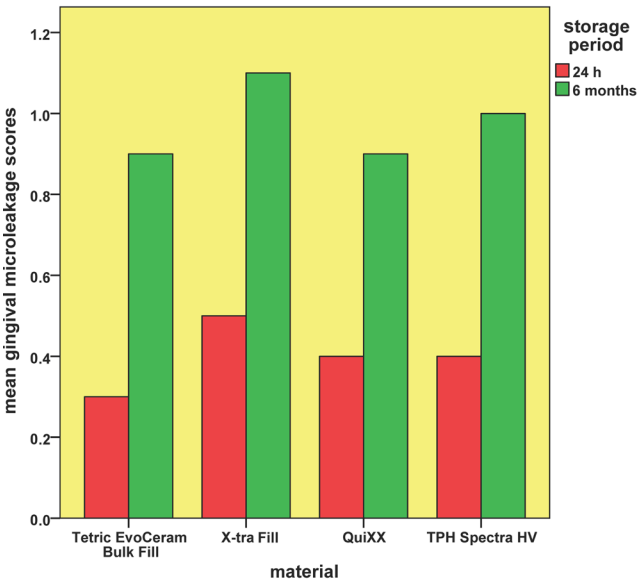

Fig. 3. Bar chart representing the mean microleakage scores of the tested groups at each storage period

Table 2. Gingival microleakage scores, means and standard deviations (SDs) of the 4 tested groups at each storage period

Material	Storage period	Gingival microleakage scores					Mean	SD	*p*-value
		0	1	2	3	4			
Tetric EvoCeram Bulk Fill	24 h	7	3	–	–	–	0.30	0.48	0.259
	6 months	5	3	1	–	1	0.90	1.29	
X-tra Fil	24 h	6	3	1	–	–	0.50	0.71	0.205
	6 months	4	2	3	1	–	1.10	1.10	
QuiXX	24 h	7	2	1	–	–	0.40	0.70	0.166
	6 months	4	3	3	–	–	0.90	0.88	
TPH Spectra HV	24 h	7	2	1	–	–	0.40	0.70	0.155
	6 months	4	3	2	1	–	1.00	1.05	

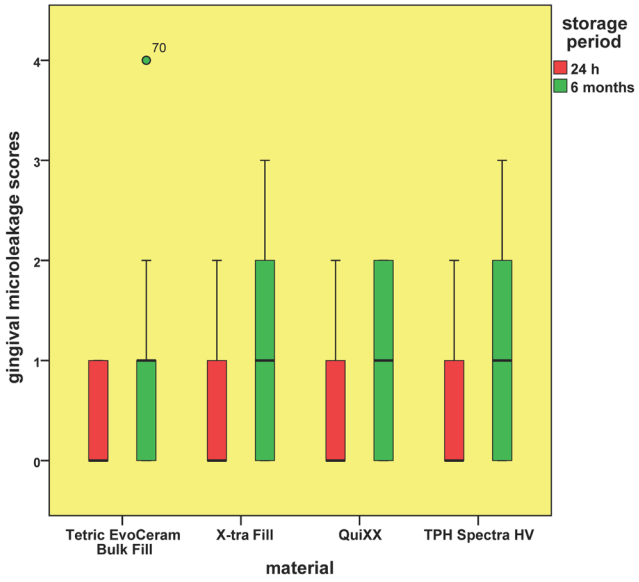

Fig. 4. Box plot representing the median and range values of the microleakage scores of the tested groups at each storage period (the circle represents the outlier)

After 24-hour storage, the mean gingival microleakage scores for Tetric EvoCeram Bulk Fill, X-tra Fil, QuiXX, and TPH Spectra HV were 0.3, 0.5, 0.4, and 0.4, respectively. The Kruskal–Wallis test revealed no statistically significant differences in the mean microleakage scores among the groups ($p = 0.945$).

After 6-month storage, the mean microleakage scores for Tetric EvoCeram Bulk Fill, X-tra Fill, QuiXX, and TPH Spectra HV were 0.9, 1.1, 0.9, and 1.0, respectively. The Kruskal–Wallis test revealed no significant differences in the mean microleakage scores among the groups ($p = 0.928$).

In spite of the increase in the mean microleakage scores after 6 months, the Mann–Whitney *U* test revealed no significant differences in the mean microleakage scores for each composite after 6-month storage as compared to the mean microleakage scores obtained after 24-hour storage ($p = 0.259$ for Tetric EvoCeram Bulk Fill; $p = 0.205$ for X-tra Fil; $p = 0.166$ for QuiXX; and $p = 0.155$ for TPH Spectra HV).

Discussion

One of the key functions of dental restorations is to seal the exposed dentin and to protect the pulp against the oral environment. An insufficient seal at the tooth/restoration interface may lead to microleakage, described as a clinically undetectable passage of bacteria, fluids, molecules, or ions between the cavity wall and the restorative material.[13,14] Microleakage tests are widely used to evaluate the marginal sealing of composite restorations.[15] Previous studies reported that composite restorations exhibited higher microleakage at gingival margins than at occlusal margins.[16–19] Gingival microleakage is more frequently observed in deep class II cavities, where gingival margins are placed apical to CEJ.[1] In this study, gingival microleakage in class II composite restorations was assessed with gingival margins of 0.5 mm apical to CEJ.

Several methods have been used to detect microleakage, such as the use of dyes, artificial caries, air pressure, bacteria, radioactive isotopes, neutron activation analysis, and scanning electron microscopy. The use of dyes as tracers is one of the most common methods of detecting microleakage in vitro. Different types of dyes with different particle sizes are used for microleakage assessment, such as procion red dye, basic fuschin and methylene blue.[13] This technique is highly feasible and carries no radiation hazards. In addition, the dye has the advantage of its contrasting color to the tooth and the restoration, without reacting chemically with specimens. In this study, 2% procion red dye solution was used as a tracer for microleakage assessment.

Gamma irradiation was used to sterilize the teeth, as it has no adverse effect on the enamel hardness or its resistance to demineralization.[20] In addition, gamma irradiation is an effective method of sterilizing the teeth, which neither alters the dentin structure and its surface morphology nor affects the strength of the shear bond to the dentin.[21,22]

A 2-step etch-and-rinse adhesive system (the Adper Single Bond Plus adhesive with Scotchbond Etchant) was used in this study with the 4 tested composite resins, as it is considered to result in optimum bonding. Adper Single

Bond Plus is an ethanol-based adhesive which contains 2-hydroxyethyl methacrylate (HEMA) and is thought to be able to maintain the collagen fibrils in an expanded form after the evaporation of the solvent, improving the monomer infiltration and the formation of a proper hybrid layer.[23–25]

In this study, the null hypotheses were not rejected. The results revealed no statistically significant differences in the means of gingival microleakage scores among the 4 composite resin restoratives tested after 24-hour and 6-month storage periods. This may indicate that polymerization and/or polymerization shrinkage of the bulk-fill composites (Tetric EvoCeram Bulk Fill, X-tra Fil and QuiXX) was comparable to that of the incrementally placed composite (TPH Spectra HV). These findings are in agreement with the findings reported by Ahmed et al., who found that the type of the composite material used (Filtek® Z250 vs Filtek LS (3M ESPE)) had no significant effect on gingival microleakage, rather the bonding agent type was more critical and had a significant effect.[12] Furthermore, Rengo et al. found no significant differences in the microleakage of class II cavities restored with bulk-fill composites (G-aenial® Universal Flo bulk-fill, G-aenial Flo bulk-fill and Kalore® bulk-fill (GC Corporation, Tokyo, Japan)) in comparison to that of the cavities incrementally restored with conventional composites (G-aenial Universal Flo, G-aenial Flo and Kalore (GC Corporation)), using the same adhesive system (G-aenial Bond (GC Corporation)) with all the groups.[26]

The statistical analysis did not reveal significant differences in the mean microleakage scores, when the values obtained for each group after 6 months were compared with the values obtained after 24 h, in spite of an obvious increase in the mean score. It is speculated that with longer storage periods, statistically significant differences may be detected.

The lack of significant differences in the mean microleakage scores between the specimens stored for 24 h and those stored for 6 months in each restorative group is in agreement with the findings reported in other studies. De Munck et al.[14] reported that the effect of artificial aging methods, such as water storage and thermocycling, on microleakage is minimal.[27–29] These findings were in accordance with those of Mahmoud and Al-Wakeel, who found that the marginal adaptation of ormocer-, silorane- and methacrylate-based composite resin restorative systems bonded to dentin cavities was not affected by aging times (immediately after polymerization, after 1 month, and after 1 year of water storage and thermocycling).[30] Khosravi et al. found that water storage (24 h, 3 months and 6 months) had no significant effect on gingival microleakage of class II cavities restored with methacrylate-based and silorane-based composite resins.[31] In another study, it was found that water storage for 6 months had no significant effect on the microleakage scores with some composite restorative system products; however, with other products, significant differences were detected.[32] Nevertheless, 6-months water storage can only be considered short-term; it is possible that with long-term water storage, significantly higher microleakage scores may be encountered. However, further research is needed in this respect.

Conclusions

Within the limitations of this in vitro study, it can be concluded that gingival microleakage of class II composite restorations was not significantly affected by the type of composite restoration used (i.e., bulk-fill composite or conventional composite) even after 6 months of water storage. Increasing the storage time from 24 h to 6 months had no significant effect on gingival microleakage for each of the 4 types of class II composite restorations used.

References

1. El-Mowafy O, El-Badrawy W, Eltanty A, Abbasi K, Habib N. Gingival microleakage of Class II resin composite restorations with fiber inserts. *Oper Dent*. 2007;32:298–305.
2. Uno S, Asmussen E. Marginal adaptation of a restorative resin polymerized at reduced rate. *Scand J Dent Res*. 1991;99:440–444.
3. Alomari QD, Reinhardt JW, Boyer DB. Effect of liners on cusp deflection and gap formation in composite restorations. *Oper Dent*. 2001;26:406–411.
4. Lee MR, Cho BH, Son HH, Um CM, Lee IB. Influence of cavity dimension and restoration methods on the cusp deflection of premolars in composite restoration. *Dent Mater*. 2007;23:288–295.
5. Behery H, El-Mowafy O, El-Badrawy W, Saleh B, Nabih S. Cuspal deflection of premolars restored with bulk-fill composite resins. *J Esthet Restor Dent*. 2016;28:122–130.
6. Ilie N, Hickel R. Investigations on a methacrylate-based flowable composite based on the SDR technology. *Dent Mater*. 2011;27:348–355.
7. Rothmund L, Reichl FX, Hickel R, et al. Effect of layer thickness on the elution of bulk-fill composite components. *Dent Mater*. 2017;33:54–62.
8. Misilli T, Gonulol N. Water sorption and solubility of bulk-fill composites polymerized with a third generation LED LCU. *Braz Oral Res*. 2017;31:e80.
9. Leprince JG, Palin WM, Vanacker J, Sabbagh J, Devaux J, Leloup G. Physico-mechanical characteristics of commercially available bulk-fill composites. *J Dent*. 2014;42:993–1000.
10. Kim RJ, Kim YJ, Choi NS, Lee IB. Polymerization shrinkage, modulus, and shrinkage stress related to tooth-restoration interfacial debonding in bulk-fill composites. *J Dent*. 2015;43:430–439.
11. Schneider LF, Cavalcante LM, Silikas N. Shrinkage stresses generated during resin-composite applications: A review. *J Dent Biomech*. 2010;2010:131630.
12. Ahmed W, El-Badrawy W, Kulkarni G, Prakki A, El-Mowafy O. Gingival microleakage of class V composite restorations with fiber inserts. *J Contemp Dent Pract*. 2013;14:622–628.
13. Kidd EA. Microleakage: A review. *J Dent*. 1976;4(5):199–206.
14. De Munck J, Van Landuyt K, Peumans M, et al. A critical review of the durability of adhesion to tooth tissue: Methods and results. *J Dent Res*. 2005;84:118–132.
15. Klein CA, Jr., da Silva D, Reston EG, Borghetti DL, Zimmer R. Effect of at-home and in-office bleaching on marginal microleakage in composite resin restorations using two adhesive systems. *J Contemp Dent Pract*. 2018;19:248–252.
16. Eakle WS, Ito RK. Effect of insertion technique on microleakage in mesio-occlusodistal composite resin restorations. *Quintessence Int*. 1990;21:369–374.
17. Ciucchi B, Bouillaguet S, Holz J. Proximal adaptation and marginal seal of posterior composite resin restorations placed with direct and indirect techniques. *Quintessence Int*. 1990;21:663–669.

18. Ferrari M, Davidson CL. Sealing performance of Scotchbond Multi-Purpose-Z100 in class II restorations. *Am J Dent*. 1996;9:145–149.
19. Hilton TJ, Schwartz RS, Ferracane JL. Microleakage of four class II resin composite insertion techniques at intraoral temperature. *Quintessence Int*. 1997;28:135–144.
20. Rodrigues LK, Cury JA, Nobre dos Santos M. The effect of gamma radiation on enamel hardness and its resistance to demineralization in vitro. *J Oral Sci*. 2004;46:215–220.
21. White JM, Goodis HE, Marshall SJ, Marshall GW. Sterilization of teeth by gamma radiation. *J Dent Res*. 1994;73:1560–1567.
22. Sperandio M, Souza JB, Oliveira DT. Effect of gamma radiation on dentin bond strength and morphology. *Braz Dent J*. 2001;12:205–208.
23. Tay FR, Gwinnett AJ, Pang KM, Wei SH. Resin permeation into acid-conditioned, moist, and dry dentin: A paradigm using water-free adhesive primers. *J Dent Res*. 1996;75:1034–1044.
24. Perdigao J, Van Meerbeek B, Lopes MM, Ambrose WW. The effect of a re-wetting agent on dentin bonding. *Dent Mater*. 1999;15:282–295.
25. El-Bouhi YMM. Bond performance and nanoleakage of resin/dentin interface under different intrapulpal pressures. PhD thesis. Cairo University, Egypt, 2009.
26. Rengo C, Spagnuolo G, Ametrano G, et al. Marginal leakage of bulk fill composites in Class II restorations: A microCT and digital microscope analysis. *Int J Adhes Adhes*. 2015;60:123–129.
27. Gwinnett AJ, Yu S. Effect of long-term water storage on dentin bonding. *Am J Dent*. 1995;8:109–111.
28. Gale MS, Darvell BW. Thermal cycling procedures for laboratory testing of dental restorations. *J Dent*. 1999;27:89–99.
29. Wahab FK, Shaini FJ, Morgano SM. The effect of thermocycling on microleakage of several commercially available composite Class V restorations in vitro. *J Prosthet Dent*. 2003;90:168–174.
30. Mahmoud SH, Al-Wakeel Eel S. Marginal adaptation of ormocer-, silorane-, and methacrylate-based composite restorative systems bonded to dentin cavities after water storage. *Quintessence Int*. 2011;42:e131–e139.
31. Khosravi K, Mousavinasab SM, Samani MS. Comparison of microleakage in Class II cavities restored with silorane-based and methacrylate-based composite resins using different restorative techniques over time. *Dent Res J (Isfahan)*. 2015;12:150–156.
32. Crim GA. Effect of aging on microleakage of restorative systems. *Am J Dent*. 1993;6:192–194.

The influence of the manufacturing process of rotary files on the shaping of L-shaped canals

Wpływ procesu wytwarzania rotacyjnych pilników endodontycznych na opracowanie kanału w kształcie litery L

Mateusz Radwański[A–D,F], Michał Łęski[A,E,F], Halina Pawlicka[E,F]

Department of Endodontics, Medical University of Lodz, Poland

A – research concept and design; B – collection and/or assembly of data; C – data analysis and interpretation;
D – writing the article; E – critical revision of the article; F – final approval of the article

Dental and Medical Problems, ISSN 1644-387X (print), ISSN 2300-9020 (online) *Dent Med Probl.* 2018;55(4):389–394

Address for correspondence
Mateusz Radwański
E-mail: mateusz.radwanski@gmail.com

Funding sources
The study was funded by Medical University of Lodz, Poland (502-03/2-044-02/502-24-069-17).

Conflict of interest
None declared

Received on August 16, 2018
Reviewed on September 2, 2018
Accepted on September 17, 2018

Published online on November 13, 2018

Cite as
Radwański M, Łęski M, Pawlicka H. The influence of the manufacturing process of rotary files on the shaping of L-shaped canals [published online as ahead of print on November 13, 2018]. *Dent Med Probl.* 2018;55(4):389–394. doi:10.17219/dmp/95201

DOI
10.17219/dmp/95201

Abstract

Background. The nickel-titanium alloy used in the production of nickel-titanium files contains approx. 56% nickel and 44% titanium by weight. To improve the properties of nickel-titanium files, the manufacturers introduce some innovations in the production process. Their purpose is primarily to decrease the stiffness of the instruments while increasing the resistance to cyclic fatigue, which reduces the risk of file separation. One of the most popular processes is the heat treatment of the nickel-titanium alloy.

Objectives. The aim of the research was to determine the influence of the manufacturing process of rotary files on the shaping of L-shaped canals.

Material and methods. Fifty L-shaped resin canals were instrumented (10/group) with ProTaper Universal®, ProTaper Next®, Hyflex CM®, Hyflex EDM®, or WaveOne Gold® files, with the same apical size of 25. Each L-shaped resin canal was photographed both before and after instrumentation. Differences between the change of the working length and apical transportation were analyzed statistically.

Results. The smallest mean loss of the working length was observed after instrumentation with Hyflex CM files. Statistically significant differences in the working length were found between ProTaper Universal and Hyflex CM ($p = 0.0032$), ProTaper Universal and Hyflex EDM ($p = 0.021$), and ProTaper Universal and WaveOne Gold ($p = 0.0112$) files. The lowest apical transportation was noted in the case of WaveOne Gold files. In terms of apical transportation, statistically significant differences were observed between ProTaper Universal and WaveOne Gold files ($p = 0.0254$). Shaping L- shaped canals with the ProTaper Universal file system resulted in the greatest changes in the working length (x = 0.35 mm) and apical transportation (x = 0.034 mm).

Conclusions. The study, with its limitations, shows that in the files whose nickel-titanium alloy was subjected to a thermal treatment process, a smaller loss of the working length and lower values of apical transportation were observed.

Key words: nickel-titanium rotary files, canal shaping, resin blocks

Słowa kluczowe: niklowo-tytanowe rotacyjne pilniki endodontyczne, opracowanie kanału, bloki żywicowe

Introduction

The nickel-titanium alloy (nitinol) used in the production of nickel-titanium files contains approx. 56% nickel and 44% titanium by weight, with the atomic ratio of the elements being the same (equiatomic). In some nickel-titanium alloys, a small percentage (<2% by weight) of nickel is converted to cobalt.[1] Due to the ability to change the type of atomic bonds by the elements included in the alloy, the mechanical properties and its crystal structure change. These changes occur under temperature and/or stress. In dentistry, 2 characteristics of the nickel-titanium alloy are important, referred to as the shape memory effect and pseudoelasticity.[1]

To improve the properties of nickel-titanium files, the manufacturers introduce some innovations in the production process. Their purpose is primarily to decrease the stiffness of the instruments, while increasing the resistance to cyclic fatigue, which reduces the risk of file separation. One of the most popular processes is the heat treatment of the nickel-titanium alloy.

The heat treatment of nickel-titanium instruments affects the temperature of phase transformations, thus determining the nickel-titanium alloy phases present in the file at room temperature.[2,3] This process can improve the alloy properties if it is carried out in specific temperatures. Zinelis et al. showed that the heat treatment up to 430–440°C gradually increased the resistance of files to cyclic fatigue, and machining above these temperatures adversely affected the file properties.[4]

In determining the structure of nitinol, it is common to compare the end temperature of austenitic transformation (the A_f temperature) to the reference temperature. The reference temperature is usually defined as room temperature (37°C). In the case when the A_f temperature is lower than the reference temperature, the alloy at room temperature will be completely in the austenitic phase. The heat treatment process can raise the A_f temperature (45–50°C).[5] This means that at room temperature the alloy can be a mixture of the martensitic phase with the austenitic phase and/or the rhombohedrally distortion of the cubic austenitic phase (R-phase).

In 2017, a classification of nickel-titanium rotary files into 3 generations was proposed, taking the crystallographic structure and the thermal process as the criteria for classification.[6]

The 1st generation includes files in the austenitic phase, with the A_f temperature below the reference temperature (A_f < 37°C).[7–10] This group includes Endo Sequence® (Brasseler, Savannah, USA) with A_f = 31.13°C,[9] ProFile® (Dentsply Tulsa Dental, Tulsa, USA) with A_f = 16.98°C[9] and ProTaper Universal® (Dentsply Tulsa Dental) with A_f = 17°C.[5]

The 2nd generation includes files that contain a stable martensite phase under clinical conditions. The heat treatment process raises the A_f temperature, producing a variable crystallographic percentage of martensite, R-phase and/or austenite around room temperature.[5,11] Depending on the thermodynamic processing of the alloy before or during production, this group includes nickel-titanium alloys referred to as M-Wire®, R-phase® and Controlled Memory® (CM-Wire).

M-Wire was introduced in 2007 by Dentsply Tulsa Dental Specialties and its production is related to the cycles of the heat treatment and annealing.[12] This cyclic process aims to stabilize the crystalline structure of nitinol in a martensitic state at room temperature.[13,14] Various analytical methods have confirmed that M-Wire contains austenite, martensite and R-phase. The relative proportions depend on the processing conditions. The A_f temperature of M-Wire is about 45–50°C.[5] The M-Wire instruments include Dentsply Tulsa Dental Specialties files: ProFile Vortex® ($A_f \approx$ 50°C),[9] ProTaper Next® ($A_f \approx$ 54°C),[15] PathFiles®, and WaveOne®. This group also includes Reciproc® (VDW, Munich, Germany).

Controlled Memory (DS Dental, Johnson City, USA) was introduced in 2010. The proprietary thermo-mechanical process aims to reduce stiffness and shape memory, raise the A_f temperature to about 50°C and achieve stable martensite phase at body temperature.[16] Testarelli et al. found that CM contains a lower percentage of nickel (52% by weight).[17] The CM instruments include Hyflex CM® (Coltene Whaledent, Cuyahoga Falls, USA) with $A_f \approx$ 57°C[18] and Typhoon CM® (Clinican's Choice Dental Products, New Milford, USA) with $A_f \approx$ 55°C.[19] Studies confirm that in addition to austenite at a reference temperature, the instruments also contain martensite and R-phase.[20]

The 3rd generation is nickel-titanium rotary instruments, whose alloys have been subjected to the heat treatment after machining. The new heating process after machining is aimed at minimizing defects that appeared while machining and modifying the structure of the crystalline phase. After the thermal cycle, the martensitic transformation of nitinol occurs in 2 stages (austenite-R-phase-martensite) instead of 1 (austenite-martensite).[21]

This group includes Dentsply Tulsa Dental Specialties: Vortex Blue®, TRU Shape®, ProTaper Gold®, and WaveOne Gold®. The 3rd generation also includes Hyflex EDM® (Coltene Whaledent), XP-endo Shaper® (FKG Dentaire, La Chaux-de-Fonds, Switzerland) and K3 XF® (SybronEndo, Orange, USA).

WaveOne Gold files are created in a unique heat treatment process, prior and after file manufacturing. In the first stage, nitinol is subjected to a special heat treatment under constant strain (3–15 kg) in the temperature range of about 410–440°C. Then, after machining, the instrument is heat-treated once again at a temperature of 120–260°C. The A_f temperature is between 40°C and 60°C.[22]

Hyflex EDM is manufactured using electrical discharging machining (EDM). Electrical discharging machining is a non-contact thermal erosion process used to treat

materials with controlled electric discharges. Electric sparks cause local melting and partial evaporation of small portions of the material. After cutting, cleaning in an acid bath is carried out with the use of ultrasound. The instrument is subjected to the heat treatment at a temperature of 300–600°C before or after the cleaning process.[23] The EDM files have $A_f > 52°C$.[24]

The aim of the research was to determine the effect of the manufacturing process of rotary files on the shaping of L-shaped canals.

Material and methods

The following nickel-titanium rotary files were used in the study: ProTaper Universal (group I), ProTaper Next (group II), Hyflex CM (group III), Hyflex EDM (group IV), and WaveOne Gold (group V).

Fifty blocks with L-shaped canals (Endo-Training Blocks® 02 taper, REFA 0177; Dentsply Maillefer, Ballaigues, Switzerland) were used in the laboratory tests. The canals were characterized by the following parameters: the working length – 16 mm, apex size – 15 and conicity – 2%.

The blocks were randomly divided into 5 groups, 10 in each. Before starting work with the rotary files, the working length of the canal and the apical patency were confirmed using K-file 15 (VDW). The working length was verified with an endodontic ruler and a rubber stop. The canals were filled with black ink. Next, the glide path and pre-flaring were performed using PathFile® (Dentsply Maillefer).

The canals were shaped with the nickel-titanium rotary files in each group, respecting the sequence, speed and torque recommended by the manufacturer. The sequence of the files is shown in Table 1. The canals were instrumented using the TECNIKA® micromotor (Dentsply Maillefer) in groups I–IV and the WaveOne Endo Motor® micromotor (Dentsply Maillefer) in group V. Each file was used once and the canals were prepared to an apical size of 25. Between using particular files, the canals were rinsed with 0.9% saline. Glycerin was used as a lubricant and apical patency was controlled using C-pilot 10 (VDW).

The resin blocks were fixed in a constant position and photographed before and after preparation. Photographs were saved as JPEG files and were superimposed using the GIMP 2.6® program (https://www.gimp.org/downloads/). The change in the working length and apical transportation were evaluated.

The working length after shaping the canals was measured with an endodontic ruler, using a magnifying glass with an accuracy of 0.25 mm. There was a change in length in relation to the previously confirmed length of the canal (16 mm). Apical transportation, i.e., the shift of the apex to the outer or inner side, was assessed by determining the difference between the average amount of the material removed from the external wall of the canal and the average amount of the material removed from the internal wall (1 measuring point

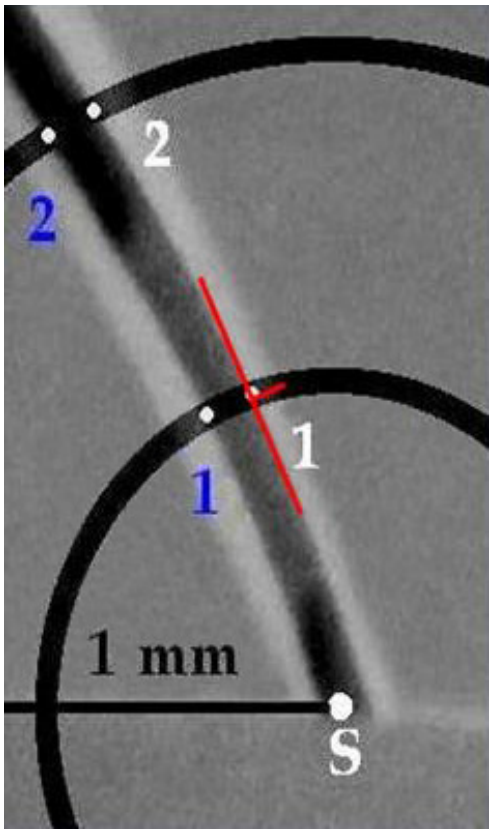

Fig. 1. Measurement of apical transportation

Table 1. Sequence of files, speed and torque

Sequence, speed and torque	ProTaper Universal group I	ProTaper Next group II	Hyflex CM group III	Hyflex EDM group IV	WaveOne Gold group V
Sequence of files	Sx (19/.04) orifice preparation S1 (18/.02) 2/3 WL (11 mm) S2 (20/.04) 2/3 WL (11 mm) F1 (20/.07) 16 mm *F2 (25/.08) 16 mm	X1 (17/.04) 16 mm *X2 (25/.06) 16 mm	25/.08 1/3 WL (5 mm) 20/.04 16 mm *25/.04 16 mm	*25/.08 (Hyflex One File) 16 mm	*25/.07 (Primary) 16 mm
Speed [rpm]	300	300	500	500	reciprocating motion
Torque [Ncm]	2.5	2.5	2.5	2.5	–

Glide path: path files – P1 (13/.02), P2 (16/.02); WL = 16 mm; WL – working length; Sx, S1, S2, F1, F2, X1, X2 – files used in the sequence;
* files used as the last.

for the outer and inner canal walls, respectively) (Fig. 1). If the result was negative, the apex moved toward the inner wall of the canal, and thus a positive result meant transport to the outer wall.

The results obtained were subjected to statistical analysis. For variables, average measurements were calculated: the arithmetic mean (x), the median (Me) and the scattering pattern – standard deviation (SD). Then, the compatibility of distributions of the variables analyzed with the normal distribution was checked using the Shapiro–Wilk test. Due to the deviation of distributions from normal distributions, the nonparametric Kruskal–Wallis test was performed to compare many means. The Dunnett multiple comparison test was used to compare the means with post-hoc pairs. The analysis was carried out using the STATISTICA v.12 PL® program (StatSoft Sp. z o.o., Kraków, Poland). The level of significance was set at $p < 0.05$.

Results

Changes in working length

The mean loss of the working length is shown in Fig. 2.

The largest loss of length was found after shaping with ProTaper Universal file (0.35 ±0.17 mm), followed by ProTaper Next (0.25 ±0.17 mm), Hyflex EDM (0.175 ±0.17 mm), WaveOne Gold (0.15 ±0.17 mm), and Hyflex CM (0.125 ±0.18 mm).

The pairwise comparison showed a statistically significant difference in the change in the canal working length between ProTaper Universal and Hyflex CM ($p = 0.0032$), ProTaper Universal and Hyflex EDM ($p = 0.021$), and ProTaper Universal and WaveOne Gold ($p = 0.0112$) files. Thus, the change in the working length of the canal was significantly lower when using Hyflex CM, Hyflex EDM and WaveOne Gold files as compared to ProTaper Universal.

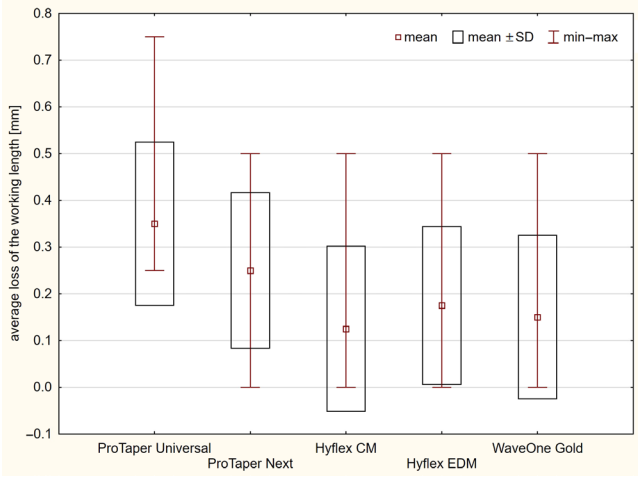

Fig. 2. Average change of the working length [mm]
SD – standard deviation.

Apical transportation

The mean apical transportation is shown in Fig. 3.

The mean apical transportation for WaveOne Gold was 0.001 ±0.024 mm, for Hyflex CM – 0.014 ±0.027 mm, for Hyflex EDM – 0.017 ±0.034 mm, for ProTaper Next – 0.022 ±0.030 mm, and for ProTaper Universal – 0.034 ±0.017 mm.

Analyzing the results of transport for individual groups, in WaveOne Gold files, the apex was transported to the outer wall in 6 cases and to the inner wall in 4 cases. In the Hyflex CM and Hyflex EDM groups, the transport was found on the external wall in 8 cases and on the internal wall in 2 cases. For the ProTaper Next group, the apex was transported to the outer wall in 7 cases, and in 3 cases to the inner wall. In 9 ProTaper Universal cases, the apex was transported to the external wall and in 1 case to the internal wall.

The comparison of apical transportation in pairs showed a statistically significant difference only between ProTaper Universal and WaveOne Gold at $p = 0.0245$. The value of apical transportation was significantly higher in the case of canals shaped with ProTaper Universal files as compared to WaveOne Gold ones.

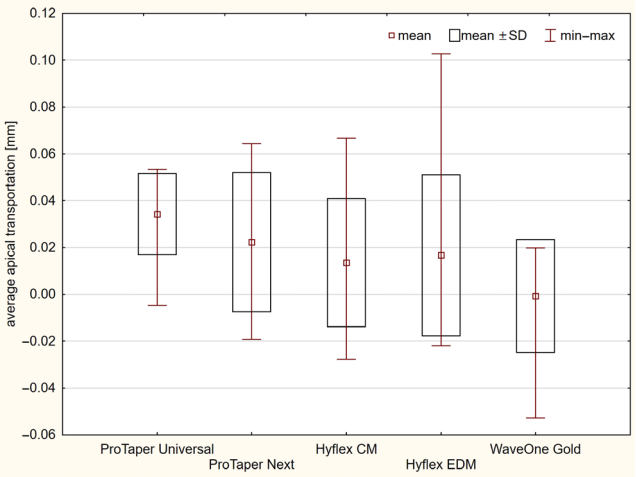

Fig. 3. Average apical transportation [mm]

Discussion

In the studies, 2 models are commonly used for the comparison of root canal shaping: resin blocks or roots of extracted teeth.[25–27] In the present study, the authors decided to use the blocks to evaluate the parameters. In these blocks, canals have precisely defined parameters, such as shape, size, conicity, and degree of curvature. Therefore, the experimental conditions are repeatable, and the only variables are the method of canal preparation and the experience of the operator.[26] Due to transparency, the blocks can be easily compared, which makes the measurements and calculations precise and accessible.

However, they do not reflect the anatomy of natural teeth and the analysis of the parameters studied takes place in 2 dimensions.[27] Another disadvantage is the fact that the test blocks are made of resin, i.e., a material with mechanical parameters completely different from those of dentin. According to González Sánchez et al., the difference in hardness between dentin and resin can affect the results of clinical work.[25] It should also be emphasized that during operations with rotary files, heat is generated, which may contribute to the softening of the resin material, thus leading to inefficient shaping.[25,26] In conclusion, resin blocks are selected for testing, as the same conditions are provided for each instrument assessed. In the case of human teeth, due to the complex anatomy of root canals, it is difficult or impossible to achieve the same experimental settings. The results of tests on resin blocks can therefore be compared, although they cannot be directly transferred to the evaluation of files in clinical situations.

To evaluate the effectiveness of canal preparation with endodontic files, the study compared the loss of the working length and apical transportation.

When comparing the shaping ability, it is important to maintain the same apical size.[28] In all the groups examined, the last used file had the same size on the tip – 25. The files differed only in conicity. In the case of groups I (ProTaper Universal) and IV (Hyflex EDM), the conicity was 8% (0.08). The last file used in group V (WaveOne Gold) was characterized by conicity of 7% (0.07), in group II (ProTaper Next) – 6% (0.06) and in group III (Hyflex CM) – 4% (0.04). During the research, none of the instruments was broken.

Modern rotary files are made of the nickel-titanium alloy, which over the years has been subjected to numerous modifications, both in the process of mechanical manufacturing and final machining. Manufacturers, through the introduction of modern technologies, influence the parameters of the traditional nickel-titanium alloy. The changes introduced are primarily aimed at reducing the stiffness of nickel-titanium files with an increase in their resistance to cyclic fatigue.

In the literature, there are more and more studies comparing the shaping of canals by means of nickel-titanium files subjected to various heat treatment processes.[29,30]

Gu et al., in their study comparing Twisted Files® (SybronEndo) (R-phase), WaveOne (M-Wire), Hyflex CM, and V Taper 2H® (SS White Dental Inc., Lakewood, USA) (CM-Wire), showed that the highest apical transportation of S-shaped canals was observed in the Twisted Files (TF) group.[29] It should be noted that the authors chose files classified into the same, 2nd generation. According to the study, the higher apical transportation is the result of the lower transformation temperature (A_f) for TF ($A_f < 20°C$) in comparison with other files ($A_f \approx 50°C$). Twisted Files are stiffer and contribute to greater changes in the apical region.[29]

The study of Liu et al. compared the shaping ability of ProTaper Universal (1st generation), ProTaper Next (M-Wire, 2nd generation), Hyflex CM (CM-Wire, 2nd generation), Reciproc (M-Wire, 2nd generation), and TF Adaptive® (SybronEndo) (2nd generation – the newly introduced TF Adaptive system uses en existing file set called Twisted Files in conjunction with the new Elements Motion featuring Adaptive Motion) in L-shaped canals. The results showed that less apical transportation was observed in the case of files whose nickel-titanium alloy was subjected to the thermal treatment process.[30]

In the present study, files from all generations included in the classification were used. The 1st one comprises ProTaper Universal, the 2nd – ProTaper Next (M-Wire) and Hyflex CM (CM), and the 3rd – Hyflex EDM and WaveOne Gold. Lower values of apical transportation and loss of the working length were observed after instrumentation with files that are characterized by lower stiffness (the 2nd and 3rd generation). ProTaper Universal, with $A_f = 17°C$, at room temperature (37°C) are in the austenitic phase and are characterized by greater stiffness. Other files, due to $A_f > 37°C$, are characterized by lower stiffness. In the study, files whose nickel-titanium alloy was subjected to the thermal treatment process better maintained the original course of the canal and contributed to a smaller loss of the working length and apical transportation.

Conclusions

The study, with its limitations, shows that in the files whose nickel-titanium alloy was subjected to the thermal treatment process, a smaller loss of the working length and lower values of apical transportation were observed.

References

1. Thompson SA. An overview of nickel-titanium alloys used in dentistry. *Int Endod J*. 2000;33:297–310.
2. Kuhn G, Jordan L. Fatigue and mechanical properties of nickel-titanium endodontic instruments. *J Endod*. 2002;28:716–720.
3. Kuhn G, Tavernier B, Jordan L. Influence of structure on nickel-titanium endodontic instruments failure. *J Endod*. 2001;27:516–520.
4. Zinelis S, Darabara M, Takase T, Ogane K, Papadimitriou GD. The effect of thermal treatment on the resistance of nickel-titanium rotary files in cyclic fatigue. *Oral Surg Oral Med Oral Pathol Oral Radiol Endod*. 2007;103:843–847.
5. Alapati SB, Brantley WA, Iijima M, et al. Micro-XRD and temperature-modulated DSC investigation of nickel-titanium rotary endodontic instruments. *Dent Mater*. 2009;25:1221–1229.
6. Walid N. Review and classification of heat treatment procedures of NiTi instruments and its implication on files fatigue. *J Dent Sci*. 2017;2:1–19.
7. Brantley WA, Svec TA, Iijima M, Powers JM, Grentzer TH. Differential scanning calorimetric studies of nickel titanium rotary endodontic instruments. *Analysis*. 2002;28:774–778.
8. Hou XM, Yahata Y, Hayashi Y, Ebihara A, Hanawa T, Suda H. Phase transformation behaviour and bending property of twisted nickel-titanium endodontic instruments. *Int Endod J*. 2011;44:253–258.
9. Shen Y, Zhou HM, Zheng YF, Campbell L, Peng B, Haapasalo M. Metallurgical characterization of controlled memory wire nickel-titanium rotary instruments. *J Endod*. 2011;37:1566–1571.

10. Zhou HM, Shen Y, Zheng W, Li L, Zheng YF, Haapasalo M. Mechanical properties of controlled memory and superelastic nickel-titanium wires used in the manufacture of rotary endodontic instruments. *J Endod*. 2012;38:1535–1540.
11. Shen Y, Zhou HM, Zheng YF, Peng B, Haapasalo M. Current challenges and concepts of the thermomechanical treatment of nickel-titanium instruments. *J Endod*. 2013;39:163–172.
12. Kell T, Azarpazhooh A, Peters OA, El-Mowafy O, Tompson B, Basrani B. Torsional profiles of new and used 20/.06 GT Series X and GT rotary endodontic instruments. *J Endod*. 2009;35:1278–1281.
13. Berendt C. Method of preparing nitinol for use in manufacturing instruments with improved fatigue resistance. United States Patent & Trademark Office, United States Patent Application 20070072147, March 29, 2007.
14. Ye J, Gao Y. Metallurgical characterization of M-Wire nickel-titanium shape memory alloy used for endodontic rotary instruments during low-cycle fatigue. *J Endod*. 2012;38:105–107.
15. Aminsobhani M, Khalatbari MS, Meraji N, Ghorbanzadeh A, Sadri E. Evaluation of the fractured surface of five endodontic rotary instruments: A metallurgical study. *Iran Endod J*. 2016;11:286–292.
16. de Arruda Santos L, de Azevedo Bahia MG, de Las Casas EB, Buono VTL. Comparison of the mechanical behavior between controlled memory and superelastic nickel-titanium files via finite element analysis. *J Endod*. 2013;39:1444–1447.
17. Testarelli L, Plotino G, Al-Sudani D, et al. Bending properties of a new nickel-titanium alloy with a lower percent by weight of nickel. *J Endod*. 2011;37:1293–1295.
18. Shen Y, Coil JM, Zhou H, Zheng Y, Haapasalo M. HyFlex nickel-titanium rotary instruments after clinical use: Metallurgical properties. *Int Endod J*. 2013;46:720–729.
19. De Vasconcelos RA, Murphy S, Carvalho CAT, Govindjee RG, Govindjee S, Peters OA. Evidence for reduced fatigue resistance of contemporary rotary instruments exposed to body temperature. *J Endod*. 2016;42:782–787.
20. Pereira ESJ, Peixoto IFC, Viana ACD, et al. Physical and mechanical properties of a thermomechanically treated NiTi wire used in the manufacture of rotary endodontic instruments. *Int Endod J*. 2012;45:469–474.
21. Otsuka K, Ren X. Physical metallurgy of Ti-Ni-based shape memory alloys. *Prog Mater Sci*. 2005;50:511–678.
22. Brantley WA, Alapati SB. Heat treatment of dental alloys: A review. In: Pardhi Y, ed. *Metallurgy – Advances in Materials and Processes*. London, UK: IntechOpen; 2012:11–15.
23. Pirani C, Iacono F, Generali L, et al. HyFlex EDM: Superficial features, metallurgical analysis and fatigue resistance of innovative electro discharge machined NiTi rotary instruments. *Int Endod J*. 2016;49:483–493.
24. Iacono F, Pirani C, Generali L, et al. Structural analysis of HyFlex EDM instruments. *Int Endod J*. 2017;50:303–313.
25. González Sánchez JA, Duran-Sindreu F, de Noé S, Mercadé M, Roig M. Centring ability and apical transportation after overinstrumentation with ProTaper Universal and ProFile Vortex instruments. *Int Endod J*. 2012;45:542–551.
26. Yoo YS, Cho YB. A comparison of the shaping ability of reciprocating NiTi instruments in simulated curved canals. *Restor Dent Endod*. 2012;37:220–227.
27. Zmener O, Banegas G. Comparison of three instrumentation techniques in the preparation of simulated curved root canals. *Int Endod J*. 1996;29:315–319.
28. Bergmans L, Van Cleynenbreugel J, Beullens M, Wevers M, Van Meerbeek B, Lambrechts P. Progressive versus constant tapered shaft design using NiTi rotary instruments. *Int Endod J*. 2003;36:288–295.
29. Gu Y, Kum KY, Perinpanayagam H, et al. Various heat-treated nickel-titanium rotary instruments evaluated in S-shaped simulated resin canals. *J Dent Sci*. 2017;12:14–20.
30. Liu Y, Qiu N, Xue M, Wang C, Yu X. Comparison of shaping ability of five nickel-titanium rotary instruments in simulated curved canals. *J Dent Oral Health*. 2017;3. https://scientonline.org/open-access/comparison-of-shaping-ability-of-five-nickel-titanium-rotary-instruments-in-simulated-curved-canals.pdf

Assessment of the influence of selected electrolytic polishing process parameters on the surface roughness of casts made of the CoCrMo alloy

Ocena wpływu wybranych parametrów polerowania elektrolitycznego na chropowatość powierzchni odlewów ze stopu kobaltowo-chromowo-molibdenowego

Małgorzata Ponto-Wolska[A–D], Leopold Wagner[C–F]

Department of Dental Propedeutics and Prophylaxis, Faculty of Medicine and Dentistry, Medical University of Warsaw, Poland

A – research concept and design; B – collection and/or assembly of data; C – data analysis and interpretation;
D – writing the article; E – critical revision of the article; F – final approval of the article

Dental and Medical Problems, ISSN 1644-387X (print), ISSN 2300-9020 (online) *Dent Med Probl.* 2018;55(4):395–398

Address for correspondence
Małgorzata Ponto-Wolska
E-mail: malgorzata.ponto@gmail.com

Funding sources
None declared

Conflict of interest
None declared

Received on May 23, 2018
Reviewed on August 13, 2018
Accepted on September 23, 2018

Published online on December 10, 2018

Cite as
Ponto-Wolska M, Wagner L. Assessment of the influence of selected electrolytic polishing process parameters on the surface roughness of casts made of CoCrMo alloy. *Dent Med Probl.* 2018;55(4):395–398. doi:10.17219/dmp/96237

DOI
10.17219/dmp/96237

Abstract

Background. To fabricate some prosthetic restorations, such as metal alloy frameworks for removable partial dentures (RPDs), casting techniques must be used. The penultimate stage of the cast finishing procedure is electropolishing.

Objectives. The aim of the study was to assess the influence of selected electrolytic polishing process parameters on the resulting surface smoothness of the cobalt-chromium-molybdenum (CoCrMo) alloy.

Material and methods. The CoCrMo alloy, 3 experimental and 2 name-brand electrolytes, were used in the study. A total of 25 samples, 63 mm × 10 mm × 1 mm in size, were cast using the Nautilus® equipment. The cast samples were shaped using metal cutters and carborundum stones and separators, and were sandblasted. The prepared samples were placed in an electrolysis cell as an anode. For each sample, measurements were made by changing the potential of the electrode by 0.2 V in the range from 1.2 V to 7.0 V. The surface of the samples was analyzed using a profilometer. An optical microscope and a scanning electron microscope (SEM) were used to examine the structure of the surface.

Results. An analysis of the obtained results showed no statistically significant differences between the BEGO Wirolyt® electrolytic polishing liquid (WB) and experimental electrolytes K15, K8 and K13, all of which were significantly better than the Dentaurum Electrolyt® polishing solution (ED). The microscope images indicated differences in the surface structure of the samples; in the SEM images, inclusions were also visible.

Conclusions. The experimental electrolytes did not differ in quality from one of the name-brand electrolytes and were even better than the other one. The obtained surface roughness values (Ra) did not differ significantly from those achieved by other researchers.

Key words: surface roughness, electrolytes, cobalt-chromium-molybdenum alloy, casting technique

Słowa kluczowe: chropowatość powierzchni, elektrolity, stop kobaltowo-chromowo-molibdenowy, technika odlewu

Introduction

To fabricate some prosthetic restorations, such as metal alloy frameworks for removable partial dentures (RPDs), casting techniques must be used. The processing of metal alloys involves many physical and chemical phenomena, which may result in difficult to remove defects in the form of excessive roughness and pits, occurring on the surface of the cast. One of the reasons why such defects occur is the mechanical penetration of the liquid metal into the pores in the molding mass.[1,2]

Once punched out of the casting ring, the cast has to undergo mechanical and electrolytic polishing. Mechanical polishing is done with tungsten-carbide grinding discs and corundum stones, followed by sandblasting to remove the residues of the molding mass.[3] The sandblasting and grinding processes may cause friction and temperature increases, and thus promote disturbances in the internal structure of the alloy, which may give rise to areas of a heterogeneous structure. A common defect is surface deformation, i.e., a thin layer of a deformed crystalline structure and highly refined (disintegrated) grains, which can result in the formation of a local corrosion center and cause corrosion of the alloy.[4] In the available literature, there are papers about the influence of cast quality on the strength of metal RPD clasps.[5–8]

The next step of the cast finishing procedure is electropolishing. The electrolytic polishing process is carried out in an electrolyte solution, containing sulfuric acid and other substances.[9] Properly conducted, the electrochemical procedure removes oxides, reduces corrosion, releases metal ions, and enhances the strength of the alloy, but it does not result in a high gloss or optimal smoothness.[10,11] Adequate electropolishing also makes the final polishing easier to carry out. The final stage of the cast finishing procedure is polishing with a rubber point, polishing paste for alloys, and steam or detergent. According to the aforementioned study by Jang at al., as well as Kuhar and Funduk, after the final stage, the average roughness value (Ra) of 0.2 μm or less is clinically satisfactory, as this rugosity will collect only a small amount of plaque.[2,12] In agreement with this, Bollen et al. define Ra = 0.2 μm as "the threshold Ra", and report a clear reduction in the amount of biofilm deposited below this value.[13]

To obtain the optimal smoothness, good casting quality is required. The lowest possible Ra values must be achieved by electropolishing and the final machining must be carried out correctly. In dental materials, smooth surfaces result in easy surface cleaning and less microbial accumulation, which means that the surface roughness of the materials is important for the long-term clinical performance of dental restorations.[14]

Due to the shortage of papers evaluating the influence of various electrolytic polishing parameters on the quality of cast surfaces, and the lack of information on the full composition of name-brand electrolytes, the authors decided to develop their own electrolytes and investigate the influence of selected process parameters (temperature, time and current) on the resulting surface smoothness of the cobalt-chromium-molybdenum (CoCrMo) alloy.

Material and methods

Wironit® Extrahard CoCrMo alloy (BEGO, Bremen, Germany) was chosen for the study. Three experimental electrolytes – K8, K13 and K15 – were formulated, containing, by weight, 8.6%, 13.5% and 15.8% sulfuric acid, 91%, 85.8% and 83.4% ethylene glycol, and 0.4%, 0.7% and 0.8% water, respectively. The 2 name-brand electrolytes selected for use in the study were Electrolyt® (Dentaurum, Ispringen, Germany) (ED) and Wirolyt® (BEGO) (WB). A total of 25 samples, 63 mm × 10 mm × 1 mm in size, were molded from casting wax and subsequently turned into CoCrMo alloy samples, cast in a Nautilus® casting machine (BEGO), using the lost wax technique.

The samples were shaped using metal cutters and carborundum stones and separators to remove the excess metal and casting channels. Next, they were sandblasted with aluminum oxide and subjected to electrolytic polishing. The electrolyte was then poured into an electrolysis cell and heated to an appropriate temperature. The prepared samples were placed in the electrolysis cell as an anode. Its potential was measured relative to the calomel electrode, which was as close as possible to the anode. Electrolysis was carried out for successive anode potential values. It was found that after about 5 min, the current was stabilized. This value was taken as the electrolysis current. The measurements were performed between the 5th and 15th minute of anodic dissolution, varying the temperature from 25°C to 60°C (35°C for the name-brand electrolytes) and varying the potential of the electrode from 1.2 V to 7.0 V in 0.2-volt steps. The course of the curves indicated the anode potential value above which electrolytic polishing occurred.

In the case of the name-brand electrolytes, a potential of 12 V and a temperature of 35°C were selected on the basis of the obtained potentiostatic curves. Electrolytic polishing was carried out for 12 min. (The electrolyte manufacturers recommend polishing for 5–15 min at a temperature of 20–40°C and at a current of 2–2.5 A.)

Once the polishing was completed, each sample was washed with distilled water and then with acetone, and finally dried with compressed air. The surfaces of the samples were analyzed using an Alpha-Step® 200 profilometer (KLA-Tencor Corp., Milpitas, USA). The Warsaw University of Technology Nikon® E995 optical microscope (Nikon Corp., Tokyo, Japan) and the Quanta® 200 scanning electron microscope (SEM) (FEI Company, Hillsboro, USA) were used to examine the structure of the surfaces. The results obtained were subjected to statistical analysis using STATISTICA v. 13.1 software (StatSoft Inc., Tulsa, USA). Ten pairwise comparisons were done using Student's *t*-test with Bonferroni corrections, so the critical *p*-value was 0.005.

Results

The data from the profilometer are presented in Table 1. The lowest Ra values were obtained for:

- WB: the average value of the current density at 35°C amounted to 49.42 mA/cm^2 for the potential range 3.2–3.6 V;
- K15 solution: the average value of the current density at 25°C amounted to 17.47 mA/cm^2 for the potential range 2.2–2.7 V, at 40°C, the average value was 49.81 mA/cm^2 for the potentials 2.6–3.2 V, and at 60°C, it was 131.97 mA/cm^2 for the potentials 3.1–3.8 V;
- K8 solution: the average value of the current density at 25°C amounted to 60.49 mA/cm^2 for the potential range 3.2–4.0 V, at 40°C, the average value was 99.09 mA/cm^2 for the potentials 3.8–4.4 V, at 60°C, it was 185.68 mA/cm^2 for the potentials 4.6–5.0V;
- K13 solution: the average value of the current density at 25°C amounted to 34.58 mA/cm^2 for the potential range 2.6–3.4 V, at 40°C, the average value was 71.78 mA/cm^2 for the potentials 2.8–3.6 V, at 60°C, it was 154.87 mA/cm^2 for the potentials 3.4–4.2 V;
- ED: the average value of the current density at 35°C amounted to 34.23 mA/cm^2 for the potential range 2.8–3.4 V.

The results of the statistical analysis are presented in Table 2.

The obtained microscope images indicated differences in the surface structure of the samples, and in the SEM images inclusions were also visible. Figure 1 shows a SEM image of a sample after electrolytic polishing with WB; there are visible inclusions on the surface.

Discussion

Current density, time, temperature, and surface size of the object are parameters that determine the rate of electrolysis.[6] Research conducted under the same conditions

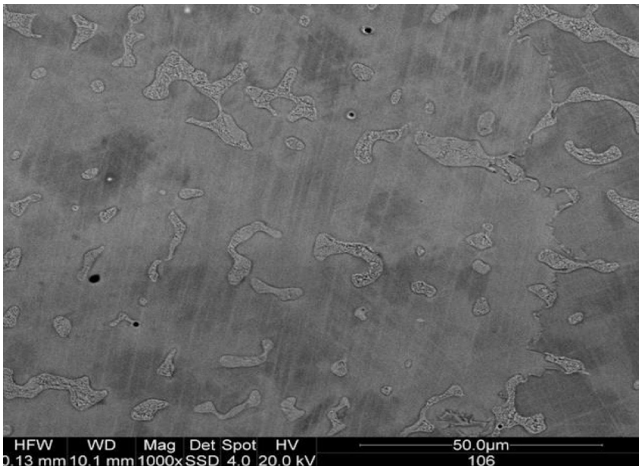

Fig. 1. Sample surface polished with WB

Table 1. Roughness values (Ra) of the tested samples [µm]

Electrolyte	Sample 1	Sample 2	Sample 3	Sample 4	Sample 5	Mean	Standard deviation
WB	0.868	0.793	0.542	0.845	0.821	0.774	0.133
ED	1.255	1.321	1.184	1.413	1.229	1.280	0.089
K8	0.926	1.020	1.032	0.905	0.842	0.945	0.080
K13	1.014	1.018	0.911	1.172	0.908	1.005	0.108
K15	0.808	0.816	0.826	1.008	0.912	0.874	0.086

WB – Wirolyt (BEGO); ED – Electrolyt (Dentaurum); K8, K13, K15 – experimental electrolytes.

Table 2. Student's *t*-test for comparisons of 10 pairs (the significance level is 0.005)

Group 1 vs group 2	Samples treated as independent variables						
	group 1 average	group 2 average	*t*	*df*	*p*-value	group 1 n	group 2 n
WB vs ED*	0.7738	1.2804	–7.09097	8	0.000103	5	5
WB vs K8	0.7738	0.9450	–2.47061	8	0.038674	5	5
WB vs K13	0.7738	1.0046	–3.02205	8	0.016508	5	5
WB vs K15	0.7738	0.8740	–1.41921	8	0.193605	5	5
ED vs K8*	1.2804	0.9450	6.25116	8	0.000245	5	5
ED vs K13*	1.2804	1.0046	4.41084	8	0.002254	5	5
ED vs K15*	1.2804	0.8740	7.34460	8	0.000080	5	5
K8 vs K13	0.9450	1.0046	–0.99232	8	0.350103	5	5
K8 vs K15	0.9450	0.8740	1.35161	8	0.213473	5	5
K13 vs K15	1.0046	0.8740	2.12130	8	0.066690	5	5

t – according to Student's *t*-test; *df* – degrees of freedom for each comparison (*df* = the number of samples in both groups – the number of groups; *df* = 5 + 5 – 2 = 8); * significant comparisons.

as the present study have shown that the current density values for the same anode potentials differ depending on the electrolyte temperature and composition.[15,16] The potential level at which the polishing process begins increases along with the decreases in the sulfuric acid concentration in the electrolyte solution and the increases in the electrolyte temperature. Based on the statistical analysis of the profilometer results, there were no statistically significant differences between electrolytes WB, K15, K8, and K13, all of which were significantly better than ED.

All the obtained images showed heterogeneity and inclusions on the surfaces of all the CoCrMo alloy samples after electrolyte polishing. Numerous studies on Co-Cr alloys have revealed that their structure is predominantly characterized by the presence of large grains, which is associated with lower mechanical and physical properties, such as compressive strength, tensile strength and flexibility.[17,18] An analysis of the alloy microstructure showed that there were smaller grains in the thinner parts and larger grains in the thicker ones. This is due to the faster cooling of the thin parts, which disenables grain growth.[17,19] Intermetallic precipitations were also observed at the boundary planes of the grains. They form clusters of trace amounts of elements such as Cr, Ni, Mo, and W, and can lower the tensile and compressive strength.[20,21]

The results of studies by Taylor et al. and Aydin, obtained using other research methods, were similar to those of the present study.[22,23] Taylor et al. examined the surface of CoCrMo alloy samples, sandblasted using Al_2O_3, and then polished in the Metrodent® electrolyte (Metrodent Ltd., Lowergate Works, Lowergate Paddock, Huddersfield, UK) . The Ra values obtained in the tests amounted to ≈1.87 μm.[22] On the other hand, Aydin investigated the surface roughness using a perthometer. The average Ra value he obtained was 1.884 μm.[23]

The roughness of a metal surface is an important factor influencing the deposition of biofilm on a denture.[20,24] Rough surfaces of dental materials near the gingiva make a suitable location for microbial accumulation. Microbes penetrate the recesses and unevenness of the surfaces and are often not sufficiently removed during hygienic procedures; consequently, they become attached to the denture.[1] Excessive surface roughness is therefore a significant cofactor in the pathogenesis of denture stomatitis.[25] The surface roughness of a casting after electropolishing is almost 10 times higher than the level considered optimal, so final polishing is required before giving the restoration to the patient.

Conclusions

The experimental electrolytes did not differ in quality from one of the name-brand electrolytes and were even better than the other one. The obtained surface roughness did not differ significantly from that achieved by other researchers.

References

1. Torabi K, Farjood E, Hamedani S. Rapid prototyping technologies and their applications in prosthodontics: A review of literature. *J Dent*. 2015;16:1–9.
2. Jang KS, Youn SJ, Kim YS. Comparison of castability and surface roughness of commercially pure titanium and cobalt-chromium denture frameworks. *J Prosthet Dent*. 2001;86:93–98.
3. Taga Y, Kawai K, Nokubi T. New method for divesting cobalt-chromium alloy castings: Sandblasting with a mixed abrasive powder. *J Prosthet Dent*. 2001;85:357–362.
4. de Melo JF, Gjerdet NR, Erichsen ES. Metal release from cobalt-chromium partial dentures in the mouth. *Acta Odontol Scand*. 1983;41:71–74.
5. Kim D, Park C, Yi Y, Cho L. Comparison of cast Ti-Ni alloy clasp retention with conventional removable partial denture clasps. *J Prosthet Dent*. 2004;91:374–382.
6. Rudd R, Rudd KD. A review of 243 errors possible during the fabrication of a removable partial denture: Part II. *J Prosthet Dent*. 2001;86:262–276.
7. Vallittu PK, Kokkonen M. Deflection fatigue of cobalt-chromium, titanium, and gold alloy cast denture clasp. *J Prosthet Dent*. 1995;74:412–419.
8. Henriques GE, Consani S, Rollo JM, Andrade e Silva F. Soldering and remelting influence on fatigue strength of cobalt-chromium alloys. *J Prosthet Dent*. 1997;78:146–152.
9. Eliaz N, Nissan O. Innovative processes for electropolishing of medical devices made of stainless steels. *J Biomed Mater Res*. 2007;83A:546–557.
10. Hassan L, Juszczyk AS, Clark RK. Immediate replacement removable partial dentures with cobalt-chromium frameworks: Rationale, technology and a case report. *J Oral Rehab*. 2005;32:772–775.
11. Knezović-Zlatarić D, Nemet M, Baućić I. Laboratory fabrication procedures of a metal partial denture framework. *Acta Stomat Croat*. 2003;37:95–98.
12. Kuhar M, Funduk N. Effects of polishing techniques on the surface roughness of acrylic denture base resins. *J Prosthet Dent*. 2005;93:76–85.
13. Bollen CM, Papaioannou W, Van Eldere J, Schepers E, Quirynen M, van Steenberghe D. The influence of abutment surface roughness on plaque accumulation and peri-implant mucositis. *Clin Oral Implants Res*. 1996;7:201–211.
14. Ţălu Ş, Stach S, Klaić B, Mišić T, Malina J, Čelebić A. Morphology of Co-Cr-Mo dental alloy surfaces polished by three different mechanical procedures. *Microsc Res Tech*. 2015;78:831–839.
15. Hensel KB. Electropolishing. *Met Finish*. 2000;98:440–448.
16. Jumer JF. Electropolishing. *Met Finish*. 1995:93;420–427.
17. Wataha JC, Lockwood PE, Khajotia SS, Turner R. Effect of pH on element release from dental casting alloys. *J Prosthet Dent*. 1998;80:691–698.
18. Carreiro AFP, Ribeiro RF, de Mattos MGC, et al. Evaluation of the castability of a Co-Cr- Mo-W alloy varying the investing technique. *Braz Dent J*. 2005;16:50–55.
19. Gupta KP. The Co-Cr-Mo (cobalt-chromium-molybdenum) system. *J Phase Equilib Diff*. 2005;26:87–92.
20. Silva JW, Sousa LL, Nakazato RZ, Codaro EN, de Felipe H. Electrochemical and microstructural study of Ni-Cr-Mo alloys used in dental prostheses. *Mater Sci Applicat*. 2011;2:42–48.
21. Örtorp A, Jönsson D, Mouhsen A, Vult von Steyern P. The fit of cobalt-chromium three-unit fixed dental prostheses fabricated with four different techniques: A comparative in vitro study. *Dent Mater*. 2011;27:356–363.
22. Taylor R, Maryan C, Verran J. Retention of oral microorganisms on cobalt-chromium alloy and dental acrylic resin with different surface finishes. *J Prosthet Dent*. 1998;80:592–597.
23. Aydin AK. Evaluation of finishing and polishing techniques on surface roughness of chromium-cobalt castings. *J Prosthet Dent*. 1991;65:763–767.
24. Bezzon OL, Pedrazzi H, Zaniquelli O, da Silva TB. Effect of casting technique on surface roughness and consequent mass loss after polishing of NiCr and CoCr base metal alloys: A comparative study with titanium. *J Prosthet Dent*. 2004;92:274–277.
25. Felipucci DN, Davi LR, Paranhos HF, Bezzon OL, Silva RF, Pagnano VO. Effect of different cleansers on the surface of removable partial denture. *Braz Dent J*. 2011;22:392–397.

Comparison of oral health condition in Polish adolescents within 7 years

Porównanie stanu zdrowia jamy ustnej młodzieży polskiej w okresie 7 lat

Dorota Olczak-Kowalczyk[1,A,B,D–F], Dariusz Gozdowski[2,C,E], Elżbieta Małkiewicz[3,A,E], Urszula Kaczmarek[4,B–F]

[1] Department of Pediatric Dentistry, Faculty of Medicine and Dentistry, Medical University of Warsaw, Poland
[2] Department of Experimental Design and Bioinformatics, Faculty of Agriculture and Biology, Warsaw University of Life Sciences, Poland
[3] Department of Mother and Child, Ministry of Health, Warszawa, Poland
[4] Department of Conservative Dentistry and Pedodontics, Faculty of Dentistry, Wroclaw Medical University, Poland

A – research concept and design; B – collection and/or assembly of data; C – data analysis and interpretation;
D – writing the article; E – critical revision of the article; F – final approval of the article

Dental and Medical Problems, ISSN 1644-387X (print), ISSN 2300-9020 (online) *Dent Med Probl.* 2018;55(4):399–404

Address for correspondence
Urszula Kaczmarek
E-mail: urszula.kaczmarek@umed.wroc.pl

Funding sources
None declared

Conflict of interest
None declared

Received on July 13, 2018
Reviewed on August 19, 2018
Accepted on September 25, 2018

Published online on December 20, 2018

Cite as
Olczak-Kowalczyk D, Gozdowski D, Małkiewicz E, Kaczmarek U. Comparison of oral health condition in Polish adolescents within 7 years. *Dent Med Probl.* 2018;55(4):399–404. doi:10.17219/dmp/96273

DOI
10.17219/dmp/96273

Abstract

Background. There is some increase in the risk of oral diseases in adolescence, as in this period of life, individuals become more independent regarding the consumption of sugary food and beverages, and they can be reluctant to apply oral hygiene procedures systematically. Therefore, adolescence is a period of life that needs special attention.

Objectives. The objective of this study was to compare some oral health parameters and oral health-related behaviors of 15-year-olds within the past 7 years.

Material and methods. In 2008 and 2015, nationwide surveys on oral health condition involving 15-year-olds were carried out in Poland. Sampling and clinical examinations were performed according to the World Health Organization (WHO) criteria, which were extended with a questionnaire concerning pro-health behaviors.

Results. Caries prevalence and severity turned out to be a constant, as neither a significant reduction in the proportion of caries-affected adolescents (94.0% vs 94.0%) nor in the decayed, missing and filled teeth (DMFT) (5.96 vs 5.65), DT, FT, and significant caries (SiC) index values was found, except for a decline in MT (0.17 vs 0.07; $p < 0.05$). The periodontal condition revealed deterioration, since some increase in the percentage of adolescents with gingival bleeding (34.2% vs 37.4%), shallow pockets (0 vs 2.8%) and loss of attachment (0 vs 1.3%), and a decrease in the mean number of sound sextants (4.85 vs 4.21; $p < 0.01$) were noticed. Moreover, fewer adolescents declared brushing their teeth at least twice a day (77.8% vs 66.7%; $p < 0.001$).

Conclusions. The high and constant prevalence of caries and deterioration of the periodontal condition indicate a significant burden on the oral health of adolescents. To improve this situation, the implementation of proper age-oriented oral health programs is needed.

Key words: adolescents, caries prevalence, periodontal condition

Słowa kluczowe: młodzież, występowanie próchnicy, stan przyzębia

Introduction

The World Health Organization (WHO) defines adolescents as subjects between 10 and 19 years of age. Adolescence is the phase of life in which individuals are in biological, psychological and social development, and assume adult roles.[1] Overall, they present the best general health. However, there is some increase in the risk to oral health in this period of life, since adolescents are more independent regarding the consumption of sugary food and beverages, and can be reluctant to apply oral hygiene procedures systematically. Therefore, it is a period of life requiring special attention.

Dental caries and periodontal diseases, being the main oral diseases, are widespread in various populations, and are age-related and cumulative diseases. Therefore, for national and international comparisons of oral health in the populations, the WHO recommends the examination of the specific age groups. Among adolescents, the individuals at the age of 12 and 15 years constitute the selected age groups. The most often examined age group are 12-year-olds due to the likelihood of having all the permanent teeth, with the exception of the third permanent molars, and because of being easily available for oral examination on the primary school basis. Therefore, this age group has been chosen as the global indicator. However, individuals at the age of 15 are also valid, because they have all their permanent teeth erupted, except for the third molars, and exposed to the oral environment for 3–9 years, and they have established oral hygiene and dietary habits. Thus, it makes the assessment of caries and periodontal diseases relevant and important.[2]

Dental caries is a chronic and multifactorial disease, developing the most frequently in children and adolescents, still people remain vulnerable to the disease for their whole lives. However, it is a preventable disease, because it can be stopped or even reversed at its early stage with the use of simple measures, i.e., by dental biofilm removal, reduction of sugary food consumption and topical fluoride applications. A number of factors have been recognized to have a modulating effect on oral health, among others, behavioral ones (e.g., proper tooth brushing, use of fluoridated toothpaste, reduction of consumption of fermentable carbohydrates), oral health-related knowledge, regular dental check-ups, the socioeconomic status, and ethnicity.[3–5] Caries prevalence among 15-year-olds is very differentiated, ranging from 21.9% to 97.6% of affected subjects with the involvement of 0.7 (Malawi) to 8.1 teeth (Latvia).[6,7]

At this age, periodontal diseases occur less frequently compared to dental caries. The data from the WHO Periodontal Profile showed that acute gingivitis occurred predominantly, manifesting itself as bleeding on probing, present in 1% (Benin, 2003) to 51% of subjects (Germany, 2005). Calculus was noticed in 13.0% (Djibouti, 1988) to 92% of subjects (Kyrgyzstan, 1987). The presence of gingival pockets was quite low, and was noted for 0 (Benin, 2003; Spain, 2005; Namibia, 2013) to 15% of subjects (Belarus, 2000/1). Healthy periodontium was observed in 0 (Belarus, 2000/1) to 46% of subjects. (Benin, 2003).[8]

The aim of the study was to compare some oral health parameters and oral health-related behaviors of 15-year-olds within the past 7 years.

Material and methods

Data for the analysis was obtained from 2 cross-sectional nationwide surveys, which were conducted in 2008 and 2015; both entitled Monitoring of Oral Health.[9,10] The population groups were selected by a 3-stage cluster sampling procedure, including 1,839 subjects in 2008, living in urban and rural areas of 16 provinces, and 615 subjects in 2015 from urban and rural areas of 3 provinces situated in western, central and eastern parts of Poland. Despite the 3-fold lower number of the examined individuals in the 2nd survey, a sample of about 600 subjects presented the minimum representative sample size. It was calculated taking into account the data on the total number of 15-year-olds retrieved from the Statistics Poland (Demographic Yearbook of Poland 2014) and caries prevalence in this age group in Poland (90% ±2.5% error tolerance at 95% confidence interval (CI)). The participation in both surveys was voluntary. The examined groups in 2008 and 2015 comprised approximately equal numbers of males and females (46.0% and 54.0% vs 40.7% and 59.3%, respectively) and similar numbers of residents of urban and rural areas (47.7% and 52.3% vs 54.3% and 45.7%, respectively). In both surveys, the inclusive criteria were the same, i.e., the age of 15 years, the parents' signed consent, a completed questionnaire, and the compliancy of the adolescent. Likewise, the exclusive criteria were the opposite: age of less or more than 15 years, no parental signed consent, an uncompleted questionnaire, and an uncooperative attitude of the adolescent. Finally, the adolescents were enrolled in the survey based on school class attendance.

Both surveys consisted of clinical oral examination and a structured questionnaire; however, the items in these questionnaires were slightly different. Therefore, it was possible to compare only the same parameters, contained in both surveys.

The oral examination was conducted with the use of artificial light, a plane mirror and a ball-ended dental probe (WHO-621 periodontal probe) by the dentists who had been trained and calibrated. In each subject, the parameters of oral health condition were recorded according to the WHO criteria.[2,11] Dental caries was diagnosed at the cavitation level. Caries experience was registered in terms of the decayed, missing and filled teeth (DMFT) index value and its components, as well as the significant caries (SiC) index. The CARE-Index

(FT / DMFT × 100%), assessing the proportion of teeth that have received restorative care, was calculated.

In 2008, the periodontal status was assessed according to the community periodontal index (CPI) criteria, registering the condition around the index teeth in 6 sextants as sound, bleeding on probing, presence of calculus, shallow and deep periodontal pockets, and loss of epithelial attachment.[9,11] In the 2nd study, the periodontal condition was assessed using the modified CPI, which registered bleeding on probing and the depth of pockets around all the examined teeth, as well as loss of epithelial attachment.[2,10]

The self-reported questionnaire in both studies contained the same items regarding the frequency of tooth brushing, consumption of sugary beverages, the date of the last dental visit, counseling obtained from the dentist, self-assessment of oral health, and 3 questions concerning the oral health-related knowledge:

– Does caries develop more quickly in children and adolescents than in adults?

– If parents have a great number of carious lesions, will their children also have dental caries, no matter if they take care of their teeth or not?

– Does fluoride use make the enamel resistant to caries?

Both surveys received the consent of the Bioethics Committee of the Warsaw Medical University of July 20, 2008 and August 18, 2015.

Statistical analysis of the data was carried out using the χ^2 test at a significance level of $p < 0.05$ in Statistica v. 10.0 software (StatSoft Polska Sp. z o.o., Kraków, Poland).

Results

The percentage of caries-affected subjects remained at the same level of 94.0%. The mean caries level expressed as mean DMFT decreased by about 6%. The SiC index was over 2.5-fold higher than DMFT for the remaining 2/3 of adolescents in both surveys. Some slight changes were observed in DT, MT and FT components. In 2015, the mean DT value increased by about 8% in comparison to 2008. The FT value declined by about 7%. The value of the CARE-Index remained nearly the same. However, the mean number of missing teeth was reduced significantly, over 2-fold (Table 1).

The percentage of children with at least 1 tooth extracted due to caries was reduced nearly by a half. However, the percentage of adolescents with DT ≤ 1 and with at least 1 tooth sealed increased slightly. On the other hand, the percentage of adolescents with DT ≥ 1 and at least 1 tooth with pit and fissure sealant rose slightly. The mean number of teeth with pit and fissure sealants in the subjects was reduced (Table 2).

The periodontal condition seemed to deteriorate, as evidenced in the 2nd survey. The frequency of gingival bleeding (3.2%), shallow gingival pocket (2.8%) and loss of attachment (1.3%) increased. The mean number of sound sextants decreased significantly (Table 3).

Within the past 7 years, the percentage of adolescents who declared brushing their teeth at least twice a day diminished significantly from 77.8% to 66.7%. In contrast, the percentage of the subjects cleaning their teeth once

Table 1. Means of the decayed, missing and filled teeth (DMFT) index values and DMFT components

Survey	DMFT	DT	MT	FT	SiC	DMFT for 2/3	CARE-Index
2008	5.96	2.03	0.17	3.76	10.08	3.67	63.1
2015	5.65	2.20	0.07	3.48	9.96	3.56	60.5
p-value	>0.05	>0.05	<0.05*	>0.05	>0.05	>0.05	>0.05

SiC – the significant caries index; * statistically significant difference.

Table 2. Percentage of subjects with at least 1 decayed, missing or sealed tooth

Survey	At least 1 tooth			Mean number of teeth with pit and fissure sealant in the subjects with sealed teeth
	with decay	missed due to caries	with pit and fissure sealant	
2008	60.7	10.8	19.7	3.09
2015	62.8	5.0	21.1	2.20
p-value	>0.05	<0.001*	>0.05	<0.05*

* statistically significant difference.

Table 3. Periodontal condition of the subjects

Survey	Percentage of subjects according to the periodontal condition				Mean number of sound sextants
	sound	bleeding on probing	shallow pockets (4–5 mm)	loss of attachment (4–5 mm)	
2008	63.1	34.2	0	0	4.85
2015	58.5	37.4	2.8	1.3	4.21
p-value	>0.05	>0.05	–	–	<0.01*

* statistically significant difference.

a day increased significantly (from 16.8% to 26.2%) and the percentage of those brushing their teeth sporadically rose slightly (from 5.4% to 7.1%). Frequent consumption of sweetened beverages remained on the same level (20%). Slightly more adolescents reported having at least 1 dental appointment during the last 12 months. Regarding the counsel offered by dentists, the 2nd survey indicated that they paid less attention to simple domestic preventive measures recommended to their young patients, especially cariostatic dietary habits, the use of fluoridated toothpaste and a schedule of check-ups, appropriately to the risk of caries.

Oral health-related knowledge in 2015 seemed to be more widespread. Approximately 7% more adolescents answered all 3 questions correctly. However, significantly fewer of the surveyed believed that fluoride makes dental enamel resistant to caries. In the 2nd survey, the adolescents assessed the condition of their teeth more realistically, as fewer of them considered it very good or good (Table 4).

Discussion

The comparison of the nationwide epidemiological data within the period of 7 years indicated that dental caries still remains a great burden in the Polish population at the age of 15 years. The caries level seemed to be steady. The only positive change was a significant diminution in the MT value and over a 2-fold reduction in the percentage of youth with at least 1 missing tooth due to caries. In contrast to our data, a substantial reduction of dental caries in other countries was observed. In the period from 1993 to 1998, 14.4% increase in caries-free 15-year-olds and ca. 22% decrease in DMFT (from 5.60 to 4.33) in Slovenia was noticed.[12] In Switzerland, in the canton of Zürich, the DMFT value also decreased by ca. 22%, from 2.02 in 1996 to 1.58 in 2000,[13] and in the canton of Basel-Landschaft by ca. 43% from 3.3 in 1977 to 1.72 in 2011.[4] However, in Lithuania, after some drop in DMFT between 1983 and 1995 (from 6.42 to 6.07), a slight increase was noticed in the last study (5.39 in 2000 vs 5.58 in 2005).[14] In Australia, the mean DMFT values for 14- and 15-year-olds have remained fairly stable over the last decade.[15]

The SiC index below 5 was suggested by Marthaler et al. to be the global goal for the 15-year-olds.[13] In Switzerland, the SiC index value dropped from 4.91 in 1996 to 4.31 in 2000.[13] However, Waltimo et al., studying Swiss and foreign children, noticed a slight increase in the SiC index value from 3.94 in 2006 to 4.39 in 2011 (ca. 10%) after a decrease in the previous years.[4] In contrast, our data presented almost no change in this index value within the last 7 years. The improvement of dental health was explained by the effectiveness of the preventive programs implemented in those countries.[4,12,13] In Poland, dental care for individuals up to the age of 18 years is free. Therefore, each child can benefit from routine dental treatment and preventive measures, including pit and fissure sealant placement on first permanent molars and the application of fluoride varnish every 3 months, check-up oral examinations with oral hygiene instruction twice a year, some preventive packages directed to specific age groups, as well as supervised tooth brushing

Table 4. Behaviors, oral health-related knowledge and self-assessment of dental health

Parameters		Survey		*p*-value
		2008	2015	
Frequency of tooth brushing	at least twice a day	77.8	66.7	<0.001*
	once a day	16.8	26.2	<0.001*
	less frequently	5.4	7.1	>0.05
Consumption of sugared beverages	at least once a day	20.0	20.1	>0.05
	less frequently	80.0	79.9	>0.05
Last dental visit	within 12 months	77.8	81.1	>0.05
	over 12 months ago	22.2	18.9	>0.05
Advice received from a dentist regarding	cariostatic dietary regimen	17.9	11.7	<0.001*
	teeth cleaning	39.0	38.5	>0.05
	fluoridated toothpaste use	29.0	10.4	<0.001*
	schedule of check-ups	54.9	46.5	<0.001*
Oral health knowledge (correct response)	question 1	66.4	67.6	>0.05
	question 2	47.5	77.4	<0.001*
	question 3	65.5	54.5	<0.001*
Self-rated dental health	very good/good	82.4	64.0	<0.001*
	satisfied	no data	27.2	–
	poor	17.6	8.8	<0.001*

Data expressed as percentages; * statistically significant difference.

with the use of fluoride gel in primary schools. However, such availability of dental care did not yield the expected satisfactory results.

In caries prevention, the efficacy in caries prevention of the sealants placement on occlusal surface of the most caries-prone permanent first molars has been indicated.[16,17] In countries with low caries prevalence, like Denmark, ca. 2/3 of 15-year-old adolescents had at least 1 sealed molar.[18] In both our surveys, the percentage of adolescents with at least 1 tooth sealed was lower and almost the same in 2008 and 2015. A similar proportion of Polish and English 15-year-olds revealed the presence of pit and fissure sealants (21.1% vs 22.0%), but the percentages were higher in the case of adolescents from Wales and Northern Ireland (28.0% and 34.0%, respectively).[19] In Greece, only 8.0% of 15-year-olds had at least 1 sealed molar. This has been attributed to the lack of public awareness and dentists not being convinced of the usefulness and effectiveness of pit and fissure sealants in caries prevention.[20]

The comparison of data from both our surveys revealed some deterioration in the periodontal condition, as we observed a slight increase in the frequency of gingival bleeding and the occurrence of shallow gingival pockets, loss of epithelial attachment and a significant reduction in the mean number of sextants with sound periodontium. The proportion of 15-year-olds with gingival bleeding varied in different countries from 25% to 92%.[5,7,19,21–23] Gingival bleeding evaluated by the application of a periodontal probe around 6 index teeth within 10 years (2003–2013) decreased in England (from 45% to 40%) and Northern Ireland (from 44% to 41%), but increased in Wales (from 37% to 42%).[19] However, taking into consideration our data, the occurrence of shallow pockets was greater than in Greece – 0.2%[23] and smaller than in Georgia – 35.36%.[22]

The proportion of Polish adolescents who reported brushing their teeth twice a day or more often was higher in 2008 than in 2015. In contrast, in England, Wales and Northern Ireland, it increased from 80% in 2003 to 85% in 2013.[24] In 2015, dental floss was used by 46.5% of Polish adolescents and 11.4% of them declared using sugar-free chewing gums.[10] In comparison to those figures, 15-year-olds living in England, Wales and Northern Ireland used dental floss less frequently (21%) and more often chose sugar-free chewing gum (34%).[24]

The exemplary sugary products were different in both our studies; therefore, we could not make any comparison. We were able to compare only the frequency of sweetened beverage consumption on the level 'at least once a day', which turned out to be the same. In contrast to our data, fewer adolescents living in England, Wales and Northern Ireland (14%) reported consumption of sugary drinks 4 or more times a day. In England, Wales and Northern Ireland, 86% 15-year-olds reported that during the last dental appointment they were provided with preventative counseling.[24] A retrospective evaluation of the provision of different types of preventive care for 15-year-olds in Australia revealed that only 7.9% of them were provided with dietary advice and 14.3% with oral hygiene instruction.[25] Our surveys also revealed that dentists in Poland rarely offered preventative counseling to their patients. A decreased percentage of adolescents were informed about the benefits of fluoride in toothpaste and got dietary counseling. This implies the need to strengthen guidance concerning the preventive role of dentists working in primary dental care units.

In the 2nd survey compared to the 1st one, the adolescents more realistically assessed the condition of their teeth, as fewer of them recognized it as very good or good (64.0% vs 82.4%). The national surveys conducted in England, Wales and Northern Ireland indicated the percentage of 15-year-olds satisfied with the appearance of their teeth ranged from 54% (Wales) to 61% (England and Northern Ireland each). Besides, Polish surveys regarding the appearance of teeth did not provide an example of the concept of appearance (e.g., white teeth, straight teeth).[21]

In 2015, 81.1% of Polish adolescents reported to have a dental visit in the last 12 months; it was slightly more than 7 years earlier (by 3.3%). In contrast, more 15-year-olds from England, Northern Ireland and Wales visited a dentist the previous year (90%, 95% and 96%, respectively) having the DT value ca. 3–4 times lower in comparison to Polish adolescents (0.5, 0.8 and 0.8 vs 2.2, respectively).[19]

Conclusions

The data indicated that within the last 7 years, oral health parameters in 15-year-old adolescents did not improve, except for the reduction of missed teeth due to caries as well as oral health-related behaviors. Moreover, such a situation suggests that the currently used preventive measures are not effective and, therefore, there is a need to implement broad age-based oral health promotion and prevention.

References

1. WHO. Adolescence: A period needing special attention. http://apps.who.int/adolescent/second-decade/section2/page1/recognizing-adolescence.html. Accessed July 11, 2018.
2. WHO. *Oral Health Surveys. Basic Methods*. 5th ed. Geneva, Switzerland: World Health Organization; 2013.
3. Campus G, Cagetti MG, Senna A, Sacco G, Strohmenger L, Petersen PE. Caries prevalence and need for dental care in 13–18-year-olds in the Municipality of Milan, Italy. *Community Dent Health*. 2008;25:237–242.
4. Waltimo T, Menghini G, Weber C, Kulik EM, Schild S, Meyer J. Caries experience in 7-, 12-, and 15-year-old schoolchildren in the canton of Basel-Landschaft, Switzerland, from 1992 to 2011. *Community Dent Oral Epidemiol*. 2016;44:201–208.
5. Rebelo MA, Lopes MC, Vieira JM, Parente RC. Dental caries and gingivitis among 15- to 19-year-old students in Manaus, AM, Brazil. *Braz Oral Res*. 2009;23:248–254.
6. Msyamboza KP, Phale E, Namalika JM, et al. Magnitude of dental caries, missing and filled teeth in Malawi: National Oral Health Survey. *BMC Oral Health*. 2016;16:29. doi:10.1186/s12903-016-0190-3
7. Bjarnason S, Berzina S, Care R, Mackevica I, Rence I. Oral health in Latvian 15-year-olds. *Eur J Oral Sci*. 1995;103:274–279.

8. WHO Periodontal country profiles. http://www.dent.niigata-u.ac.jp/prevent/perio/contents.html. Accessed July 11, 2018.
9. Jodkowska E, Wierzbicka M, Szatko F, et al. *Stan zdrowia jamy ustnej dzieci i młodzieży. Monitoring zdrowia jamy ustnej. Polska 2018.* Warsaw, Poland: Medical University of Warsaw Press; 2008:31–49,75–79.
10. Olczak-Kowalczyk D, Kaczmarek U, Kawala B, et al. *Monitoring zdrowia jamy ustnej. Monitorowanie stanu zdrowia jamy ustnej populacji polskiej w latach 2013–2015. Ocena stanu zdrowia jamy ustnej i jego uwarunkowań w populacji polskiej w wieku 3, 10 i 15 lat. Polska 2015.* Warsaw, Poland: Medical University of Warsaw Press; 2015:178–197,211–214,261–287.
11. WHO. *Oral Health Surveys. Basic Methods.* 4th ed. Geneva, Switzerland: World Health Organization; 1997.
12. Vrbič V. Reasons for the caries decline in Slovenia. *Community Dent Oral Epidemiol*. 2000;28:126–132.
13. Marthaler T, Menghini G, Steiner M. Use of the Significant Caries Index in quantifying the changes in caries in Switzerland from 1964 to 2000. *Community Dent Oral Epidemiol.* 2005;33:159–166.
14. Milčiuvienė S, Bendoraitienė E, Andruškevičienė V, et al. Caries dental prevalence among 12–15-year-olds in Lithuania between 1983 and 2005. *Medicina (Kaunas).* 2009;45:68–76.
15. Skinner J, Johnson G, Phelan C, Blinkhorn A. Dental caries in 14- and 15-year-olds in New South Wales, Australia. *BMC Public Health*. 2013;13:1060.
16. Hiiri A, Ahovuo-Saloranta A, Nordblad A, Mäkelä M. Pit and fissure sealants versus fluoride varnishes for preventing dental decay in children and adolescents. *Cochrane Database Syst Rev*. 2006;4:CD003067.
17. Ahovuo-Saloranta A, Forss H, Hiiri A, Nordblad A, Mäkelä M. Pit and fissure sealants versus fluoride varnishes for preventing dental decay in the permanent teeth of children and adolescents. *Cochrane Database Syst Rev*. 2016;1:CD003067.
18. Ekstrand KR, Martignon S, Christiansen ME. Frequency and distribution patterns of sealants among 15-year-olds in Denmark in 2003. *Community Dent Health*. 2007;24:26–30.
19. Children's Dental Health Survey 2013. Report 2: Dental disease and damage in children. England, Wales and Northern Ireland. Health and Social Care Information Centre. 2015. http://www.hscic.gov.uk/catalogue/PUB17137/CDHS2013-Report2-Dental-Disease.pdf. Accessed July 11, 2018.
20. Oulis CJ, Berdouses ED, Mamai-Homata E, Polychronopoulou A. Prevalence of sealants in relation to dental caries on the permanent molars of 12- and 15-year-old Greek adolescents. A national pathfinder survey. *BMC Public Health*. 2011;11:100.
21. Yazdani R, Vehkalahti MM, Nouri M, Murtomaa H. Validity of self-assessment of oral health among 15-year-olds in Tehran, Iran. *Oral Health Prev Dent*. 2008;6:263–269.
22. Levin L, Margvelashvili V, Bilder L, Kalandadze N, Machtei EE. Periodontal status among adolescents in Georgia. A pathfinder study. *Peer J*. 2013;1:e137.
23. Vadiakas G, Oulis CJ, Tsinidou K, Mamai-Homata E, Polychronopoulou A. Oral hygiene and periodontal status of 12- and 15-year-old Greek adolescents. A national pathfinder survey. *Eur Arch Paediatr Dent*. 2012;13:11–20.
24. Children's Dental Health Survey 2013. Report 1: Attitudes, behaviours and children's dental health. England, Wales and Northern Ireland. Health and Social Care Information Centre. 2015. http://content.digital.nhs.uk/catalogue/PUB17137/CDHS2013-Report1-Attitudes-and-Behaviours.pdf. Accessed July 11, 2018.
25. Masoe AV, Blinkhorn AS, Taylor J, Blinkhorn FA. Preventive and clinical care provided to adolescents attending public oral health services New South Wales, Australia: A retrospective study. *BMC Oral Health*. 2014;14:142.

Prevalence of oral mucosal lesions in young seniors in the Wrocław region

Występowanie chorób błony śluzowej jamy ustnej u młodych seniorów rejonu Wrocławia

Beata Głowacka[B,D,F], Tomasz Konopka[A–C,E,F]

Department of Periodontology, Faculty of Dentistry, Wroclaw Medical University, Poland

A – research concept and design; B – collection and/or assembly of data; C – data analysis and interpretation;
D – writing the article; E – critical revision of the article; F – final approval of the article

Dental and Medical Problems, ISSN 1644-387X (print), ISSN 2300-9020 (online) *Dent Med Probl.* 2018;55(4):405–410

Address for correspondence
Tomasz Konopka
E-mail: tomasz.konopka@umed.wroc.pl

Funding sources
None declared

Conflict of interest
None declared

Received on July 20, 2018
Reviewed on August 24, 2018
Accepted on October 4, 2018

Published online on December 31, 2018

Abstract

Background. The morbidity of certain oral pathologies, for example denture-related stomatitis, burning mouth syndrome (BMS) and benign neoplasms is higher in the elderly. It is necessary to periodically assess the changes in the profile of the occurrence of these diseases and determine the dominant risk factors associated with their incidence.

Objectives. The aim of the study was to evaluate the prevalence of oral mucosal pathologies (in particular, potentially malignant and cancerous disorders) in a randomly selected population of 65–74-year-old residents of Wrocław and Oława, Poland.

Material and methods. A group of 1,600 persons aged 65–74 years, living in Wrocław (a large city) and Oława (a small town) were randomly selected to participate in the study. 285 people from Wrocław and 102 from Oława were examined. In a clinical dental examination, the following parameters were assessed: the number of teeth; probing/pocket depth (PD) and clinical attachment level (CAL) for all the teeth at 4 measuring points (on this basis, periodontal diagnoses were made according to American recommendations – of the American Center for Disease Control and Prevention and the American Academy of Periodontology (CDC/AAP)); and the presence of prosthetic restorations and their quality. In the anamnestic study, variables concerning the socioeconomic status, systemic conditions (comorbidity of selected general diseases, nicotine addiction status, body mass) and selected behaviors promoting oral health were determined.

Results. The most common clinical changes in the oral mucosa were denture-related stomatitis (6.7%), hemangiomas (5.9%) and fibromas (4.1%). Potentially malignant disorders and cancerous lesions were diagnosed in 59 persons (15.2% of the respondents). One case of tongue cancer was diagnosed in an inhabitant of Oława.

Conclusions. More than 1/3 of the examined persons were diagnosed with certain clinical, pathological oral mucosal lesions requiring treatment, of which nearly half were potentially malignant and cancerous. Poor tooth brushing efficiency was associated with a higher incidence of pre-cancerous and cancerous lesions in the oral cavity.

Key words: the elderly, oral mucosa diseases, potentially malignant disorders, cross-sectional epidemiological study

Słowa kluczowe: osoby starsze, choroby błony śluzowej jamy ustnej, zaburzenia potencjalnie złośliwe, przekrojowe badanie epidemiologiczne

Cite as
Głowacka B, Konopka T. Prevalence of oral mucosal lesions in young seniors in the Wroclaw region. *Dent Med Probl.* 2018;55(4):405–410. doi:10.17219/dmp/97310

DOI
10.17219/dmp/97310

Introduction

Some oral mucosal lesions are characteristic of old age and do not require treatment. These include dislocated and enlarged sebaceous glands observed in the buccal mucosa, and dilated lingual veins on the ventral surface of the tongue. Most oral mucosal lesions in the elderly have a multifactorial etiology. This includes systemic conditions typical for this age group, such as systemic diseases and a large number of medicines taken, metabolic changes and nutritional deficiencies. Moreover, the condition of the oral mucosa is affected by local factors: mechanical irritation (habitual biting of the oral mucosa, irritation caused by the edge of an ill-fitting denture or dental filling), thermal irritation (related to food intake or smoking), biofilm on natural and artificial surfaces, qualitative or quantitative changes in the secreted saliva, nicotine addiction, and alcohol abuse.[1–5]

The most common oral mucosa diseases in the elderly include candidiasis, burning mouth syndrome (BMS), lichen planus, leukoplakia, traumatic lesions, recurrent aphthous stomatitis, and pigmented nevus.[6–8] Rare pathologies include lesions occurring during the course of dermatoses, e.g., in pemphigoid and in benign (fibroma, papilloma, hemangioma) and malignant tumors (cancer of the oral mucosa).[7,8]

The GLOBOCAN (project of the International Agency for Research on Cancer) data of 2012 shows that in Poland, 53.1% of cases of oral cancer (including lips) regard people aged 65–74 years. Mortality rates linked with this disease also demonstrate a positive correlation with aging, and for the 65–74 age group, it is 7.6% in women and 38.1% in men.[8] Therefore, oncological prophylaxis is an extremely important aspect of geriatric patient health. Squamous cell carcinoma, which accounts for 90% of head and neck lesions,[9] in the early stages of development does not often display obvious morphological changes, which may hinder its early diagnosis. Elderly patients are not always regularly examined by a dentist, especially if they do not have natural teeth. Focusing on the treatment of systemic diseases additionally contributes to the delay in making a diagnosis and commencing treatment. Screening tests conducted as part of oncological prophylaxis should include the assessment of the oral mucosa in geriatric patients. An early detection of malignant tumors or potentially malignant disorders with a high probability of cancer development gives a chance for a complete recovery.

An ailment often diagnosed in the elderly is xerostomia. Australian studies show that the hypofunction of salivary glands occurs in 22.1% and a subjective feeling of dry mouth in 22.5% of the elderly.[10] The simultaneous presence of both abnormalities was found in 5.7% of subjects.[10] In the elderly, sialopenia is most frequently the side effect of drugs like anticholinergics, antidepressants, diuretics, hypotensives, sedatives, myorelaxants, antihistamines, opioid analgesics, and non-steroidal anti-inflammatory drugs.[11–13] The reduction of salivary gland secretion may also be caused by the occurrence of endocrinopathy (diabetes, thyroid disease), autoimmune diseases (Sjögren's syndrome, rheumatoid arthritis, systemic lupus erythematosus, scleroderma), granulomatous diseases, and local causes (head and neck radiotherapy, salivary gland diseases).[11,14,15] Xerostomia has certain effects on the emotional state of the elderly, leading to a low mood and depressive states. Both subjective and objective complaints associated with dry mouth reduce the quality of life of geriatric patients.

The incidence of oral mucosal lesions in the elderly should be periodically examined in order to define their risk factors, including dental iatrogeny. Therefore, one of the assumptions of the undertaken cross-sectional epidemiological study was to assess the prevalence of clinical oral pathologies (in particular, potentially malignant oral disorders and neoplasms) in the selected population of 65–74-year-old residents of Wrocław and Oława.

Material and methods

An epidemiological study was carried out to assess the population aged 65–74 years, living in a city (Wrocław, 638,000 inhabitants) and a small town (Oława, 33,000 inhabitants) in the province of Lower Silesia in southwest Poland.

At the Ministry of the Interior and Administration in Warsaw, a group of 1,600 people (1,000 and 600 for Wrocław and Oława, respectively) was selected in a two-tier draw (sex and age, respectively), thus a group with the symmetrical structure of sex and age was formed. A letter of invitation to participate in a free examination of oral health was sent to all the randomly drawn people. Persons for whom a valid phone number was established were additionally notified by telephone.

The study was carried out at the Department of Periodontology of Wroclaw Medical University and in a private specialist dental clinic in Oława (Praktyka Prywatna, Dentyści Oława). Persons reporting to take part in the study signed the statement approved by the Bioethics Commission at Wroclaw Medical University (opinion No. KB-712/2017), thereby agreeing to participate in the study and on the processing of data obtained. The applied exclusion criteria were as follows: general contraindications (including bacterial endocarditis in the past) and local contraindications (including acute odontogenic infection).

In the period between June 25 and October 30, 2017, 387 people (136 men and 149 women from Wrocław, and 50 men and 52 women from Oława) were examined. The response rate for the research was 32.8% (35.6% for the large city and 25.5% for the small town).

Based on the interview conducted among patients who agreed to participate, the following information was obtained:
– place of residence (Wrocław or Oława);
– age;
– gender;
– education (elementary, secondary, higher);
– general diseases: cardiovascular diseases (conditions without an incident, for instance coronary heart disease, cardiac arrhythmias or thrombotic diseases, and with a previous incident – myocardial infarction or stroke), hypertension, diabetes, osteoporosis – with the pharmacological treatment of the declared disease taken as the diagnostic criterion;
– genetic load in the form of periodontitis in the history (a survey question whether family members like grandparents, parents or siblings had lost their teeth because of progressive mobility);
– body weight and height along with the body mass index (BMI) based on these measurements;
– nicotine addiction: non-smokers (people who had never smoked or had smoked fewer than 100 cigarettes throughout their lives), ex-smokers (people who used to smoke regularly, but had been free of addiction for at least a year at the time of the examination) and current smokers (people who had been smoking a minimum of 1 cigarette a day during the 6 months preceding the examination) – for this subgroup, the pack-year index was determined, being the product of multiplying the number of packs of cigarettes smoked per day by the number of years the person had smoked);
– oral health behaviors: average number of visits to a dental clinic during the previous 5 years (at least 2 visits a year were considered regular), frequency of brushing natural teeth or prostheses (brushing at least twice daily was considered regular), frequency of replacing a toothbrush per year (at least once every 3 months was considered regular brush replacement), daily additional cleaning of the interdental spaces with dental floss or a special brush (yes/no);
– forms of dental treatment funding: only in state-financed facilities, only in private facilities, or a mix of the two.

The clinical examination was performed in LED lighting, with the use of a dental mirror and the Hu-Friedy PCPUNC 15 periodontal probe (Hu-Friedy, Chicago, USA). Pathological oral mucosal lesions were evaluated clinically. All the lesions were verified by a periodontologist with more than 20 years' diagnostic experience (TK). Congenital anomalies or lesions not requiring treatment, for instance dislocated sebaceous glands, linea alba or varicose veins of the tongue, were not recorded. The effectiveness of tooth brushing was also evaluated, on the basis of the presence of supragingival plaque on the vestibular and lingual surfaces of the teeth, and was expressed by the plaque index (PI) according to O'Leary et al.[16] The value of PI < 30% was assumed as the exponent of effective brushing and the value >70% was an indication of ineffective tooth brushing. The probing/pocket depth (PD) and clinical attachment level (CAL) were also determined at 4 points around each tooth: distal-buccal, mesial-buccal, mid-buccal, and mid-lingual. On the basis of this examination, the periodontal health status was categorized according to the American Center for Disease Control and Prevention and the American Academy of Periodontology (CDC/AAP) classification by Eke et al.[17] The presence, condition and usefulness of existing dental prostheses were also assessed. The permanent restorations were assessed in terms of their quality in the perigingival area, the reconstruction of occlusal points/planes, the absence of their interference with central and non-central occlusion, and the absence of mechanical damage. The removable dentures were assessed in terms of their adhesion to the prosthetic base, their retention and stabilization, as well as the restored occlusal height.

In the statistical analysis, the difference in the prevalence of a feature in the adopted groups was analyzed by the χ^2 test. The value of $p \leq 0.05$ was considered statistically significant. The statistical analysis was carried out using Statistica 13.1 software (StatSoft, Inc., Tulsa, USA).

Results

In total, 26 types of diagnoses were made in 137 subjects (35.4%), including 71 women (35.3%) and 66 men (35.3%). As Table 1 shows, most often – in as many as 6.7% of people – denture-related stomatitis occurred. Another large group of diagnoses included potentially malignant disorders (leukoplakia, lichen planus and pigmented nevus) and benign neoplasms (hemangioma, fibroma, papilloma, and epulis), which – along with 1 case of tongue cancer – accounted for the morbidity of these changes in as many as 15.2% of the subjects. The less frequent diagnoses were as follows: angular cheilitis (11), leukokeratosis (8), candidiasis (3), herpesvirus infection (3), and diagnoses confirmed only in women – BMS (3), xerostomia (3) and geographic tongue (3). In the residents of Oława, the most common was fibroma (7.8%), and in men – hemangioma (8.1%). Table 2 presents the influence of selected factors on the incidence of the identified potentially neoplastic and neoplastic disorders. A significantly more frequent occurrence of this group of pathologies was found in the people with the worst efficiency of tooth brushing ($p = 0.048$). A more frequent occurrence of these changes in current nicotine addicts was not confirmed statistically, although the lesions were diagnosed in 20% of these people.

Table 1. Occurrence of oral pathologies depending on place of residence and sex

Diagnosis	Entire group (n = 387)	Place of residence		Sex	
		Wrocław (n = 285)	Oława (n = 102)	women (n = 201)	men (n = 186)
Denture-related stomatitis	26 (6.7)	19 (6.7)	7 (6.9)	14 (7)	12 (6.5)
Hemangioma	23 (5.9)	17 (6)	6 (5.9)	8 (4)	15 (8.1)
Fibroma	16 (4.1)	8 (2.8)	8 (7.8)	8 (4)	8 (4.3)
Angular cheilitis	11 (2.8)	6 (2.1)	5 (4.9)	7 (3.5)	4 (2.2)
Leukokeratosis	8 (2.1)	8 (2.8)	0	3 (1.5)	5 (2.7)
Leukoplakia	7 (1.8)	4 (1.4)	3 (2.9)	3 (1.5)	4 (2.2)
Lichen planus	6 (1.6)	6 (2.1)	0	5 (2.5)	1 (0.5)
Papilloma	4 (1)	4 (1.4)	0	3 (1.5)	1 (0.5)
Candidiasis	3 (0.8)	1 (0.4)	2 (2)	2 (1)	1 (0.5)
Herpesvirus infection	3 (0.8)	3 (1.1)	0	2 (1)	1 (0.5)
Geographic tongue	3 (0.8)	1 (0.4)	2 (2)	3 (1.5)	0
BMS	3 (0.8)	2 (0.7)	1 (1)	3 (1.5)	0
Xerostomia vera	3 (0.8)	2 (0.7)	1 (1)	3 (1.5)	0
Recurrent aphthous stomatitis	2 (0.5)	2 (0.7)	0	1 (0.5)	1 (0.5)
Smoker's palate	2 (0.5)	2 (0.7)	0	1 (0.5)	1 (0.5)
Tongue cancer	1 (0.3)	0	1 (1)	0	1 (0.5)
Epulis	1 (0.3)	1 (0.4)	0	1 (0.5)	0
Other	15 (3.9)	13 (4.6)	2 (2)	4 (2)	11 (5.9)
Total	**137 (35.4)**	**99 (34.7)**	**38 (37.3)**	**71 (35.3)**	**66 (35.5)**

Data presented as number (percentage); BMS – burning mouth syndrome.

Discussion

Among the examined residents of Wrocław and Oława, clinical lesions of the oral mucosa requiring treatment were found in 35.4% of people. This was decidedly more compared to a regional study of young seniors from the province of West Pomerania (Poland), where they were observed in only 22.5% of people.[18] The comparative study also noted the presence of lesions not requiring treatment, e.g., linea alba or dislocated sebaceous glands. Thus, the real difference between these studies in the incidence of treatment need for pathological changes on the mucous membrane was even greater. The inclusion of congenital abnormalities in the registered diagnoses, subjective complaints, for example xerostomia spuria, or not clearly defined, for example coated tongue, makes a comparative analysis very difficult. The most common diagnosis in our own study was denture-related stomatitis, observed in 6.7% of people. This is in line with the results of the Fifth German Oral Health Study (Fünfte Deutsche Mundgesundheitsstudie – DMS V) in young seniors, in which this diagnosis was made in 4.6% of people, significantly more often in the subjects with the lowest social status.[19] In a regional cross-sectional Turkish study conducted in one of the districts of Istanbul in people over 65 years of age, denture-related stomatitis was the second, after varicose veins, pathology of the oral mucosa and occurred in 14.1% of the subjects.[20] In a Polish nationwide study of people at this age, the most common diagnosis was leukoplakia with leukokeratosis, diagnosed in as many patients as 10.5%, with a significant predominance in men.[21] A comparison of the third and fifth German national studies shows a decrease in the prevalence of leukoplakia by 0.3% over a period of 17 years.[19] This is related to the decline in the number of people addicted to tobacco, observed in recent decades. In our own observation, there were 16.5% of patients with nicotine addiction (leukoplakia in 1.8%), in the province of West Pomerania there were 8.5% (leukoplakia in 1%),[18] and in Germany there were 10.7% (leukoplakia 0.7%).[19] The decrease in the prevalence of leukoplakia is related to the blurring of significant differences in the occurrence of this diagnosis in both sexes. In the assessment of the oral mucosa in young seniors from Lower Silesia, the rule regarding the more frequent incidence of lichen planus and BMS in women is confirmed, but from an epidemiological point of view, these differences were not spectacular. Also, the place of residence was not observed to influence in a particular way the incidence of oral mucosal lesions (with the exception of the more frequent incidence of leukokeratosis in a large city).

Diagnosing clinical oral mucosa pathologies in an epidemiological study sometimes can be difficult due to the inability to perform additional examinations (in particular,

Table 2. Influence of the analyzed variables on the incidence of precancerous and cancer lesions (including tongue cancer, hemangioma, fibroma, papilloma, epulis, leukoplakia, lichen planus, and pigmented nevus in the oral mucosa) (59 lesions)

Variable	Incidence	*p*-value
Place of residence		
Wrocław	44 (15.4)	0.86
Oława	15 (14.7)	
Sex		
female	34 (16.9)	0.34
male	25 (13.4)	
Smoking status		
non-smoker	26 (12.4)	0.12
ex-smoker	20 (17.8)	
current smoker	13 (20)	
BMI		
normal weight	17 (15.9)	0.76
overweight	23 (13.5)	
obesity	19 (17.4)	
Diabetes		
yes	13 (18.1)	0.46
no	46 (14.6)	
Cardiovascular disease		
yes	17 (14.8)	0.87
no	42 (15.4)	
Osteoporosis		
yes	3 (7)	0.17
no	56 (16.3)	
Hypertension		
yes	31 (17.9)	0.18
no	28 (13.1)	
Periodontitis (defined by the CDC/AAP criteria)		0.43
yes	28 (17.6)	
no	25 (14.5)	
Effectiveness of teeth brushing		
PI < 30%	10 (10)	0.048*
PI > 70%	20 (20)	
Dental appointments		
regularly	26 (21.3)	0.052
irregularly	33 (12.9)	
Tooth brushing		
regularly	45 (16.5)	0.29
irregularly	14 (12.3)	
Cleaning of interdental spaces		
yes	10 (13.7)	0.55
no	43 (16.6)	
Prosthetic treatment		
correct	18 (14)	0.41
incorrect	33 (17.4)	
Form of dental treatment funding		
state-financed (National Health Fund)	20 (15)	0.93
private	21 (15.4)	
mixed	18 (15.3)	

Data presented as number (percentage); BMI – body mass index; CDC/AAP – the American Center for Disease Control and Prevention and the American Academy of Periodontology; PI – plaque index; * statistical significance.

mycological and histopathological). However, in all the dubious cases, the diagnostic process was widened, because the subjects were treated at our facility.

In our own material, the group of most frequently occurring oral mucosa pathologies (15.2% patients) comprised potentially malignant disorders (leukoplakia, lichen planus and pigmented nevus), as well as neoplasms (benign – hemangioma, fibroma, papilloma, and epulis, and also 1 case of tongue cancer). This observation strengthens the message about the need for continuous education among patients and primary care physicians in the field of cancer prevention, and proper diagnostic and treatment processes. Our analysis of the influence of selected general factors (nicotine addiction, BMI, diabetes, cardiovascular diseases, osteoporosis, hypertension), local factors (periodontitis, prosthetic treatment, efficient tooth brushing) and behavioral factors (related to oral cavity hygiene) did not indicate a significant relationship between these factors and the occurrence of the aforesaid group of disorders. The only exception was the significantly more frequent incidence of these pathologies in people ineffectively brushing their teeth (PI > 70%). This could result from the relatively small size of the assessed proliferative lesion group (59 patients with such diagnoses) and the etiological heterogeneity of the lesions, e.g., viral in papillomas, traumatic in fibromas or nicotine in leukoplakia.

In many studies, the incidence of oral mucosal lesions is not assessed in random samples in cross-sectional or cohort studies, but is referred to people seeking treatment in a specialist center.[5,7,22–24] In contrast to an epidemiological assessment, in a short observational study, the possibility of conducting additional tests significantly broadens the diagnostic possibilities. The morbidity of all deviations from the physiological state of the oral mucosa (including congenital abnormalities and disorders not requiring treatment) may then be very high, especially in the elderly, and reach even more than 90% in the age group over 70 years.[22] The most frequent deviations from the physiological clinical picture of the oral mucosa in the elderly are varicose veins and fissured tongue, reported in more than 1/2 and 1/3 of the subjects, respectively.[22] In turn, the most frequent pathologies requiring treatment in such observations were as follows: in Wrocław (Poland) – oral candidiasis in 25% of the examined patients,[7] in Bangkok (Thailand) – traumatic ulceration in 15.6% of the respondents[22] and in Talca (Chile) – fibroma in 10.8% of people aged over 60 years.[24] Even among the elderly who seek treatment, benign soft tissue tumors (fibroma, hemangioma and pyogenic granuloma epulis) may be the most common group of diseases, reaching up to 29% of diagnoses.[24] Of course, the exact verification of the diagnoses is possible only after a histopathological examination. A certain limitation in studying the incidence of oral mucosa diseases in random samples is the necessity of making only clinical diagnoses, which may be subject to error in some situations, for instance, in the differentiation of fibroma and papilloma, or leukoplakia and lichen planus located on the tongue.

Conclusions

To sum up, attention should be paid to the high frequency and variety of pathological oral mucosal lesions in young seniors in the Wrocław area. A matter of particular concern is the high incidence of potentially malignant lesions and benign neoplastic lesions. Therefore, regular visits to the dentist's office are necessary, even for toothless patients, to seek clinical verification and specialist treatment as soon as possible.

References

1. Pai A, Deverashetty P. Changing trends in the oral mucosa geriatric population – an epidemiological study. *J Ind Acad Geriatr*. 2017;13:10–17.
2. Scully C. *Oral & Maxillofacial Medicine. The Basis of Diagnosis and Treatment*. 3rd ed. Edinburgh, UK: Churchill Livingstone Elsevier; 2013;10–20.
3. Kim SK, Allen ED. Structural and functional changes in salivary glands during aging. *Microsc Res Tech*. 1994;28:243–253.
4. Agnihotri R, Gaur S. Implications of tobacco smoking on the oral health of older adults. *Geriatr Gerontol Int*. 2014;14:526–540.
5. Knychalska-Karwan Z. Oral mucosal pathological lesions in 4,752 patients treated at the Department of Conservative Dentistry at Jagiellonian University in Kraków, Medical College in the years 1961–1998 [in Polish]. *Magazyn Stomatol*. 2004;14(3):10–14.
6. MacEntee MI, Glick N, Stolar E. Age, gender, dentures, and oral mucosal disorders. *Oral Dis*. 1998;4:32–36.
7. Konopka T, Mendak M. Prevalence of oral mucosal diseases in patients of specialist clinics in Wrocław in the years 1992–2003 [in Polish]. *Dent Med Probl*. 2004;41:717–725.
8. GLOBOCAN 2012: Estimated cancer incidence, mortality and prevalence worldwide in 2012. http://iarc.fr/Databases/Iarc-Cancerbases/GLOBOCAN-2012. Accessed July 10, 2018.
9. Vigneswaran N, Williams MD. Epidemiological trends in head and neck cancer and aids in diagnosis. *Oral Maxillofac Surg Clin North Am*. 2014;26:123–141.
10. Thomson WM, Chalmers JM, Spencer AJ, Ketabi M. The occurrence of xerostomia and salivary gland hypofunction in a population-based sample of older South Australians. *Spec Care Dent*. 1999;19:20–23.
11. Smidt D, Torpet LA, Nauntofte B, Heegaard KM, Pedersen AM. Associations between labial and whole salivary rates, systemic diseases and medications in a sample of older people. *Community Dent Oral Epidemiol*. 2010;38:422–435.
12. Shetty SR, Bhowmick S, Castelino R, Babu S. Drug induced xerostomia in elderly individuals: An institutional study. *Contemp Clin Dent*. 2012;3:173–175.
13. Chew ML, Mulsant BH, Pollock BG, et al. Anticholinergic activity of 107 medications commonly used by older adults. *J Am Geriatr Soc*. 2008;56:1333–1341.
14. Lopez-Pintor RM, Casanas E, Gonzalez-Serrano J, et al. Xerostomia, hyposalivation, and salivary flow in diabetes patients. *J Diab Res*. 2016;2016:4372852.
15. Acauan MD, Figueiredo MA, Cherubini K, Gomes AP, Salum FG. Radiotherapy-induced salivary dysfunction: Structural changes, pathogenetic mechanisms and therapies. *Arch Oral Biol*. 2015;60:1802–1810.
16. O'Leary TJ, Drake RB, Naylor JE. The plaque control record. *J Periodontol*. 1972;43:38.
17. Eke PI, Dye BA, Wei L, Thornton-Evans GO, Genco JR. Prevalence of periodontitis in adults in the United States: 2009 and 2010. *J Dent Res*. 2012;91:914–920.
18. Lipkiewicz M. Periodontal condition in 65-74-year-old persons in West Pomerania [in Polish]. PhD thesis. Pomeranian Medical University in Szczecin, Poland, 2016.
19. Hertrampf K. Disease and medical care prevalence in young seniors (65–74 years of age). Oral mucosa findings [in German]. In: Jordan AR, Micheelis W, eds. *Fünfte Deutsche Mundgesundheitsstudie (DMS V)*. Koln, Germany: Deutscher Zahnärzte Verlag DÄV; 2016:359–362.
20. Mumcu G, Cimilli H, Sur H, Hayran O, Atalay T. Prevalence and distribution of oral lesions: A cross-sectional study in Turkey. *Oral Dis*. 2005;11:81–87.
21. Konopka T, Dembowska E, Pietruska M, Dymalski P, Górska R. Periodontal status and selected parameters of oral condition of Poles aged from 65 to 74 years [in Polish]. *Przegl Epidemiol*. 2015;69:643– 47.
22. Jainkittivong A, Aneksuk V, Langlais RP. Oral mucosal conditions in elderly dental patients. *Oral Dis*. 2002;8:218–223.
23. Cebeci AR, Gülşahi A, Kamburoğlu K, Orhan BK, Öztaş B. Prevalence and distribution of oral mucosal lesions in an adult Turkish population. *Med Oral Patol Oral Cir Bucal*. 2009;14:E272–277.
24. Rivera C, Droguett D, Arenas-Márquez MJ. Oral mucosal lesions in a Chilean elderly population: A retrospective study with a systemic review from thirteen countries. *J Clin Exp Dent*. 2017;9:e276–283.

Utility of the morphometry of the maxillary sinuses for gender determination by using computed tomography

Użyteczność morfometrii zatok szczękowych przy użyciu tomografii komputerowej w ustalaniu płci

Suwarna Dangore-Khasbage[A–E], Rahul Bhowate[F]

The Datta Meghe Institute of Medical Sciences, Wardha, India

A – research concept and design; B – collection and/or assembly of data; C – data analysis and interpretation;
D – writing the article; E – critical revision of the article; F – final approval of the article

Dental and Medical Problems, ISSN 1644-387X (print), ISSN 2300-9020 (online) *Dent Med Probl.* 2018;55(4):411–417

Address for correspondence
Suwarna Dangore-Khasbage
E-mail: dangore_suwarna@rediffmail.com

Funding sources
None declared

Conflict of interest
None declared

Received on June 7, 2018
Reviewed on October 6, 2018
Accepted on November 6, 2018

Published online on December 27, 2018

Cite as
Dangore-Khasbage S, Bhowate R. Utility of morphometry of maxillary sinuses for gender determination by using computed tomography. *Dent Med Probl.* 2018;55(4):411–417. doi:10.17219/dmp/99622

DOI
10.17219/dmp/99622

Abstract

Background. It is impossible to use the routine skeletal parts for gender identification if the skeleton of unknown human remains is obtained in a fragmented and incomplete state. The alternative is to use other parts of the skeleton for gender identification.

Objectives. The objective of this study was to assess the utility of the morphometry of the maxillary sinuses using computed tomography (CT) for gender determination.

Material and methods. The study, approved by the institutional ethics committee, analyzed CT scans of 200 patients (100 males, 100 females). The measurement of the mediolateral (ML), superoinferior (SI) and anteroposterior (AP) dimensions, as well as of the volume and the antero-lateral (AL) angle of both the maxillary sinuses, was performed using a CT scan. Head circumference and head area were also measured on an axial image in order to evaluate the correlation between the sinus volume and the head circumference and head area.

Results. The mean of the mediolateral, superoinferior and anteroposterior dimensions, volume and AL angle of the right and left maxillary sinuses showed a statistically significant difference between males and females. Head circumference as well as head area were observed to be greater in males than in females, with a statistically significant difference. A positive correlation was observed between the volume of maxillary sinuses and the head circumference and head area on both sides and in both genders; however, it was not significant. Amongst all the parameters, the left AL angle with a 78.5% accuracy was found to be the best discriminative parameter, followed by the right AL angle with a 73% accuracy. The overall accuracy of the maxillary sinus parameters to identify gender was 86%.

Conclusions. The maxillary sinus measurements, as well as head circumference and head area are valuable parameters for sex determination in forensic medicine, with a relatively good accuracy rate. However, the prediction rate can be increased by including the AL angle of the maxillary sinus.

Key words: maxillary sinus, head circumference, head area, gender determination

Słowa kluczowe: zatoka szczękowa, obwód głowy, powierzchnia głowy, ustalanie płci

Introduction

Identification of skeletal and decomposing human remains is one of the most difficult tasks in forensic medicine, just as determining the sex of an individual. However, if successful, sex determination eliminates 50% of the population from further consideration and assists in the collection of information for the biological profile of the unknown individual.[1]

It is said that the skeleton, next to the enamel of the teeth, provides important information in the identification of gender, as it is last to decompose after death.[2] Though certain skeletal components, like the pelvis and sternum, are widely used in gender determination, these are sometimes recovered in a fragmented or incomplete state.[3] In such cases, it is imperative to use for forensic purposes alternate areas of the skeleton, like the maxilla, since they are reported to remain intact, irrespective of the severe destruction of the skull and other bones, and can be used for identification of victims.[4,5] In view of that, there are a number of studies stating the importance of maxillary sinuses in forensic medicine, especially for gender determination, where the dimensions of sinuses between males and females are compared by means of various imaging methods.[5–14] The results of most of these studies suggested the utility of the maxillary sinuses in gender determination. Almost all these studies reported that the sinus measurement values (dimensions and volume) are larger in males than in females and they correlated this fact with the differences in the overall stature of males and females.

Head circumference is also a significant craniofacial criterion which can be used for gender determination, as the literature states that there is a strong association between head circumference and body size.[15,16] Thus, the correlation between the volume of the maxillary sinus and the head circumference can provide additional information with regard to the utility of the maxillary sinuses in gender determination.

Computed tomography (CT) scans provide an accurate assessment of the paranasal sinuses, craniofacial bones, as well as the extent of pneumatization of the sinuses.[4–6,17] Furthermore, the image represents a series of contiguous cross-sections and 3-dimensional information, and the necessary equipment is available in most hospitals. Therefore, the present study was designed to assess the utility of the morphometry of the maxillary sinuses using CT for gender determination.

Material and methods

This retrospective study, approved by the institutional ethics committee (at the Datta Meghe Institute of Medical Sciences, Wardha, India), analyzed CT scans of 200 patients.

The inclusion criteria were as follows: CT scans of patients above 20 years of age, irrespective of gender, and with both sinuses shown completely. On the other hand, the exclusion criteria were: 1. CT scans with artifacts impeding the assessment of sinuses; 2. CT scans depicting a craniofacial anomaly or conditions affecting midfacial development; 3. CT scans with any anatomic variation that might affect the sinus volume, like nasal septal deviation[18,19]; and 4. CT scans exhibiting signs of sinus pathologies or a surgical defect in the area of interest.

Maxillary sinus hypoplasia is an uncommon pathology of the paranasal sinuses, which is classified into 3 types, depending on the embryological development of the sinus, and the uncinate process might be encountered in the clinical practice. Computed tomography scans confirm its existence and any associated anatomical anomaly and variations that might coexist.[20,21] Computed tomography scans depicting sinus hypoplasia were not included in the present study.

Axial and coronal images were obtained using a spiral CT scanner (Siemens Healthineers, Erlangen, Germany) with a scan setting of 140 kV (peak), 129 mAs, scan time of 1,000 ms and matrix size of 512 × 512 pixels. During the selection of CT scans for the study, the uniformity regarding all the parameters relevant to CT scan imaging was ensured, namely, a uniform position of patients, 120-kV tube voltage and 175-mAs current-time product, tube rotation time, pitch, acquisition collimation, field of view in diameter, slice thickness, etc. Plain CT scans were used in the present study. On the contrary, the contrast-enhanced CT scans showing evidence of pathology were not included in the study.

The study was designed to measure the mediolateral (ML), superoinferior (SI) and anteroposterior (AP) dimensions, along with the volumes of both the right and the left maxillary sinuses of an individual using CT. The measurements were taken after analyzing different slices in axial and coronal sections.

– the AP dimension was measured on an axial reconstructed image and was defined as the longest distance antero-posteriorly from the most anterior point to the most posterior point (Fig. 1);
– the SI dimension or the height of the sinus was measured on a coronal reconstructed image and was defined as the longest distance from the lowest point of the sinus floor to the highest point of the sinus roof (Fig. 2);
– the ML dimension or the width of the sinus was measured on an axial reconstructed image and was defined as the longest distance perpendicular from the median wall of the sinus to the outermost point of the lateral wall of the maxillary sinus (Fig. 1).

The volume of the sinuses was calculated using a simple formula described by Sahlstrand-Johnson et al.[17]:

$$(\text{ML dimension} \times \text{SI dimension} \times \text{AP dimension}) / 2 \quad (1)$$

where:
ML dimension – mediolateral dimension;
SI dimension – superoinferior dimension;
AP dimension – anteroposterior dimension.

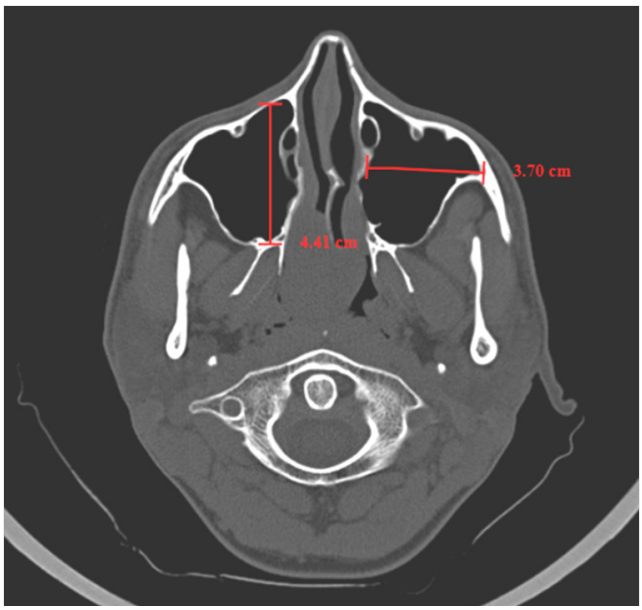

Fig. 1. Axial computed tomography (CT) scan showing the measurement of the anteroposterior (AP) and mediolateral (ML) dimensions

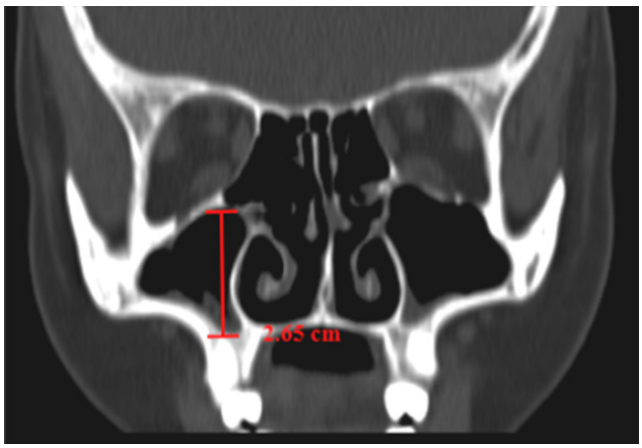

Fig. 2. Coronal CT scan showing the measurement of the superoinferior (SI) dimension

Considering the differences in the midfacial contour between males and females, such as malar prominence in females, the present study assessed and compared the angle formed by the anterior and lateral wall of the maxillary sinuses on an axial view, named the antero-lateral (AL) angle (Fig. 3). Head circumference and head area were also measured in the present study on an axial image in order to evaluate the correlation between the sinus volume and the head circumference and head area (Fig. 4). All these measurements were made with the help of a screen linear measurement tool on the CT workstation.

The data thus obtained was then tabulated and statistically analyzed using relevant statistical tests, and the software – SPSS v. 22 (IBM, Armonk, USA), GraphPad Prism™ v. 6.01 (GraphPad Software, Inc., San Diego, USA) and Epi Info™ v. 6.0 (https://www.cdc.gov/epiinfo/support/downloads/previous/ei6.html). The independent samples *t*-test was used to determine the mean, standard deviation (SD) and *t*-value, necessary to assess the level of the parameters

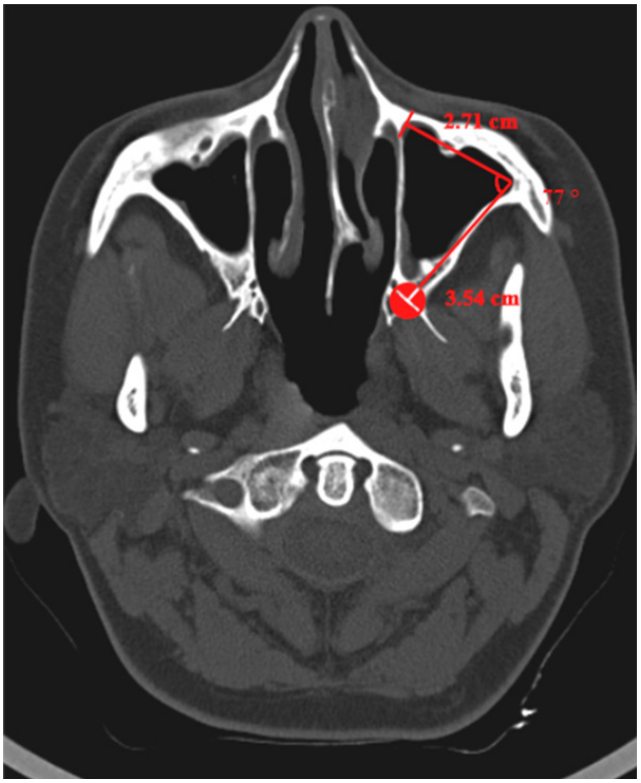

Fig. 3. Measurement of the antero-lateral (AL) angle of the maxillary sinus

in males and females. A difference at $p < 0.05$ was considered significant. A discriminant function analysis was done to determine the percentage of correctly sexed maxillary sinuses.

Fig. 4. Measurement of head circumference

Results

The present study assessed CT scans of 200 patients, with equal distribution amongst males and females. In males, most of the CT scans (49%) belonged to the patients of the age group of 20–30 years and in females, 42% CT scans were of the 41–50 years age group.

Comparative evaluation of various parameters of the right maxillary sinus between males and females, such as the mean of AP, ML and SI dimensions, as well as the volume and AL angle of the right maxillary sinuses, presented a statistically significant difference with a *p*-value of 0.0001, as shown in detail in Table 1. The mean volume of the right maxillary sinuses was 17.21 ±6.26 cm^3 in males, while for females it was 11.58 ±4.90 cm^3. In males, the mean AL angle was 76.25 ±9.18° and in females it was 69.74 ±7.25°, showing a statistically significant difference between the genders (Fig. 5).

The study showed similar results for various parameters of the left maxillary sinus. In males, the mean AL angle was 82.50 ±17.02° and in females it was 71.68 ±8.36° (Fig. 5). Detailed observations referring to all the parameters of the left maxillary sinus are shown in Table 2.

Again, with reference to the assessment of the head circumference and head area, a statistically significant difference was observed between males and females in the mean values. In males, the mean head circumference was 46.07 ±1.54 cm, while in females the mean was 44.26 ±1.52 cm. For the head area, the mean was 164.51 ±10.73 cm^2 for males and for females it was 9.19 ±0.91 cm^2, with a *t*-value of 8.30 and 10.38 for the head circumference and head area, respectively (Fig. 6).

The overall comparative results of all the parameters assessed in the present study showed that females had significantly smaller values for all parameters as compared to males. To establish the correlation between the sinus volume and the head circumference and head area, the Pearson correlation coefficient was calculated. A positive correlation was observed between the volume of the maxillary sinuses and the head circumference and head area on both sides and in both genders; however, it was not significant. The findings suggest that the volume of the sinuses is directly proportional to the head circumference and head area in males as well as in females.

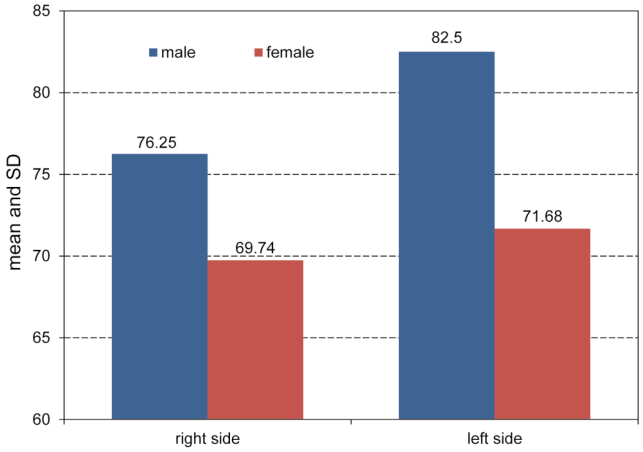

Fig. 5. Comparison of the mean AL angle between males and females

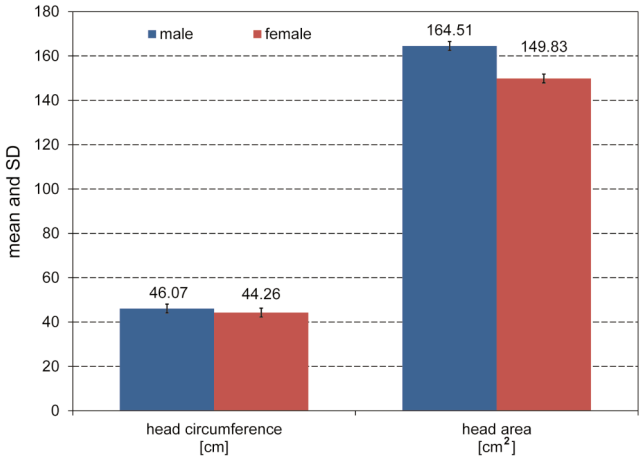

Fig. 6. Comparison of the mean head circumference and head area between males and females

Table 1. Comparison of different parameters of the right maxillary sinuses between males and females (Student's unpaired *t*-test)

Parameter	Gender	Number	Mean	SD	SEM	*t*-value	*p*-value
AP dimension [cm]	M	100	3.67	0.35	0.03	4.05	0.0001*
	F	100	3.47	0.34	0.03		
ML dimension [cm]	M	100	2.78	0.47	0.04	5.74	0.0001*
	F	100	2.42	0.42	0.04		
SI dimension [cm]	M	100	3.30	0.92	0.09	5.55	0.0001*
	F	100	2.66	0.68	0.06		
Volume [cm^3]	M	100	17.21	6.26	0.62	7.07	0.0001*
	F	100	11.58	4.90	0.49		
AL angle [°]	M	100	76.25	9.18	0.91	5.56	0.0001*
	F	100	69.74	7.25	0.72		

M – male; F – female; SD – standard deviation; SEM – standard error of mean; * statistical significance.

Table 2. Comparison of different parameters of the left maxillary sinuses between males and females (Student's unpaired *t*-test)

Parameter	Gender	Number	Mean	SD	SEM	*t*-value	*p*-value
AP dimension [cm]	M	100	3.56	0.63	0.06	2.21	0.028*
	F	100	3.39	0.36	0.03		
ML dimension [cm]	M	100	2.73	0.58	0.05	6.45	0.0001*
	F	100	2.25	0.47	0.04		
SI dimension [cm]	M	100	3.33	0.62	0.06	6.93	0.0001*
	F	100	2.66	0.74	0.07		
Volume [cm^3]	M	100	16.46	6.39	0.63	6.99	0.0001*
	F	100	10.77	5.03	0.50		
AL angle [°]	M	100	82.50	17.02	1.70	5.70	0.0001*
	F	100	71.68	8.36	0.83		

* statistical significance.

Table 3. Classification function coefficient and accuracy level for each parameter in determining gender

Parameter	Male		Female		Percentage of correctly classified gender [%]
	constant	coefficient	constant	coefficient	
Right – AP	–56.05	64	–50.18	64	64
Right – ML	–19.74	65	–15.06	71	68
Right – SI	–8.88	70	–6.01	63	66.5
Right – volume	–5.38	59	–2.81	69	64
Right – AL angle	–43.12	68	–36.18	78	73
Left – AP	–24.08	67	–21.99	47	57
Left – ML	–14.03	54	–9.73	68	61
Left – SI	–12.38	73	–8.12	70	71.5
Left – volume	–4.78	59	–2.44	67	63
Left – AL angle	–19.61	76	–14.98	81	78.5

The classification function coefficient and the accuracy level for each parameter of the maxillary sinus on both sides in determining gender is depicted in Table 3. Amongst all the parameters, the left AL angle with 78.5% accuracy was found to be the best discriminative parameter, followed by the right AL angle with 73% accuracy.

The classification function coefficient and the accuracy level for the head circumference and head area in determining gender was 69% and 76%, respectively.

The final result of the discriminative analysis showed that the potential of the maxillary sinus in identifying gender was 85% in males and 87% in females, with an overall accuracy of 86%, as shown in Table 4.

The accuracy of the final model in determining gender for the head circumference and head area was 73% in males and 76% in females, with an overall accuracy of 74.5%.

Table 4. Accuracy of the final model in determining gender for the maxillary sinus

Actual gender	Male		Total	Percentage of correctly classified gender [%]
	male	female		
Male	85	15	100	86
Female	13	87	100	
Total	98	102	200	

Discussion

Gender determination of skull remnants is an essential step in the identification of an unknown person. The present study assessed the utility of the maxillary sinuses for that purpose. The comparative assessment of the parameters of the right and left sides of the maxillary sinuses showed statistically significant differences for all the parameters, and the findings are comparable to the previous studies.[5,10,12,14,22,23] Amongst all analyzed parameters, the left AL angle with an accuracy of 78.5% was the best discriminative parameter, followed by the right AL angle. To our knowledge, the AL angle measurement has not been previously estimated, and thus its significance has not been reported yet.

The AL angle is an angle formed between the anterior and lateral wall of the maxillary sinus and was named by the authors as the antero-lateral (AL) angle. The reason behind the selection of this angle for gender comparison was the suspicion that there could be a difference in this angle between males and females, just as there is a difference in the midfacial contour between men and women. For example, females have a prominent molar region. The researchers thought that if the difference was significant, the AL angle might be used as an additional parameter in gender determination.

The presence of a statistically highly significant difference between males and females in the AL angle of the right and left side maxillary sinuses, as well as the maximal final accuracy level for angle criteria in the present study suggest that the AL angle of the maxillary sinus can be used in gender determination for forensic purposes. The reason for a greater AL angle in males could be the overall larger size of the maxillary sinus as compared to females. The findings of this study are considered distinctive.

In the present study, amongst the remaining parameters of the maxillary sinus, the left SI dimension was the best discriminative parameter next to the AL angle. Similarly, previous studies mentioned various parameters of the maxillary sinus to be the best discriminants in their studies, some of which are depicted in Table 5.

In a review article by Xavier et al., it is concluded that the frontal and maxillary sinuses provide important information in the forensic context and, in the case of the maxillary sinus, allow for sex determination.[24]

On the contrary, Saccucci et al. stated that it was impossible to support the use of the maxillary sinuses to discern sexual differences in corpse identification by means of cone beam CT.[11] Also, the results of the study by Etemadi et al.[25] showed that the volume of the maxillary sinus could not serve as a definite and reliable indicator for sexual determination.[25]

The overall results of the present study showed that the dimensions and volume of the maxillary sinuses were greater in males; this finding is comparable to many previous studies, and thus can be used for gender determination as mentioned above. The common parameter for sexual difference mentioned in the literature is a bigger body size in males in comparison to females. Males tend to exhibit larger, more robust features, which can be seen throughout the cranial and post-cranial skeleton. Females tend to retain more of the pedomorphic traits throughout development.[26]

Sahlstrand-Johnson et al. suggested that, since men are generally larger than women, men have larger sinuses, and thus the difference in volume between males and females exists.[17] Sharma et al. correlated the difference in the maxillary sinus dimensions between the genders with the physiological changes in the nasal cavity size and shape, which occur as a direct result of respiration-related needs.[5]

The present study draws attention to the fact that, although men are generally larger than women, this rule is not always applicable. There can be a strong, stout, tall female and, by contrast, a short, thin, average built male. Considering this fact, the authors attempted to correlate the volume of the sinuses with the head circumference, as the literature states that there is a strong association between the head circumference and body size.[15,16] It was not possible to correlate the volume of the sinuses with the height, weight and body size of the patients in the present study, as this study was retrospective. The Pearson correlation between the mean volume of the sinuses and the head circumference was assessed in terms of significance. A positive correlation was observed between the volume of the maxillary sinuses of both sides and in both genders and the head circumference and head area. Still, the correlation was not significant.

Table 5. Best discriminative maxillary sinus parameters in previous studies with their accuracy level

Authors	Maxillary sinus parameters	Accuracy level [%]
Urooge et al.[27]	left width	60
Uthman et al.[7]	height	71.6
Attia et al.[8]	right height	69.9
Ahmed et al.[10]	left width	61.3
Sharma et al.[5]	AP dimension	69.81

Based on all the parameters used, the overall accuracy rate in terms of determining the sex by means of maxillary sinus measurements was 86% (85% in males and 87% in females) in the present study. The results are comparable to those presented in a study by Prabhat et al.,[6] in which the overall accuracy rate was 83.3%. In a similar study by Bangi et al., it was 88%.[14] However, in most of the previous studies, the percentage was comparatively low.[4,7,9,13,26,27] In the studies by Teke et al. and Kiruba et al., the overall accuracy rate was below 70%.[4,28] The reasons for these variations are multiple and may include such factors as different ethnic and racial groups, genetic and environmental factors, differences in the body stature, skeletal size, height, etc. Besides, the anatomical variations of the sinus, differences in osteoclastic and osteoblastic activity and in the pneumatization process in the sinus in different age and sex groups, or past infections may influence the results.

The final result of the discriminative analysis showed that the efficiency of using the head circumference and head area to identify gender was 73% in males and 76% in females, with an overall accuracy of 74.5%.

To our knowledge this is the first report mentioning the significance of the AL angle of the maxillary sinus, head circumference and head area in sexual determination. There is scope for further research on these new parameters for sex determination. The authors mention 1 possible limitation of this study; as the study was retrospective, it was not possible to establish a direct correlation between the volume of the sinuses and the body size of the participants.

Conclusions

The maxillary sinus measurements, as well as head circumference and head area, are valuable parameters for sex determination in forensic medicine, with a relatively good accuracy rate. However, the prediction rate can be increased by including the AL angle of the maxillary sinus. The overall accuracy of using the maxillary sinus to identify gender was 86%.

References

1. Christensen AM, Passalacqua NV, Bartelink EJ. *Forensic Anthropology: Current Methods and Practice*. San Diego, CA: Elsevier Academic Press; 2014:199–220.
2. Deshmukh AG, Deversh DB. Comparison of cranial sex determination by univariate and multivariate analysis. *J Anat Soc India*. 2006;55:1–5.
3. Singal K. Significance of radiology forensic identification. *ARC J Forensic Sci*. 2016;1:21–24.
4. Teke HY, Duran S, Canturk N, Canturk G. Determination of gender by measuring the size of the maxillary sinuses in computerized tomography scans. *Surg Radio Anat*. 2007;29:9–13.
5. Sharma SK, Jehan M, Kumar A. Measurements of maxillary sinus volume and dimensions by computed tomography scan for gender determination. *J Anat Soc India*. 2014;63:36–42.
6. Prabhat M, Rai S, Kaur M, Prabhat K, Bhatnagar P, Panjwani S. Computed tomography-based forensic gender determination by measuring the size and volume of the maxillary sinuses. *J Forensic Dent Sci*. 2016;8:40–46.
7. Uthman AT, Al-Rawi NH, Al-Naaimi AS, Al-Timimi JF. Evaluation of maxillary sinus dimensions in gender determination using helical CT scanning. *J Forensic Sci*. 2011;56:403–408.
8. Attia AM, El-Badrawy AM, Shebel HM. Gender identification from maxillary sinus using multi-detector computed tomography. *Mansoura J Forensic Med Clin Toxicol*. 2012;20:17–28.
9. Ekizoglu O, Inci E, Hocaoglu E, Sayin I, Kayhan FT, Can IO. The use of maxillary sinus dimensions in gender determination: A thin-slice multi-detector computed tomography-assisted morphometric study. *J Craniofac Surg*. 2014;25:957–960.
10. Ahmed A, Gataa AG, Fateh IS, Salah MM Ghadah N. CT scan images analysis of maxillary sinus dimensions as a forensic tool for sexual and racial detection in a sample of Kurdish population. *Euro Sci J*. 2015;11:271–281.
11. Saccucci M, Cipriani F, Carderi S, et al. Gender assessment through three-dimensional analysis of maxillary sinuses by means of cone beam computed tomography. *Eur Rev Med Pharmacol Sci*. 2015;19:185–193.
12. Dkhar W, Pradhan A, Shajan M. Measurement of different dimension of maxillary and frontal sinus through computed tomography. *Online J Health Allied Scs*. 2017;16:5.
13. Paknahad M, Shahidi S, Zarei Z. Sexual dimorphism of maxillary sinus dimensions using cone-beam computed tomography. *J Forensic Sci*. 2017;62:395–398.
14. Bangi BB, Ginjupally U, Nadendla LK, Vadla B. 3D evaluation of maxillary sinus using computed tomography: A sexual dimorphic study. *Int J Dent*. 2017;2017:9017078.
15. Mansur DI, Haque MK, Sharma K, Mehta DK, Shakya R. Use of head circumference as a predictor of height of individual. *Kathmandu Uni Med J*. 2014;12:89–92.
16. Geraedts EJ, Dommelen PV, Caliebe J, et al. Association between head circumference and body size. *Horm Res Paediatr*. 2011;75:213–219.
17. Sahlstrand-Johnson P, Jannert M, Strömbeck A, Abul-Kasim K. Computed tomography measurements of different dimensions of maxillary and frontal sinuses. *BMC Med Imag*. 2011;11:8.
18. Kapusuz GZ, Ozkırış M, Okur A, Karaçavuş S, Saydam L. The effect of nasal septal deviation on maxillary sinus volumes and development of maxillary sinusitis. *Eur Arch Otorhinolaryngol*. 2013;270:3069–3073.
19. Jadia S, Qureshi S, Agrawal S, Singh SG. Effect of deviated nasal septum on maxillary sinus volume and occurrence of sinusitis. *Ind J Otolaryngol Head Neck Surgery*. 2018. https://doi.org/10.1007/s12070-018-1276-9
20. Erdem T, Aktas D, Erdem G, Miman MC, Ozturan O. Maxillary sinus hypoplasia. *Rhinology*. 2002;40:150–153.
21. Hasan HYA, Prabhu S, Mohammed MA. Hypoplastic maxillary antra. *Bahrain Med Bull*. 2017;39:150–153.
22. Kim DI, Lee UY, Park SO, Kwak DS, Han SH. Identification using frontal sinus by three dimensional reconstruction from computed tomography. *J Forensic Sci*. 2012;58:5–11.
23. Michel J, Paganeli A, Varoquaux A, et al. Determination of sex: Interest of frontal sinus 3D reconstructions. *J Forensic Sci*. 2015;60:269–273.
24. Xavier TA, Sayuri Silveira Dias Terada A, Alves da Silva RH. Forensic application of the frontal and maxillary sinuses: A literature review. *J Forensic Radiol Imaging*. 2015;3:105–110.
25. Etemadi S, Seylavi G, Yadegari A. Correlation of the maxillary sinus volume with gender and some of craniofacial indices using cone beam computed tomography. *Biosci Biotech Res Comm*. 2017;10:580–586.
26. Krishan K, Chatterjee PM, Kanchan T, Kaur S, Baryah N, Singh RK. A review of sex estimation techniques during examination of skeletal remains in forensic anthropology case work. *Forensic Sci Int*. 2016;261:165e1–e8.
27. Urooge A, Patil BA. Sexual dimorphism of maxillary sinus: A morphometric analysis using cone beam computed tomography. *J Clin Diag Res*. 2017;11:ZC67–ZC70
28. Kiruba LN, Gupta C, Kumar S, D'Souza AS. A study of morphometric evaluation of the maxillary sinuses in normal subjects using computer tomography images. *Arch Med Health Sci*. 2014;2:12–15.

The role of vitamin D in the human body with a special emphasis on dental issues: Literature review

Rola witaminy D w organizmie ze szczególnym uwzględnieniem jej znaczenia w patologiach jamy ustnej – przegląd piśmiennictwa

Maciej Krawiec[A–D], Marzena Dominiak[A,E,F]

Department of Oral Surgery, Faculty of Dentistry, Wroclaw Medical University, Poland

A – research concept and design; B – collection and/or assembly of data; C – data analysis and interpretation;
D – writing the article; E – critical revision of the article; F – final approval of the article

Dental and Medical Problems, ISSN 1644-387X (print), ISSN 2300-9020 (online) *Dent Med Probl.* 2018;55(4):419–424

Address for correspondence
Maciej Krawiec
E-mail: maciejkrawiec@ptss.pl

Funding sources
None declared

Conflict of interest
None declared

Received on April 30, 2018
Reviewed on June 4, 2018
Accepted on October 18, 2018

Published online on December 28, 2018

Abstract

The aim of the study was to review the current literature on the role of vitamin D in dentistry. The term vitamin D is defined as a group of compounds which are cholesterol derivatives with a similar chemical structure. It is produced in the human body and passes through many stages of synthesis. Vitamin D affects our body through the immune, muscular, nervous, and cardiovascular systems. It is also relevant in dentistry and in the carbohydrate metabolism. Nowadays, vitamin D deficiency levels are high in both the Polish and the world population as a whole. This is due to many factors: latitude, diseases and lifestyle. The data shows that over 90% of people of color (black, Latino, Asian, etc.) and nearly 3/4 of whites living in the United States suffer from a shortage of 25-hydroxycholecalciferol (25(OH) vitamin D). Meanwhile, studies performed in Poland report that a concentration of vitamin D <20 ng/mL (50 nmol/mL) occurs in 70% of the population. Preliminary reports suggest that vitamin D, through the maintenance of normal bone metabolism, as well as its antibacterial and anti-inflammatory activity, modulates periodontal disease. A normal level of vitamin D is important in the treatment of periodontitis. More and more studies are focusing on the problem of vitamin D deficiency and its role in the human body. It is very important to maintain normal levels of vitamin D in the blood and supplement it in the case of shortfalls.

Key words: periodontitis, vitamin D, vitamin D deficiency, calcitriol

Słowa kluczowe: zapalenie przyzębia, witamina D, niedobór witaminy D, kalcytriol

Cite as
Krawiec M, Dominiak M. The role of vitamin D in the human body with a special emphasis on dental issues: Literature review]. *Dent Med Probl.* 2018;55(4):419–424.
doi:10.17219/dmp/99051

DOI
10.17219/dmp/99051

Introduction

The term vitamin D refers to a group of chemical compounds that are cholesterol derivatives. Their similar chemical construction includes rings A, B, C, and D, and a side chain. Due to the B ring opening, vitamin D is classified as belonging to the secosteroid compound group. Vitamin D occurs in 2 basic forms: cholecalciferol (vitamin D_3) and ergocalciferol (vitamin D_2). They differ in terms of their side chain structure and their occurrence – cholecalciferol is present in animal organisms, while ergocalciferol is found in plants and fungi.

The PubMed database of the U.S. National Library of Medicine and the Thomson Reuters Web of Knowledge were used as electronic databases to perform a systematic search for relevant articles published in the dental literature between 1969 and 2015. The combination of key words (i.e., Medical Subject Headings – MeSH) and free text terms included: [periodontitis OR periodontal disease] AND [vitamin D OR calcitriol] AND [vitamin D deficiency].

The electronic search was complemented by a hand search of the following journals: "Journal of Clinical and Diagnostic Research" and "Journal of Periodontology".

Vitamin D metabolism

The synthesis of biologically active molecules in the human body involves a number of stages. The reaction precursor is a cholesterol derivative – 7-dehydrocholesterol. It is present in the plasma membrane of keratinocytes, in the basal and spinous layer (called the Malpighian layer; at a volume of 0.4 mg/cm^2) and in dermis fibroblasts, where under UV radiation (wavelengths of 290–315 nm), in a photochemical reaction, it is transformed over the course of 30 min into lumisterol or tachysterol.

Next, at a high temperature (a skin temperature of 25°C) and with the participation of a reductase enzyme, isomerization to cholecalciferol (calciol) begins. This is a stable compound, which is released into the extracellular matrix and then into the blood, where it binds to a specific globulin, which in turn binds vitamin D (vitamin D binding protein – DBP) and is transported to the liver. The 1st hydroxylation process takes place in the presence of vitamin D 25-hydroxylase, which is dependent on P-450 cytochrome (CYP27A1). This leads to the creation of 25-hydroxycholecalciferol (25(OH) vitamin D, calcidiol). The biological activity of this compound is low and its surplus is stored in adipocytes.

The next stage that takes place in renal proximal tubules is 1α-hydroxylation of the calcidiol A ring, involving 1α-hydroxylase (CYP27B1). During this reaction, 1,25-dihydroxy-cholecalciferol (1,25(OH)$_2$ D3, calcitriol) is formed. It is described as a vitamin hormone, the activity of which is 1,000 times higher as compared to calcidiol, but its half-life is shorter, i.e., 4–6 h. Calcitriol regulates numerous processes in the body, e.g., renal excretion of calcium (Ca) and phosphate with the urine, and increases osteolytic activity of parathyroid hormone (parathormone, PTH). Moreover, it lowers the immunity of the bone tissue to PTH activity, sensitizes parathyroid cells to calcemia transitions, increases the number of Ca ion receptors, simplifies the flow of ions to parathyroid cells and therefore reduces the secretion of PTH, and takes part in Ca absorption from the digestive tract. Calcitriol plays an essential role in the mineralization of bones, regulates the immunological processes, has an impact on cell proliferation and differentiation, and also may increase myopathy and cardiomyopathy.[1] This stage in the synthesis process is activated by the accumulation of 1,25(OH)$_2$D3 metabolite, hypocalcemia, hypophosphatemia, and an elevated concentration of PTH. Tyrosine, estrogens, androgens, insulin, prolactin, cortisol, and somatotropin also exert a positive impact on hydroxylation.[2]

What is essential is that the 1α-hydroxylation process also occurs in other human cells, such as macrophages, keratinocytes, placenta, parathyroid and prostate cells, osteoblasts, immune system cells, pancreatic islets, smooth muscle tissue cells, and tumor cells. Locally synthesized vitamin D impacts physiological processes at synthesis points[3–5] by auto- and paracrine regulation. Vitamin D is also delivered to the body through a proper diet, although it only accounts for approx. 10% of the total concentration. Products rich in cholecalciferol include fish and cod-liver oil. Milk, eggs and cheese also contain cholecalciferol, but in lower amounts. Legume plants are rich in ergocalciferol.

The vitamin D receptor

Vitamin D affects the human body and its particular systems by binding with a specific calcitriol receptor called the vitamin D receptor (VDR). It is present in over 30 tissues and organs, including the bones, kidneys, intestine, heart, brain, skin, pancreas, blood vessels, hypophysis, adrenal glands, and striated and smooth muscle tissue, as well as in T and B lymphocytes, neutrophils and macrophages. This suggests that the functioning of vitamin D is pleiotropic (heliotropic) in character.

The vitamin D receptor belongs to the steroid hormone receptor superfamily. It is a specific nuclear receptor. Its molecular mass equals approx. 55 kDa, it consists of 427 amino acid residues and is encoded by the *VDR* gene. The gene which encodes the vitamin D receptor protein is located in the 2nd arm of chromosome 12. It consists of 9 exons, which are transcriptional DNA sequences, and of intertwined mRNA particles, which create transcriptional RNA. This gene is highly volatile due to mutations in the non-coded region.

Several polymorphisms of the *VDR* gene are known. The most common are single nucleotide polymorphisms

(SNPs) – FokI (C/T), BsmI (A/G), ApaI (A/C), TaqI (T/C), and Cdx2 (A/G). Their names come from the restriction site that was originally used to identify them. FokI (rs2228570, C/T) polymorphism is located in the 2nd start codon (ATG) in exon 2. When the C (mutant) allele is present, an alternative start site is used, leading to the expression of a shorter VDR protein (424 aa), which demonstrates a greater transcriptional activity as a consequence of enhanced binding to transcription factor II B. The T (wild-type) allele leads to the expression of a longer VDR protein (427 aa).[6] BsmI (rs1544410), ApaI (rs7975232) and TaqI (rs731236) polymorphisms are located in the 3' untranslated region (UTR), and are all involved in regulating the stability of VDR mRNA.[7,8]

The calcitriol receptor comprises 2 important fragments. The larger fragment (ligand-binding domain; the activation function for regulating gene transcription through calcitriol) is responsible for binding with the active form of vitamin D, and the smaller fragment (DNA-binding domain; dimerization) is responsible for binding with the regulatory DNA sequences of protein coding genes, whose expression is modulated by vitamin D (i.e., osteocalcin, osteopontin, collagen, alkaline phosphatase, hydroxycholecalciferol, parathyroid hormone).[1,9] There are over 50 genes involved in Ca/P homeostasis. They are responsible for cell proliferation and differentiation, and immune response.

The ligand-binding domain with calcitriol is characterized by a low yield but a high affinity. It is composed of 80 amino acids, where 20 combine to build 2 tin fingers, with 3 amino acids that are crucial at the base. Here, after calcitriol binding, serine residue phosphorylation begins in positions 51, 119 and 125. Due to this process, it is possible to recognize the characteristic sequence in the promoter region of the target gene – vitamin D-responsive element (*VDRE*). The modification of the binding domain of the ligand may result in a lack of or poor responses to vitamin D.[10,11]

The dimerization domain is located near the ligand-binding domain. It consists of a sequence of 7 hydrophobic amino acids, repeated 9 times. The binding of calcitriol induces a conformational change in the dimerization domain, which enables the binding to the retinoic acid receptor–retinoid X receptor (RXR) so as to form a heterodimer, and then the specific binding of the heterodimer to the regulatory sequences of DNA.[1,2,12,13]

Vitamin D: Deficiency, determination and supplementation

Epidemiological studies show that vitamin D deficiency is a very common occurrence, not only in the Polish population, but also globally.[14] This deficiency is determined by a concentration of <30 ng/mL (75 nmol/mL) in the blood serum. Adams and Hewison have published data which shows that over 90% of people of color (black, Latino and Asians) and nearly 3/4 of whites living in the United States suffer from a shortage of 25(OH) vitamin D.[15,16] Meanwhile, studies performed in Poland report that a concentration of vitamin D <20 ng/mL (50 nmol/mL) occurs in 70% of the population.[17,18]

The main reasons for vitamin D deficiency are as follows: latitude (though also in countries with high insolation, such as India, vitamin D deficiency is becoming a growing problem), usage of UVB filters, lifestyle, vocation, melanin deficiencies in the skin, aging, air pollution, inadequate dietary intake and supplements.[19,20] An inadequate concentration of vitamin D is also accompanied by other diseases: cirrhosis of the liver, kidney dysfunctions, malabsorption, and obesity. It can also be a consequence of drug treatment (long-term intake of glucocorticoids, anti-epileptic drugs or ketoconazole).

Vitamin D concentration in the serum is determined using immunochemical methods, or a more accurate and sensitive technique of liquid chromatography-tandem mass spectrometry (LC-MS/MS). This method consists in isolating a single ion from a substance present in the sample by calculating the fraction mass-to-charge of ions. In tests determining vitamin D levels, liquid chromatography (LC) is used, which in the initial phase can precisely extract particles for further spectrometer analysis. 25-hydroxyvitamin D (25(OH)D), due to its stability in the serum and the fact that the speed of its synthesis is dependent on the supply of ingested vitamin D from diet, drugs or supplements, it is regarded as a marker and the best indicator of vitamin D concentration in the body. It is worth performing laboratory tests to measure both subunit 25(OH)D2 and 25(OH)D3. The sum of their total concentrations represents the total vitamin D concentration in the serum.[21]

Depending on the level of vitamin D deficiency and the age of the patient, various supplementation doses have been proposed. Table 1 shows the dosing regimen for adults aged >18 years according to the concentration of vitamin D. The recommended total dose of vitamin D in therapy can also be calculated using the Groningen formula[22]:

$$40 \times (75 - \text{concentration of 25(OH)D [nmol/L]}) \times \times \text{body weight [kg]} \quad (1)$$

where 1 ng/mL = 2.5 nmol/mL.

It is essential that supplementation in the form of tablets is applied after a meal, due to better absorption and the presence of agents containing vitamin K_2 MK-7, which affects bone metabolism through activating and enhancing matrix Gla-protein (MGP). The supply may be carried out using ergocalciferol (vitamin D_2), cholecalciferol (vitamin D_3) or calcifediol (25(OH)D3). The latter is used in the treatment of liver diseases, and complications arising

Table 1. Dose of vitamin D in relation to its concentration in the blood

Concentration of 25(OH) vitamin D in the blood	Supplementation doses
Correct values	800–2,000 IU/day in the September–April period; max dose for healthy people: 4,000 IU/day
Correct values; obese people	1,600–4,000 IU/day throughout a year
Correct values; lack of effective synthesis in the skin	800–2,000 IU/day throughout a year
<20 ng/mL	10,000 IU/day or 50,000 IU/week with a control test after 3 months
20–30 ng/mL	8,000 IU/day with a control test after 3 months

25(OH) vitamin D – 25-hydroxycholecalciferol.

from glucocorticosteroid treatment and antiepileptic drugs. The administration of calcitriol and its derivatives has no effect on improving the performance of vitamin D_3, defined as an increase in the concentration of 25(OH) D3 in the serum, and is treated as hormonal treatment.

Vitamin D in medicine

Due to the discovery of the presence of VDR in many tissues, it has been proven that the effects of its action are wide and regard many systems. Its influence, beyond the skeletal system, has been shown for example in the immune, muscle, neural, and circulatory systems, as well as in dermal diseases, rheumatic diseases, mental disorders, and in anticancer activities. Thanks to such multidirectional effects, vitamin D has become known as the vitamin of life.

Vitamin D in dentistry

Vitamin D plays an important role in the stomatognathic system, where its influence in preventing caries has been demonstrated. An analysis by Hujoel points to vitamin D as one of the promising factors preventing caries.[23] The same study showed that vitamin D supplementation was correlated with a 47% lower risk of caries. This effect was achieved through better tooth development, changes in the amount or biochemical composition of saliva, modulated caries activity due to immunological factors,[24–26] and stimulating the production of antimicrobial peptides, such as defensins and cathelicidin.[27] It is also known that vitamin D can modulate Behçet's disease, aphthous stomatitis and Sjögren's syndrome.[27] There are reports on the existence of a correlation between the level of vitamin D and the activity of various diseases, including acromegaly.[28,29] Halupczok-Żyła et al. found vitamin D deficiency in all patients with the active form of acromegaly.[29] There was also a statistically significant difference in the level of vitamin D between the control group and active acromegaly patients.[29]

Another study suggests that *VDR* FokI genotypes might affect the development of acromegaly and *VDR* polymorphisms, and may play a role in the course of acromegaly as a consequence of altering the hormonal status.[30]

Vitamin D is also capable of modifying the course of periodontal disease. There are 3 basic mechanisms responsible for this: the maintenance of normal bone metabolism, antibacterial activity and anti-inflammatory activity. The impact of vitamin D and its active metabolites on the skeletal system occurs through the regulation of the Ca metabolism. The level of 25(OH) vitamin D in the serum is positively correlated with the degree of bone mineralization, and negatively with the concentration of PTH.

Chronic vitamin D deficiency results in abnormal Ca absorption in the small intestine, which in turn reduces its blood concentration. In consequence, parathyroid glands increase the production of PTH (thereby developing tertiary hyperparathyroidism), which, by affecting the bone, increases the release of Ca into the blood to compensate for the deficiency in the serum.

This process is driven by the activation of osteoclasts, which results in the destruction of bone tissue, leading in turn to a reduction in bone calcification, rickets, osteomalacia, and osteoporosis. The role of vitamin D in the bone mineralization process can be proven by the fact that the condition of bone tissue deteriorates during the winter/spring, when the synthesis of vitamin D through the action of sunlight is considerably reduced.[31]

Vitamin D can reduce bone resorption by increasing intestinal absorption of Ca and its reabsorption in the distal renal tubules. However, it also accelerates the secretion of calcitonin and decreases parathyroid cell proliferation, which in turn inhibits the synthesis and activity of PTH. It also aids bone repair processes and bone matrix synthesis, reduces the perforation of trabeculae and increases the activity of bone growth factors.

The antibacterial activity of vitamin D is based primarily on the induction of secretion of beta-defensins and cathelicidin LL-37 (showing the chemotactic activity of neutrophils, monocytes and T lymphocytes), for example by human gingival epithelial cells (GEC), and thereby modulating the innate immune response. Another important issue is the fact that calcitriol affects the regulation of triggering receptor expressed on myeloid cells (TREM-1), which is a key amplifier initiating the immune responses of macrophages, which in turn leads to increased production of inflammatory response genes. This information suggests that vitamin D may be used to treat and prevent infectious diseases of the mouth.[32]

The final impact of vitamin D on the mouth consists in its anti-inflammatory activity. It has been shown to inhibit the release of cytokines, including interleukin 1β (IL-1β), interleukin 6 (IL-6), interleukin 12 (IL-12), and tumor necrosis factor (TNF), help decrease the number of T and B cells, and block the proinflammatory activity of type 1 and type 17 helper (Th1 and Th17) cells.

In light of all the reports mentioned above, researchers have begun to closely observe and study any possible correlation between the effects of vitamin D and the course of periodontal diseases.[33–36] Vitamin D has a multi-level role in maintaining periodontal health, namely, in reducing alveolar bone loss, gingival inflammation and/or attachment loss. Dietrich et al. used the Third National Health and Nutrition Examination Survey (NHANES III) to show that a lower level of vitamin D is associated with greater loss of attachment.[36] Another interesting conclusion of this analysis was that people with high vitamin D levels showed 20% less bleeding on probing. It is worth noting that these results were independent of other factors, such as diabetes or smoking. Such effects are evidence of the anti-inflammatory activity of vitamin D.[37]

Studies conducted by Perayil et al. demonstrated the inhibiting effect of vitamin D and Ca supplementation on periodontitis.[38] They observed a statistically significant decrease in gingival index (GI) and simplified oral hygiene index (OHI-S) among patients taking an additional 250 IU of vitamin D and 500 mg of Ca, compared to those patients whose treatment consisted solely in scaling, root planing and curettage. Moreover, the bone density of respondents from the experimental group significantly increased. Hiremath et al. showed that vitamin D was a safe and effective anti-inflammatory agent when used in the treatment of gingivitis.[39] This characteristic leads to a reduced risk of tooth loss.[40]

According to Mangano et al., the risk of early implant loss is more than 4 times higher in people with deficient vitamin D (<10 ng/mL) than in patients with normal serum vitamin D levels.[41]

Conclusions

The above discussion points out the importance of maintaining normal levels of vitamin D in the blood. Scientists have again started to examine the effect of vitamin D on many processes. They also highlight the fact that there is a general deficiency of vitamin D and the need for appropriate supplementation.

An analysis of the available publications clearly shows that more attention should be paid to the role of vitamin D deficiency in the etiology and treatment of periodontal diseases, as well as to vitamin D supplementation as an aid in treating periodontitis and gingivitis. In addition, it is worth focusing on possible vitamin D deficiency as a factor that increases the risk of bone implant loss.

References

1. August R, Gumprecht J, Karasek D, et al. Polymorphism A, B and T of the receptor gene for vitamin D and bone density in diabetic patients with terminal renal failure treated with renal replacement therapy [in Polish]. *Diabetol Doświad Klin*. 2003;3:61–70.
2. Tuchendler D, Bolanowski M. Seasonality of changes in vitamin D concentrations in the human body [in Polish]. *Endokrynol Otył Zab Przem Mat*. 2010;6:36–41.
3. Alpert PT, Shaikh U. The effects of vitamin D deficiency and insufficiency on the endocrine and paracrine systems. *Biol Res Nurs*. 2007;9:117–129.
4. DeLuca HF. Overview of general physiologic features and functions of vitamin D. *Am J Clin Nutr*. 2004;80:1689–1696.
5. Grygiel-Górniak B, Puszczewicz M. Vitamin D – a new look in medicine and rheumatology [in Polish]. *Postepy Hig Med Dosw*. 2014;68:359–368.
6. Kaleta B, Walicka M, Sawicka A, et al. Vitamin D receptor gene polymorphism in Polish patients with morbid obesity [in Polish]. *Post Nauk Med*. 2014;1:65–69.
7. Uitterlinden A, Fang Y, Van Meurs J, Pols H, Van Leeuwen J. Genetics and biology of vitamin D receptor polymorphisms. *Gene*. 2004;338:143–156.
8. Yang C, Li J, Li Y, et al. The vitamin D receptor gene ApaI polymorphism is associated with increased risk of renal cell carcinoma in Chinese population. *Sci Rep*. 2016;6:25987.
9. Alegretto EA, Pike JW. Tripsin cleavage of chick 1.25-dihydroxyvitamin D receptors. Generation of discrete polypeptides which retain hormone but are uncreative to DNA and monoclonal antibody. *J Biol Chem*. 1985;260:10139–10145.
10. Haussler MR, Norman A. Chromosomal receptor for a vitamin D metabolite. *Proc Natl Acad Sci USA*. 1969;62:155–162.
11. Norman AW. Minireview: Vitamin D receptor: New assignments for an already busy receptor. *Endocrinol*. 2006;147:5542–5548.
12. Sprague SM, Popovtzer MM. Is beta2-microglobulin a mediator of bone disease? *Kidney Int*. 1995;47:1–7.
13. Freedman LP, Luisi BF, Korszun ZR. The function and structure of metal coordination sites within the glucocorticoid receptor DNA binding domain. *Nature*. 1988;334:543–546.
14. Olędzka R. Vitamin D in the light of recent studies [in Polish]. *Bromat Chem Toksykol*. 2013;46:121–131.
15. Adams JS, Hewison M. Update in vitamin D. *J Clin Endocrinol Metab*. 2010;95:471–478.
16. Holick MF. Ressurection of vitamin D deficiency and rickets. *J Clin Invest*. 2006;116:2062–2072.
17. Płudowski P, Karczmarewicz E, Chlebna-Sokół D, et al. Vitamin D supplementation in healthy population and risk groups of vitamin D deficiency – practice guidelines for Central Europe 2013 [in Polish]. *Stand Med Pediatr*. 2013;10:573–578.
18. Karczmarewicz E, Czekuć- Kryśkiewicz E, Płudowski P. Effect of vitamin D status on pharmacological treatment efficiency. Impact on cost-effective management in medicine. *Dermatoendocrinol*. 2013;5:299–304.
19. Żukowska-Szczechowska E, Kiszka B. Vitamin D deficiency – diagnosis and management in order to reduce cardiovascular risk in patients with diabetes [in Polish]. *Forum Zab Metabol*. 2011;2:151–157.
20. Holick M. Vitamin D deficiency. *N Engl J Med*. 2007;357:266–281.
21. Płudowski P, Karczmarewicz E, Bayer M, et al. Practical guidelines for the supplementation of vitamin D and the treatment of deficits in Central Europe – recommended vitamin D intakes in the general population and groups at risk of vitamin D deficiency. *Endokrynol Pol*. 2013;64:319–327.
22. van Groningen L, Opdenoordt S, van Sorge A, Telting D, Giesen A, de Boer H. Cholecalciferol loading dose guideline for vitamin D-deficient adults. *Eur J Endocrinol*. 2010;162:805–811.
23. Hujoel P. Vitamin D and dental caries in controlled clinical trials: Systematic review and meta-analysis. *Nutr Rev*. 2013;71:88–97.
24. Kosińska J, Billing-Marczak K, Krotkiewski M. New unknown functions of vitamin D [in Polish]. *Med Rodz*. 2008;2:34–47.
25. Glerup H, Mikkelsen K, Poulsen L, et al. Hypovitaminosis D myopathy without biochemical signs of osteomalacic bone involvement. *Calcif Tissue Int*. 2000;66:419–424.

26. Arai H, Miyamoto KI, Taketani Y. A vitamin D receptor gene polymorphism in the translation initiation codon: Effect on protein activity and relation to bone mineral density in Japanese women. *J Bone Miner Res*. 1997;12:915–921.
27. Geusens P, Vandevyver C, Vanhoof J, Cassiman JJ, Boonen S, Raus J. Quadriceps and grip strength are related to vitamin D receptor genotype in elderly non-obese women. *J Bone Miner Res*. 1997;12:2082–2088.
28. Mahjoubi S, Kandara H, Mekni S, et al. Vitamin D status in acromegaly: A comparative study. *Endocrine Abstracts*. 2018;56:P844.
29. Halupczok-Żyła J, Jawiarczyk-Przybyłowska A, Bolanowski M. Patients with active acromegaly are at high risk of 25(OH)D deficiency. *Front Endocrinol (Lausanne)*. 2015;6:89.
30. Ilhan M, Toptas-Hekimoglu B, Yaylim I, et al. Investigation of the vitamin D receptor polymorphisms in acromegaly patients. *Biomed Res Internat*. 2015;2015:625981.
31. Dawson-Hughes B, Heaney RP, Holick MF, Lips P, Meunier PJ, Vieth R. Estimates of optimal vitamin D status. *Osteoporos Int*. 2005;16:713–716.
32. McMahon L, Schwartz K, Yilmaz O, Brown E, Ryan LK, Diamond G. Vitamin D-mediated induction of innate immunity in gingival epithelial cells. *Infect Immun*. 2011;79:2250–2256.
33. Miley DD, Garcia MN, Hildebolt CF, et al. Cross-sectional study of vitamin D and calcium supplementation effects on chronic periodontitis. *J Periodontol*. 2009;80:1433–1439.
34. Hildebolt CF. Effect of vitamin D and calcium on periodontitis. *J Periodontol*. 2005;76:1576–1587.
35. Garcia MN, Hildebolt CF, Miley DD, et al. One-year effects of vitamin D and calcium supplementation on chronic periodontitis. *J Periodontol*. 2011;82:25–32.
36. Dietrich T, Joshipura KJ, Dawson-Hughes B, Bischoff-Ferrari HA. Association between serum concentrations of 25-hydroxyvitamin D_3 and periodontal disease in the US population. *Am J Clin Nutr*. 2004;80:108–113.
37. Stein SH, Livada R, Tipton DA. Re-evaluating the role of vitamin D in the periodontium. *J Periodont Res*. 2013;49:545–553.
38. Perayil J, Menon KS, Kurup S, et al. Influence of vitamin D & calcium supplementation in the management of periodontitis. *J Clin Diagn Res*. 2015;9:35–38.
39. Hiremath VP, Rao CB, Naik V, Prasad KV. Anti-inflammatory effect of vitamin D on gingivitis: A dose-response randomised control trial. *Oral Health Prev Dent*. 2013;11:61–69.
40. Krall EA, Wehler C, Garcia RI, Harris SS, Dawson-Hughes B. Calcium and vitamin D supplements reduce tooth loss in the elderly. *Am J Med*. 2001;111:452–456.
41. Mangano F, Mortellaro C, Mangano N, Mangano C. Is low serum vitamin D associated with early dental implant failure? A retrospective evaluation on 1625 implants placed in 822 patients. *Mediat Inflamm*. 2016;2016:5319718.

Prophylaxis of osteonecrosis in the case of patients treated with bisphosphonates: A review paper

Zapobieganie martwicy kości u pacjentów leczonych bisfosfonianami – przegląd piśmiennictwa

Paweł Nieckula[1,A–F], Anna Stempniewicz[2,A–D], Monika Tubaja[2,A–D]

[1] Department of Dental Surgery, Faculty of Medicine and Dentistry, Medical University of Warsaw, Poland
[2] Medical University of Warsaw, Poland

A – research concept and design; B – collection and/or assembly of data; C – data analysis and interpretation;
D – writing the article; E – critical revision of the article; F – final approval of the article

Dental and Medical Problems, ISSN 1644-387X (print), ISSN 2300-9020 (online) *Dent Med Probl.* 2018;55(4):425–429

Address for correspondence
Anna Stempniewicz
E-mail: stempniewicz.ania@gmail.com

Funding sources
None declared

Conflict of interest
None declared

Acknowledgements
We would like to thank lek. dent. Dariusz Mateńko and prof. dr hab. Andrzej Wojtowicz for their professional support and valuable comments.

Received on April 26, 2018
Reviewed on June 30, 2018
Accepted on October 17, 2018

Published online on December 4, 2018

Cite as
Nieckula P, Stempniewicz A, Tubaja M. Prophylaxis of osteonecrosis in the case of patients treated with bisphosphonates: A review paper. *Dent Med Probl.* 2018;55(4):425–429. doi:10.17219/dmp/99021

DOI
10.17219/dmp/99021

Abstract

Bisphosphonates are a group of medicines used in the treatment of oncological osteoporosis, Paget disease and osteogenesis imperfecta. They significantly interfere with the regeneration processes of bone tissue and have a tendency to accumulate in the areas of increased bone remodeling, i.e., the maxilla and the mandible. One of their most serious and problematic side effects is the induction of bisphosphonate-related osteonecrosis of the jaw (BRONJ), characterized by an exposed, necrotic bone in the maxillofacial area, which lasts longer than 8 weeks, in the case of a patient who is using or was using bisphosphonates and who did not undergo radiotherapy in this anatomical area. Dentistry manipulations are one of the factors which may increase the risk of BRONJ occurrence. The existing recommendations for preventing osteonecrosis are ambiguous. Some authors recommend that the bisphosphonate therapy be discontinued prior to dental procedures, while others say that there is no evidence for the effectiveness of interrupting the therapy. There is also no unequivocal attitude toward antibiotic prophylaxis. According to this research, each case should be considered individually, primarily having regard to the good of a patient.

Key words: oral health, bisphosphonates, prophylaxis, bone healing, osteonecrosis

Słowa kluczowe: zdrowie jamy ustnej, bisfosfoniany, profilaktyka, gojenie się kości, martwica kości

Bisphosphonates are a group of medicines used in the treatment of malignancies metastatic to bone, multiple myeloma, hypercalcemia of malignancy, osteoporosis, Paget disease, and osteogenesis imperfecta.[1,2]

They belong to a group of inorganic pyrophosphatic derivatives and are a compound of 2 phosphonate groups connected by esterification.[1] They can be divided into 2 groups: non-nitric and those containing 1 or more nitrogen atoms (Table 1). Their action is based on the affinity to bone hydroxyapatites, which inhibits bone disintegration and calcification.[1,3] Moreover, bisphosphonates are able to induce the apoptosis of osteoclasts, which are responsible for bone destruction, as they release hydrolytic enzymes. The strong affinity of bisphosphonates to bone tissue and, in consequence, their accumulation in its structure, lead to their high concentration in the whole skeletal system.[1] Those major properties have led to their medical utility.

Nowadays, apart from the obvious positive effects of using bisphosphonates, side effects such as gastrointestinal disorders, flu-like symptoms, nausea, emesis, headaches, dizziness, increased risk of atrial fibrillation, renal dysfunction, and the possibility of initiating the osteonecrosis of the jaw are also highlighted.[1,4,5] The latter has recently been classified as a separate disease entity and described for the first time by Marx in 2003 on the basis of a study of 36 patients who took bisphosphonates intravenously.[6] In fact, it is also diagnosed in the cases of drugs administered orally. It has been noticed that bisphosphonates significantly interfere with the regeneration processes of bone tissue. They have a tendency to accumulate in the areas of increased bone remodeling, i.e., the maxilla and the mandible.[7]

According to the American Association of Oral and Maxillofacial Surgeons (AAOMS), bisphosphonate-related osteonecrosis of the jaw (BRONJ) is an exposed, necrosis-affected bone in the maxillofacial area, which lasts longer than 8 weeks, in the case of a patient who is using or was using bisphosphonates and who did not undergo radiotherapy in this anatomical area.[8] Teeth extractions, dental trauma, radio- and chemotherapy, infectious disease, and concomitant therapy with corticosteroids are listed as potential factors which may increase the risk of BRONJ development.[9] Researchers highlight that BRONJ occurs mostly after an intravenous application of zoledronic acid. Among orally applied medicines, alendronate is the one that causes BRONJ most frequently.[10]

Clinical symptoms of BRONJ may vary – from an asymptomatic process to local pains, presence of fistulas, ulceration, inflammatory reaction of soft tissues, teeth loosening, and the exposure of a necrotic bone (Fig. 1).[4,11] Developing BRONJ may also cause sinus pain related to the thinning of the sinus walls and infection.[12] A radiological picture shows the deterioration of the bone structure, bone defects that cannot be related to periodontitis, a loss of bone density, and the separating of bone sequestra (Fig. 2).[13]

In 2006, Ruggiero et al. developed a classification of BRONJ, which defines the advancement of necrosis. The 1st stage includes patients with an exposed necrotic bone with no soft tissue inflammation. The 2nd stage includes patients with an exposed necrotic bone with pain affliction and soft tissue infection. The 3rd stage includes

Fig. 1. Necrotic bone after the procedure of hemisection of distal root of first mandible molar – a patient using bisphosphonates

Fig. 2. Osteonecrosis after the procedure of hemisection of distal root of first mandible molar visible on orthopantomography of a patient using bisphosphonates

Table 1. Types of bisphosphonates

Non-nitric bisphosphonates	Bisphosphonates with nitrogen atoms
etidronate (Ostedron®) clodronate (Sindronat®, Bonefos®)	alendronate (Fosamax®, Alendron®)* ibandronic acid (Bonviva®, Bondenza®) zoledronate (Zometa®, Desinobon®)* pamidronate (Aredia®, Pamifos®) risedronate (Actonel®, Risendros®)

* bisphosphonates causing bisphosphonate-related osteonecrosis of the jaw (BRONJ) most frequently.

patients who, in addition to the aforementioned symptoms, also present with pathological fractures, the creation of extraoral fistulas and osteolysis spreading to the edge of the mandible.[9]

In 2009, Bagán et al. noticed the need to update the previously developed classification of BRONJ, since it did not include a group of patients with intraoral fistulas without exposed necrotic bone tissue. They proposed a separate BRONJ classification.[acc.13] However, the most common classification was created by AAOMS; it differs from the abovementioned classifications (Table 2).[8]

Due to difficulties in treating the highlighted BRONJ complication of the bisphosphonate therapy, it seems to be reasonable to apply proper prophylaxis actions. The basis for preventing side effects is ensuring proper oral hygiene before commencing the bisphosphonate therapy. Teeth that do not qualify for conservative, endodontic or prosthetic treatment should be extracted. If possible, the treatment should be postponed until the extraction wound is fully healed.[14]

During the bisphosphonate treatment, the criteria for conservative and endodontic procedures do not differ from a standard case. Regular check-up visits every 4 months are very important during the therapy with bisphosphonates, and the treatment should be applied immediately in order to prevent the infection from spreading to bone tissue and to limit the need for possible surgical procedures. It is also recommended that patients be educated about maintaining perfect oral hygiene. Routine dental cleaning should be performed carefully to avoid the injuries of soft tissue.[9]

There is no proof of an increased risk of BRONJ after nonsurgical periodontics procedures. Using bisphosphonates does not change the criteria for prosthetic treatment; however, special attention should be paid to the correct moulding of dentures. They should not traumatize the tissues of denture foundation.[15] Both intravenously and orally applied bisphosphonates are not contraindications to orthodontic treatment; however, they can slow down the moves of teeth during the treatment.[16]

Surgical procedures require separate prevention methods. The research shows that the inhibition of the bisphosphonate therapy before a surgical procedure does not decrease the risk of BRONJ.[17] It has been proven that the concentration of bisphosphonates remains high for many years after the therapy. The exact duration of the half-life period of bisphosphonates is not well defined due to technical difficulties in marking their concentration in the urine and blood. It is estimated that alendronate can stay in the organism for 10 years, even after applying a single dose.[1]

If it is necessary to perform a surgical procedure in the maxillofacial area on a patient using bisphosphonates, the patient should always be informed about the potential risk of bone necrosis. It is also advised to perform the procedure in an atraumatic way by an experienced surgeon. It is also recommended to sew the wound tightly, without too much tension, and to maintain good oral hygiene, assisted with antibacterial solutions.[18,19] The scientific research does not provide unambiguous conclusions with regard to applying the antibiotic therapy in BRONJ prevention.

Antibiotic prophylaxis is used in oral surgery to prevent infections in high-risk cases, i.e., in patients whose general health conditions or specific medical procedures they have undergone make them more susceptible to contracting new infections. There are many reasons to use antibiotic prophylaxis in patients treated with bisphosphonates because of their specific mechanism of action, connected with suppressed bone remodeling, inhibited angiogenesis, delayed healing, immunology dysfunction, and the toxification of soft tissues.[20]

Penicillin still remains a drug of choice in antibiotic prophylaxis, but the decision which medicine should be used depends on the pathogens, the patient's tolerance or allergies, and costs. The results of microbiological examinations taken from the extraction site at the time of procedure may be helpful in this regard.[9]

According to Hoefert and Eufinger, a longer application of antibiotics may have a positive influence on the healing process. They compared the results of 2 groups of patients. In the 1st group, the antibiotic therapy was maintained for 1–8 days, while in the 2nd one, it lasted for 23–54 days. The researchers noticed that in the 2nd group, full healing was achieved in 70–87% of the cases, in contrast to the 1st group with the results oscillating from 35% to 53%.[21] The efficacy of this approach is confirmed by the research which analyzed the frequency of BRONJ occurrence after dental procedures.[14] The occurrence of BRONJ was noted only in the group of patients who had not received the antibiotic therapy. Instead, the treatment used mostly amoxicillin or amoxicillin with clavulanate and metronidazole. The alternative for allergic patients is erythromycin, clindamycin and lincomycin. Suggested medicine doses are presented in Table 3.[20]

Table 2. Classification of bisphosphonate-related osteonecrosis of the jaw (BRONJ) by the American Association of Oral and Maxillofacial Surgeons (AAOMS)

Stage	Advancement of necrosis
0	lack of a clinical proof of bone necrosis, still the presence of nonspecific clinical symptoms
1	exposure of a necrotic bone without symptoms of infection
2	exposure of a necrotic bone, accompanied by infection, pain, erythema with or without purulent exudate
3	exposure of a necrotic bone with pain, infection and 1 or more of the following: exposure of a necrotic bone causing pathological fractures, extraoral fistula, oral-sinus fistula, or osteolysis spreading to the edge of the mandible or to the maxillary sinus

However, due to the extended period of administering antibiotics, the usage of clindamycin should be considered carefully, because of the high probability of side effects, including pseudomembranous colitis. Some studies show that clindamycin prophylaxis may also be insufficient for some Gram-negative bacteria, because of the bacteriostatic mechanism of action.[22,23]

On the other hand, there are authors who do not advise prescribing antibiotic prevention for routine dentistry, but recommend bacterial prophylaxis only for patients from the high-risk group with cardiovascular diseases. Some research does not confirm the effectiveness of antibiotic usage in preventing BRONJ.[15,24]

Observations of 15 patients in the Department of Dental Surgery at Medical University of Warsaw suggest that good results in preventing BRONJ were achieved by using antibiotics according to the following guidelines: antibiotic (amoxicillin 1 g every 12 h) for 3 days before the procedure and on the day of the procedure, and then for ±21 days until the epithelialization of the wound. The wound was dressed with sutures, removed after 7–14 days, and the patient was examined on a weekly basis for wound regeneration. Moreover, the advanced platelet rich fibrin (A-PRF) fraction, obtained from the patient's blood collected before the procedure, can be used to accelerate post-extraction wound healing. The effectiveness of the antibiotic prophylaxis used in the Department of Dental Surgery at Medical University of Warsaw was proven in the study by Giovanni et al.[acc.9] In the group of patients who received antibiotics for 3 consecutive days before the procedure, on the day of the procedure and 17 days after, BRONJ was not noticed.[9]

It is difficult to define unambiguous rules of using prophylaxis in the cases of osteonecrosis of the jaws, being a result of the bisphosphonate therapy. Each case should be considered individually, having regard to the good of the patient. Doctors should remember that the chances to encounter people using bisphosphonates (both men and women) in the ageing Polish society are significant. These patients might not inform the dentist about using this medicine or may simply not be aware that this could affect the process of wound healing. It seems reasonable to pay more attention to a general medical interview, which would facilitate proper prophylaxis application.

References

1. Drake MT, Clarke BL, Khosla S. Bisphosphonates: Mechanism of action and role in clinical practice. *Mayo Clin Proc*. 2008;83:1032–1045.
2. American Dental Association Council on Scientific Affairs. Dental management of patients receiving oral bisphosphonate therapy: Expert panel recommendations. *J Am Dent Assoc*. 2006;137:1144–1150.
3. Migliorati CA, Siegel MA, Elting LS. Bisphosphonate-associated osteonecrosis: A long-term complication of bisphosphonate treatment. *Lancet Oncol*. 2006;7:508–514.
4. Varun B, Sivakumar T, Nair BJ, Joseph AP. Bisphosphonate induced osteonecrosis of jaw in breast cancer patients: A systematic review. *J Oral Maxillofac Pathol*. 2012;16:210–214.
5. Sarin J, DeRossi SS, Akintoye SO. Updates on bisphosphonates and potential pathobiology of bisphosphonate-induced jaw osteonecrosis. *Oral Dis*. 2008;14:277–285.
6. Marx RE. Pamidronate (Aredia) and zoledronate (Zometa) induced avascular necrosis of the jaws: A growing epidemic. *J Oral Maxillofac Surg*. 2003;61:1115–1117.
7. Leśniak W, Chloupek A, Biernacka B, et al. Bisphosphonate-associated osteonecrosis of the jaws. Case reports [in Polish]. *Pediatr Med Rodz*. 2013;9:197–200.
8. Ruggiero SL, Dodson TB, Assael LA, Landesberg R, Marx RE, Mehrotra B. American Association of Oral and Maxillofacial Surgeons Position Paper on bisphosphonate-related osteonecrosis of the jaw – 2009 update. *Aust Endod J*. 2009;35:119–130.
9. Ruggiero SL, Gralow J, Marx RE, et al. Practical guidelines for the prevention, diagnosis, and treatment of osteonecrosis of the jaw in patients with cancer. *J Oncol Pract*. 2006;2:7–14.
10. Pelaz A, Junquera L, Gallego L, et al. Epidemiology, pharmacology and clinical characterization of bisphosphonate-related osteonecrosis of the jaw. A retrospective study of 70 cases. *Acta Otorrinolaringol Esp*. 2015;66:139–147.
11. Kolur T, Nair SC, Kumar B. Osteonecrosis of maxilla secondary to bisphosphonate therapy: A case report. *J Maxillofac Oral Surg*. 2015;14:52–56.
12. Salvatore L, Ruggiero SL, Fantasia J, Carlson E. Bisphosphonates related osteonecrosis of the jaws. *Oral Surg Oral Med Oral Pathol Oral Radiol Endod*. 2006;102:433–441.

Table 3. Antibiotic therapy schemas

Orally and intravenously applied bisphosphonates			
Study	Antibiotic used	Frequency of use	Time of use
Lodi et al. 2004[24]	amoxicillin	1 g every 8 h	3 days before extraction, antibiotic therapy continued for 17 days
Saia et al. 2010[25]	amoxicillin with clavulanic acid	1 g every 8 h for 3 days, then 1 g every 12 h for 4 days (together with metronidazole)	7 days before extraction, in case of the occurrence of pain conditions, antibiotic therapy continued for additional 7 days
	metronidazole	0.5 g every 8 h for 4 days	
	in case of allergies: lincomycin	0.5 g every 12 h	
Intravenously applied bisphosphonates			
Study	Antibiotic used	Frequency of use	Time of use
Scoletta et al. 2011[26]	amoxicillin / potassium clavulanate	1 g every 8 h	1 day before extraction, antibiotic therapy continued for 5 following days
	in case of allergies: erythromycin	0.6 g every 8 h	
Ferlito et al. 2011[27]	amoxicillin with clavulanic acid	1 g every 12 h	2 days before extraction, antibiotic therapy continued for 5 following days

13. Gavaldá C, Bagán JV. Concept, diagnosis and classification of bisphosphonate-associated osteonecrosis of the jaws. A review of the literature. *Med Oral Patol Oral Cir Buccal*. 2016;21:260–270.
14. Montefusco V, Gay F, Spina F, et al. Antibiotic prophylaxis before dental procedures may reduce the incidence of osteonecrosis of the jaw in patients with multiple myeloma treated with bisphosphonates. *Leuk Lymphoma*. 2008;49:2156–2162.
15. Edwards BJ, Hellstein JW, Jacobsen PL, Kaltman S, Mariotti A, Migliorati CA; American Dental Association Council on Scientific Affairs Expert Panel on Bisphosphonate-Associated Osteonecrosis of the Jaw. Updated recommendations for managing the care of patients receiving oral bisphosphonate therapy: An advisory statement from the American Dental Association Council on Scientific Affairs. *J Am Dent Assoc.* 2008;139:1674–1677.
16. Iglesias-Linares A, Yáñez-Vico RM, Solano-Reina E, Torres-Lagares D, González Moles MA. Influence of bisphosphonates in orthodontic therapy: Systematic review. *J Dent*. 2010;38:603–611.
17. European Medicines Agency. *CHMP Assessment Report on Bisphosphonates and Osteonecrosis of the Jaw.* London, 2009. https://www.ema.europa.eu/documents/report/chmp-assessment-report-bisphosphonates-osteonecrosis-jaw-procedure-under-article-53-regulation-ec-no/2004_en.pdf. Accessed March 20, 2018.
18. Frank S, Fiołna K, Wojtowicz A. Bisphosphonate-related osteonecrosis of the jaw. A review of the literature [in Polish]. *Dental Forum*. 2013;41:79–82.
19. Heufelder MJ, Hendricks J, Remmerbach T, Frerich B, Hemprich A, Wilde F. Principles of oral surgery for prevention of bisphosphonate-related osteonecrosis of the jaw. *Oral Surg Oral Med Oral Pathol Oral Radiol*. 2014;117:429–435.
20. Bermúdez-Bejarano EB, Serrera-Figallo MA, Gutiérrez-Corrales A, et al. Prophylaxis and antibiotic therapy in management protocols of patients treated with oral and intravenous bisphosphonates. *J Clin Exp Dent*. 2017;9:141–149.
21. Hoefert S, Eufinger H. Relevance of a prolonged preoperative antibiotic regime in the treatment of bisphosphonate-related osteonecrosis of the jaw. *J Oral Maxillofac Surg*. 2011;69:362–380.
22. Ching-Hsiang Y, Khong-Yik C, Solomkin J, Pao-Yuan L, Yuan-Cheng C, Yur-Ren K. Surgical site infections among high-risk patients in clean-contaminated head and neck reconstructive surgery: Concordance with preoperative oral flora. *Ann Plas Surg*. 2013;71:55–60.
23. Cannon RB, Houlton JJ, Mendez E, Futran ND. Methods to reduce postoperative surgical site infections after head and neck oncology surgery. *Lancet Oncol*. 2017;18:405–413.
24. Lodi G, Sardella A, Salis A, Demarosi F, Tarozzi M, Carrassi A. Tooth extraction in patients taking intravenous bisphosphonates: A preventive protocol and case series. *J Oral Maxillofac Surg*. 2010;68:107–110.
25. Saia G, Blandamura S, Bettini G, et al. Occurrence of bisphosphonate-related osteonecrosis of the jaw after surgical tooth extraction. *J Oral Maxillofac Surg*. 2010;68:797–804.
26. Scoletta M, Arduino PG, Pol R, et al. Initial experience on the outcome of teeth extractions in intravenous bisphosphonate-treated patients: A cautionary report. *J Oral Maxillofac Surg*. 2011;69:456–462.
27. Ferlito S, Puzzo S, Liardo C. Preventive protocol for tooth extractions in patients treated with zoledronate: A case series. *J Oral Maxillofac Surg.* 2011;69:e1–e4.

Effects of fruit and vegetables intake in periodontal diseases: A systematic review

Wpływ spożywania owoców i warzyw na przebieg chorób przyzębia – systematyczny przegląd piśmiennictwa

Aleksandra Skoczek-Rubińska[A–D], Joanna Bajerska[E,F], Katarzyna Menclewicz[B–D]

Institute of Human Nutrition and Dietetics, Poznan University of Life Sciences, Poland

A – research concept and design; B – collection and/or assembly of data; C – data analysis and interpretation;
D – writing the article; E – critical revision of the article; F – final approval of the article

Dental and Medical Problems, ISSN 1644-387X (print), ISSN 2300-9020 (online) *Dent Med Probl.* 2018;55(4):431–439

Address for correspondence
Aleksandra Skoczek-Rubińska
E-mail: aleksandra.skoczek-rubinska@up.poznan.pl

Funding sources
None declared

Conflict of interest
None declared

Received on February 27, 2018
Reviewed on August 28, 2018
Accepted on October 19, 2018

Published online on December 27, 2018

Abstract

Periodontal diseases affect up to 90% of the population worldwide. Deficiencies in vitamins, minerals and polyphenolic compounds, whose main sources are fruit and vegetables (F&V), may predispose to these diseases. The PICO (Patient, Intervention of interest, Comparison or Control Intervention, and Outcome) question was: What is the effect of F&V intake on the outcomes of periodontal diseases, observed in either experimental or observational studies of human populations suffering from periodontitis or gingivitis, compared to controls without intervention or healthy people.

The review was conducted using the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) protocol for search strategy, selection criteria and data extraction. The searched databases included MEDLINE (PubMed), Scopus and Google Scholar. A total of 181 potentially relevant articles were identified, which were then evaluated according to pre-specified criteria relating to relevance and quality. Finally, 15 articles were selected for review. Four articles described intervention studies, 3 reported on prospective and retrospective cohort studies, and 8 concerned cross-sectional studies. A total of 10,604 people aged 15–90 years took part in the studies. On the basis of the research it can be concluded that the consumption of at least 5 servings of F&V per day may prevent the progression of periodontal diseases, especially periodontitis, and even tooth loss. Moreover, incorporation of specific F&V into the diet or, alternatively, their lyophilized forms, and nutritional education activities seem to support the standard of care therapy of gingivitis and periodontitis. However, further observational and well-designed experimental studies, with homogeneous periodontal status outcomes, are needed to confirm these findings. Furthermore, professional dietetics care for periodontal patients should become an integral component of the healthcare program.

Key words: diet, fruit, vegetables, periodontal diseases

Słowa kluczowe: dieta, owoce, warzywa, choroby przyzębia

Cite as
Skoczek-Rubińska A, Bajerska J, Menclewicz K. Effects of fruit and vegetables intake in peridontal diseases: A systematic review. *Dent Med Probl.* 2018;55(4):431–439.
doi:10.17219/dmp/99072

DOI
10.17219/dmp/99072

Introduction

Periodontal diseases refer to a range of serious pathological conditions that occur in the tissues surrounding the teeth in response to bacterial accumulation or dental plaque. It is estimated that they affect as much as 90% of the population worldwide, and almost half of the world's population suffers from periodontitis.[1–3] The classification established during the 2017 International Workshop for a Classification of Periodontal Diseases and Conditions distinguishes dental biofilm-induced gingivitis, non-plaque-induced gingival diseases and conditions, necrotizing periodontal diseases, periodontitis as a manifestation of systemic diseases, forms of the periodontal disease previously recognized as 'chronic' or 'aggressive', now grouped under a separate category – 'periodontitis', and progressive and acquired deformities and conditions.[4] A significant role in the pathogenesis of periodontal diseases is attributed to the formation of bacterial biofilm on tooth surfaces, i.e., dental plaque.[2,5] However, what triggers the progression of inflammatory conditions is the disturbance of the equilibrium between the pathogenic bacteria attacking the periodontal tissue and the host's defense mechanisms. The severity and progression of the diseases is a result of numerous factors, including genetic predisposition, age, general health condition, and improper nutrition. It has also been observed that the prevalence of periodontitis is greater in smokers, less educated individuals and those of a lower socioeconomic status.[6] Untreated periodontitis disturbs the process of mastication and may lead to partial or total tooth loss.[7,8] Problems associated with the mastication of food affect the composition of the diet and result in further deterioration of the patient's health condition. It has been confirmed that patients suffering from periodontitis have higher rates of diabetes, cardiovascular disease and cerebral stroke, with the risk increasing with age.[9,10] Typically, patients seek medical attention only in situations requiring dental intervention or pharmacological treatment. However, next to adequate oral hygiene, proper diet composition seems to be an effective measure to prevent the diseases or even to modulate an already existing condition.[11] It has been confirmed that deficiencies in several nutrients, such as vitamins and minerals, strongly enhance the progression of periodontal diseases.[12,13] The primary sources of these important nutrients include fruit and vegetables (F&V). A PICO (Patient, Intervention of interest, Comparison or Control Intervention, and Outcome) question was formulated to identify key words that would drive the literature search.[14] The PICO question was: What is the effect of F&V intake on the outcomes of periodontal diseases, observed in either experimental or observational studies of human populations suffering from periodontitis or gingivitis, compared to controls without intervention or healthy people.

Search strategy

The MEDLINE (PubMed), Scopus and Google Scholar electronic databases were searched to find articles that might answer the above question. The cut-off date for this search was December 15, 2017. The search was limited to studies on human subjects, published between 1990 and 2017, in English, and available in full text. The search terms were: [periodontitis OR periodontal OR chronic periodontitis OR periodontal disease OR periodontal diseases OR aggressive periodontitis] AND [fruit OR fruits OR vegetable OR vegetables] AND [longitudinal OR studies OR supplementation OR consumption OR prospective studies OR cohort studies OR randomized clinical trial OR cross-sectional studies OR intervention]. No other restrictions were established, and the free-text strategy and Medical Subject Headings (MeSH) terms were applied in the search process. This systematic review was conducted in line with the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) statement.[15]

Study selection and eligibility criteria

The study selection was conducted independently by 2 reviewers (ASR, KM), with any disagreements resolved by the 3rd reviewer (JB). The eligibility criteria were formed based on the study question. This systematic review considered only original studies with the following designs: randomized controlled trials (RCTs), and cohort and cross-sectional studies on the effect of F&V intake on gingivitis and periodontitis patients. We also decided to exclude descriptive observational studies (e.g., case studies), reviews, systematic reviews with and without meta-analysis, letters, book chapters, reports, studies without an abstract or where the full text was not available, research conducted on cells, research conducted on nonhuman species, studies conducted only among healthy people or among patients with oral diseases other than gingivitis and periodontitis (e.g., caries), and studies evaluating the effect of extracts derived from F&V or, for example, mouthwash enriched with F&V extracts. Moreover, only papers in English were included. Due to the potential erosive effect of fruit juice,[16] studies on fruit juice intake were also excluded from this systematic review. Different age groups were included in this study and there was no restriction on the severity of periodontitis or gingivitis. The following periodontal outcomes were used to assess the periodontal status: pocket depth/probing pocket depth (PD/PPD), plaque index (PI), bleeding index (BI), bleeding on probing (BOP), alveolar bone loss (ABL), clinical attachment level (CAL), attachment

loss (AL), gingival cervical fluid (GCF), gingival index (GI), gingival recession (GR), modified gingival index (MGI), community periodontal index of treatment needs/community periodontal index (CPITN/CPI), sulcus bleeding index (SBI), vascular endothelial growth factor (VEGF), and tooth loss (TL). Periodontal disease events noted during the observational period were also used to assess the periodontal status. The concentration of vitamin C in blood serum, ferric-reducing antioxidant power (FRAP) and Trolox equivalent antioxidant capacity (TEAC) were determined. For evaluating the inflammation status, the concentration of interleukin 1β (IL-1β) and interleukin 6 (IL-6) was measured. All the papers included in references were additionally reviewed, but there was only 1 report that met all the inclusion criteria. The literature search is illustrated in Fig. 1.

Analysis of study bias and quality

To assess the potential sources of bias, the studies were reviewed using the critical appraisal checklists from the Scottish Intercollegiate Guideline Network.[17] Analysis of the quality of the RCTs was independently performed by 2 investigators (ASR, KM), using a 9-category scoring system, being a modified version of the system proposed by Downs and Black.[18] The cohort and cross-sectional studies were also assessed by 2 reviewers (ASR, KM) in terms of their methodological quality, using an adapted Newcastle-Ottawa Quality Assessment Scale for cohort studies[19] and a separate scale for cross-sectional studies.[20]

Data extraction

Data items extracted from the included papers were as follows: author, year, country, study design, study duration, sample size, participant characteristics (age, gender and periodontal status), method(s) for assessing F&V intake, periodontal status indicator(s), intervention (I) and control (C) conditions in RCTs, and results reported for periodontal status indicators. The data was extracted independently by 2 authors (ASR, KM), with any conflicting judgments discussed and a 3rd independent judgment (JB) sought if agreement could not be reached.

Search results

In total, electronic search through the 3 databases and references revealed 181 potentially relevant papers. Seventy-five papers were selected from the MEDLINE (PubMed) database, 55 from the Scopus database, 50 from the Google Scholar database, and 1 from the reference lists. During the first screening, based on title and abstract, 120 records were excluded from future analysis. In addition, 12 studies were excluded from analysis due to duplication. In the next step, 34 full-text articles failed to meet the inclusion criteria. Overall, a total of 15 articles were enrolled into the qualitative synthesis and systematic review.

Quality assessment

Four of the studies examining dietary interventions obtained an overall average rating of 88%, which allowed these studies to be classified as high-quality.[21] For example, the study by Staudte et al. met 7 out of 9 conditions and obtained a total score of 77.77, and was qualified as a high-quality study.[22] In the case of all the assessed observational studies, sample representativeness was considered to be adequate and the presence of periodontal diseases was confirmed by clinical indicators reported at baseline. The comparability of the study groups based on age, gender and socioeconomic factors was described. Follow-up and outcome assessment was judged to be adequate in all studies. Only 1 study did not describe the timeline of the research.[23] Sample size or power calculations were reported in 5 studies.[24–28] Periodontal therapy was provided by a range of operators, including specialists, general dentists and hygienists. Overall, the methodological quality of all the observational studies was considered to be medium.

Study characteristics

The total number of subjects participating in the studies selected for review was 10,604. The age of the participants in the studies ranged from 15 to 90 years. One study was conducted with children and teenagers,[29] 15 studies involved adults,[22–36] while older adults (≥65 years) participated in 9 studies.[22,24,25,27,28,31–33,36] One study included pregnant women.[35] Among the studies selected for review, 4 involved dietary intervention experiments,[22,32–34] 1 was a retrospective cohort study,[26] 2 were prospective cohort studies,[24,36] and 8 were cross-sectional studies.[23,25,27–31,35] The consumption of F&V was mostly assessed using the Food Frequency Questionnaire (FFQ) method,[26,28,30,33,35,36] the food diary method[33] and the 24-hour recall method.[26–28,30,31] We abstracted the following data from each study: author's first name, year of publication, country where the study was conducted, study design, study duration, sample size, characteristics of the participants, use of periodontal indices, and results. The studies selected for review are characterized in Table 1.

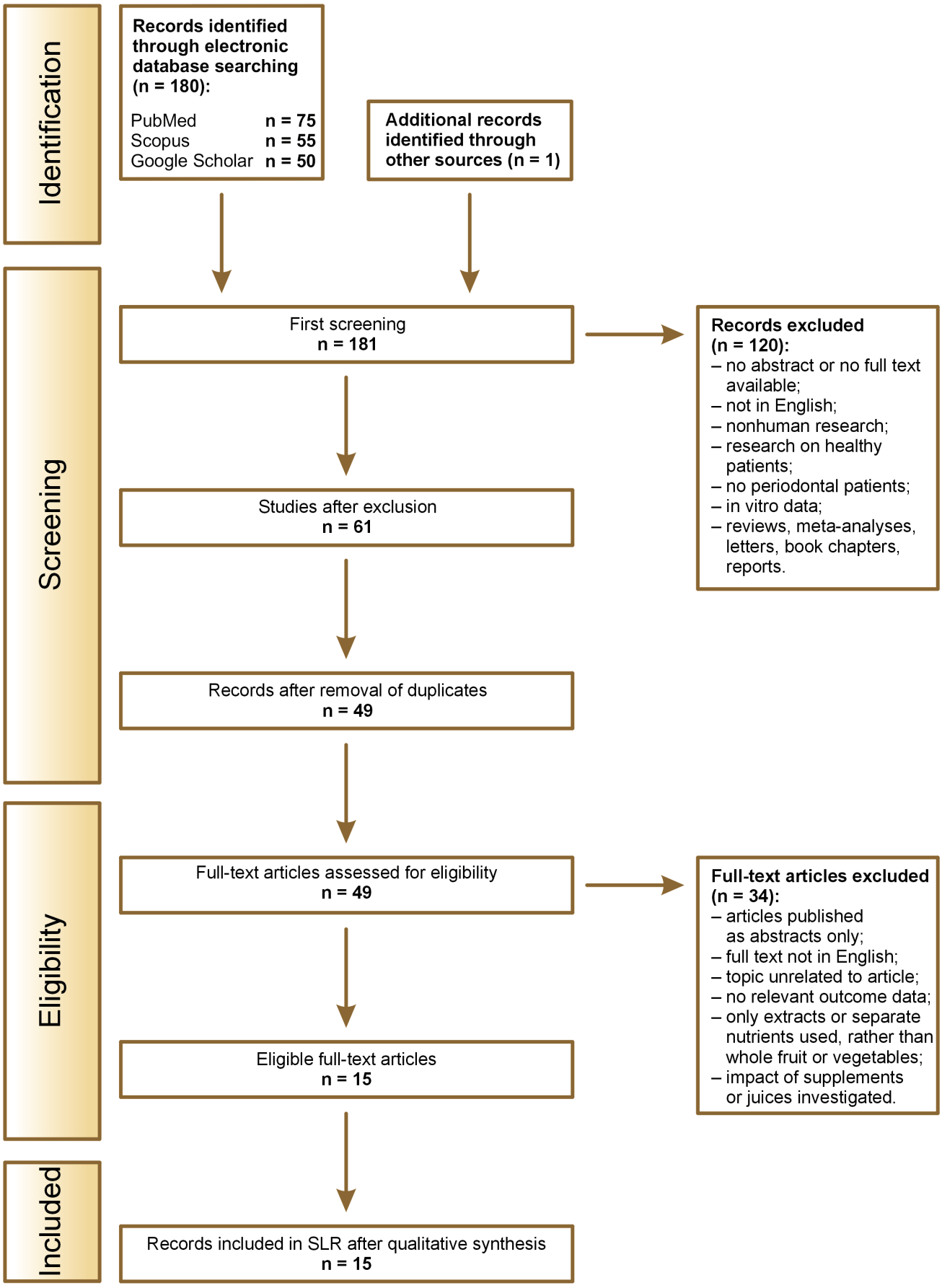

Fig. 1. Flow chart of the literature review process

SLR – systematic literature review.

Table 1. Fruit and vegetables (F&V) intake and periodontal diseases – data analysis

Study	Population	Study duration	Study design	Periodontal indices	Results
Dietary interventions					
Staudte et al. Germany, 2005[22]	51 F and 29 M; aged 24–65 years; chronic periodontitis; smokers and nonsmokers	2 weeks	I – 2 grapefruits/day + dietary recommendations; smokers and nonsmokers C – smokers and nonsmokers on a usual diet	Serum level of vitamin C; PPD; SBI; PI	↓ SBI in nonsmokers; ↑ vitamin C level in smokers and nonsmokers
Chapple et al. UK, 2012[32]	39 F and 21 M; aged 30–60 years; chronic periodontitis	8 months	I – diet + lyophilized fruit and vegetables (FV) and fruit / vegetables / blueberries (FVB) C – placebo (primarily microcrystalline cellulose)	PPD; BOP; CAL; GCF; MGI; recession; cumulative Quigley–Hein index	↓ PPD; ↓ BOP; ↑ CAL (after just 2 months of dietary treatment)
Zare Javid et al. UK, 2014[33]	51 F and M; aged 30–65 years; chronic periodontitis	6 months	I – nutritional education + check-up meetings: before the study (T0), after 3 months (T1) and after 6 months (T2) C – control meetings without education	TEAC and FRAP in plasma and saliva; PI; GR; BI; CAL; PD	↑ TEAC (I vs C in T1 and T2)
Widén et al. Sweden, 2015[34]	17 F and 7 M; aged ≥18 years; gingivitis	7 days	I – 250 g bilberries/day or 500 g bilberries/day CI – placebo (potato starch) CII – standard of care therapy (debridement only)	BOP; level of IL-1β, IL-6 and VEGF in GCF	↓ BOP; ↓ IL-1β, IL-6, VEGF in GCF (only in the group consuming 500 g bilberries/day)
Cross-sectional studies					
Tanaka et al. Japan, 2007[35]	1,002 pregnant women; aged 30 years; healthy and with periodontal diseases	28 months	consumption of green and yellow vegetables, other vegetables and fruit	TL: extraction of ≥1 tooth	↓ TL (in the group eating vegetables other than green and yellow)
Yamori et al. Tanzania, 2011[30]	81 F; aged 46–58 years; healthy and with periodontitis	6 years	frequency of F&V intake	CPITN	↓ CPITN (at ↑ intake of green F&V)
Bawadi et al. Jordan, 2011[25]	340 F and M; aged 18–70 years; healthy and with periodontitis	6 months	frequency of F&V intake and calculating HEI (a well-balanced diet: HEI > 80)	PI; GI; PPD; CAL; TL	↓ CAL; ↓ TL (at ↑ intake of F&V)
Nielsen et al. USA, 2016[31]	3,107 F and 2,945 M; aged ≥30 years; healthy and with periodontitis	2 years	F&V intake	PD; GR; AL	↑ PD; ↑ AL (≤4.5 servings/day of F&V without potatoes and other starchy vegetables) no statistical significance
Rivas-Tumanyan et al. Puerto Rico, 2013[27]	182 F and 43 M; aged ≥60 years; healthy and with periodontitis	2 years	F&V intake	PD; AL	↑ PD; ↑ AL (<5 servings/day of F&V)
Blihnaut and Grobler South Africa, 1992[29]	227 F and 252 M; aged ≥15 years; farm workers; healthy and with periodontal diseases	12 months	consumption of citrus fruit and other fruit (apples, grapes and mixed fruit)	CPITN 0 – healthy; CPITN 3 – periodontitis, PD ≥ 4 mm	↓ PD ≥ 4 mm (in participants with CPTIN 3 in the citrus group)
Dodington et al. Canada, 2015[28]	63 nonsmokers, 23 smokers, F and M; aged 34–90 years; chronic generalized periodontitis	18 months	I tertile – the lowest F&V intake (1.5–5.0 servings*/day) II tertile – medium F&V intake (5.1–6.7 servings/day) III tertile – the highest F&V intake (6.8–16.8 servings/day)	BOP; PD	↓ PD in nonsmokers (>5 servings/day of F&V)
Tomofuji et al. Japan, 2011[23]	388 F and 413 M; aged 18–25 years; students; healthy and with periodontitis	–	consumption of vegetables	CPI	↑ CPI (at ↓ vegetable intake) (for BMI > 23 kg/m^2)
Retrospective cohort studies					
Amaliya et al. Indonesia, 2015[26]	53 F and 45 M; aged 39–50 years; healthy and with periodontitis	6 years	guava fruit intake as a vitamin C source	plasma level of vitamin C; ABL	↓ ABL (at ↑ guava fruit intake)
Prospective cohort studies					
Schwartz et al. USA, 2012[24]	625 M; aged 43–86 years; healthy and with periodontitis	15 years	fruit intake as a dietary fiber source	ABL; PPD; TL; plaque accumulation	↓ ABL; ↓ PPD; ↓ TL (at ↑ high-fiber fruit intake) (for subjects aged ≥65 years)
Yoshihara et al. Japan, 2009[36]	600 subjects (294 F and 306 M); aged 70 years; healthy and with periodontitis	6 years	intake of dark green and yellow vegetables intake of other F&V	change in TL over 6 years; number of periodontitis events over 6 years	↓ number of periodontitis events over 6 years (at ↑ intake of dark green and yellow vegetables [g/kg])

ABL – alveolar bone loss; AL – attachment loss; BI – bleeding index; BMI – body mass index; BOP – bleeding on probing; C – control group; CAL – clinical attachment level; CPITN/CPI – community periodontal index of treatment needs/community periodontal index; F – females; FRAP – ferric-reducing antioxidant power; F&V – fruit and vegetables; GCF – gingival cervical fluid; GI – gingival index; GR – gingival recession; HEI – healthy eating index; I – intervention group; IL-1β – interleukin 1β; IL-6 – interleukin 6; M – males; MGI – modified gingival index; PD – pocket depth; PI – plaque index; PPD – probing pocket depth; SBI – sulcus bleeding index; TEAC – Trolox equivalent antioxidant capacity; TL – tooth loss; VEGF – vascular endothelial growth factor; *a serving means 125 mL of fresh, frozen or preserved fruit or vegetables, or 250 mL of green leafy vegetables or salads, or 1 piece.

Fruit and vegetables consumption as an adjunct to standard of care treatment (dietary intervention studies)

Although diet is described as a modifiable risk factor for periodontal diseases,[37] data on dietary manipulations where F&V were added to the diet of patients with periodontal diseases is very limited. Our review found 4 such dietary intervention studies.[22,32–34] In the study by Staudte et al., it was found that incorporation of 2 servings of grapefruit (500 g) into the diet of smoking and nonsmoking patients diagnosed with chronic periodontitis resulted in a significant increase in blood serum vitamin C concentration after a 2-week intervention in comparison to a control group consuming a usual diet.[22] Moreover, among diseased nonsmokers, a significant reduction in the value of SBI was also observed.[22] Widén et al. reported a significant reduction in BOP, as well as in the concentrations of proinflammatory cytokines (IL-1β and IL-6) and VEGF in GCF among individuals with gingivitis who consumed 500 g bilberries per week in comparison to controls receiving a placebo.[34] Moreover, it was stated that the intake of 500 g bilberries caused similar changes in BOP as did standard of care therapy (debridement only).[34] Significant improvements in the PPD and BOP values were observed after only 2 months in patients suffering from chronic periodontitis who received nonsurgical treatment and freeze-dried F&V.[32] In a 6-month study conducted by Zare Javid et al. among adults suffering from chronic periodontitis who had completed nonsurgical treatment, nutritional education activities focusing on adequate intake of F&V (≥5 servings daily) were linked with a significant increase in plasma total antioxidant capacity, as measured by the TEAC assay, compared to the control group.[33] No significant differences were observed between the groups with respect to the periodontal indices measured (PI, GR, BI, CAL, and PD) or the FRAP index.[33] To conclude, on the basis of the collected dietary intervention studies, it can be stated that the incorporation of F&V into the diet, especially citrus fruit, berries and lyophilized F&V, as well as nutritional education activities focusing on adequate F&V intake, may be useful as an adjunctive measure in the management of periodontitis or gingivitis. However, further RCTs are required to confirm this effect.

Fruit and vegetable intake in the prevention of periodontal diseases (cohort and cross-sectional studies)

We saw an association between F&V intake and periodontal health in 8 cross-sectional studies and 3 cohort studies. For example, Yamori et al., in a study of 81 women aged 46–58 years, reported that the severity of periodontitis (assessed on the basis of the CPITN) was inversely correlated with the frequency of intake of green F&V.[30] Bawadi et al. stressed that a well-balanced diet (as assessed by the healthy eating index, HEI > 80) with adequate intake of F&V (min 5 servings per day) was associated with improved CAL.[25] It was also observed that higher intake of F&V was related to a lower number of lost teeth.[25] In a study conducted by Rivas-Tumanyan et al., it was shown that among elderly patients, having at least 2 teeth with the AL score of ≥6 mm and at least 1 tooth with the PD value of ≥5 mm was significantly associated with low intake of F&V (<5 servings per day).[27] In a study conducted during the years 2009–2010 and 2011–2012 on a population of 6,052 adults, Nielsen et al. observed that insufficient intake of F&V of ≤4.5 servings per day was associated with an increase in PD and AL; however, this relation was statistically insignificant.[31] Blihnaut and Grobler, in a study of 479 fruit pickers in South Africa, assessed the relationship between periodontal health (evaluated on the basis of CPITN) and the intake of fresh fruit (including citrus fruit, apples, grapes, and mixed fruit).[29] The recommended daily fruit intake was established as at least 8 apples, 8 bunches of grapes, 8 oranges or mandarins, or 11 fruits being a mixture of different kinds. In individuals eating citrus fruit, PD ≥ 4 mm was diagnosed less often.[29] Similarly, during an 18-month observation, Dodington et al. recorded that increased intake of F&V (≥5 servings per day) was associated with a significantly lower incidence of PD > 3 mm.[28] However, this association was seen only among nonsmokers. Tomofuji et al. observed that the frequency of vegetable consumption among obese students diagnosed with periodontitis was significantly lower (10.9%) than among non-obese individuals (33%).[23] No such association was found in underweight students and students with normal body weight.[23] In a study conducted by Tanaka et al., involving 1,002 pregnant women, a relationship between the intake of F&V and TL was seen.[35] The lowest number of lost teeth was recorded in the group of women consuming the largest amounts (>170 g per day) of vegetables other than green or yellow, such as cabbage, radishes and onions.[35] The protective role of adequate F&V intake on periodontal health, as reported by cross-sectional studies, was also confirmed in 2 prospective and 1 retrospective cohort studies. For example, Schwartz et al. observed among veterans aged over 65 years that the intake of high-fiber fruits, such as bananas, apples, pears, oranges, and plums, was associated with a lower risk of progression in ABL, PPD and TL.[24] No significant associations were seen in younger veterans.[24] Moreover, the intake of dark green and yellow vegetables was negatively correlated with the number of periodontitis events during the 6 years of observations conducted in a group of 600 older adults.[36] In her retrospective study, Amaliya et al. found opposite associations between the consumption of guava fruit, rich in vitamin C,

and the amount of ABL.[26] To conclude, the findings from the collected studies suggest strong inverse associations between the progression of periodontal diseases, especially periodontitis, and adequate consumption (at least 5 servings a day) of F&V. In this matter, special attention should be given to adequate consumption of dark green and yellow vegetables (spinach, broccoli, yellow peppers, and carrots) and some other vegetables (cabbage, radishes and onions), and fruits with a high content of vitamin C (black currants, grapefruits and oranges) and dietary fiber (bananas, apples, pears, berries, and plums).

Discussion

The data collected from the cross-sectional studies and confirmed by the prospective and retrospective cohort studies clearly indicates that the recommended intake of F&V (at least 5 servings a day) is a significant factor that can prevent the progression of periodontal diseases and even tooth loss among people at all ages. It should be highlighted, however, that smoking is a significant risk factor in the progression of periodontitis, irrespective of the actual intake of F&V.[37] Our findings were similar to those presented by Nanri et al. and Moynihan, where higher F&V consumption was also associated with better oral health-related quality of life.[38,39] Moreover, our systematic literature review indicated that incorporating F&V (especially citrus fruit and berries) into the diet, as well as nutritional education activities that stress the need for adequate intake of F&V by individuals with various forms of periodontal diseases, could lead to a significant enhancement in the oral health status by improving gingival inflammation indices[34] and inhibiting the progression of periodontitis.[22,33,34] An interesting alternative seems to be provided by the potential use of freeze-dried F&V in the treatment of periodontitis.[32] This particularly pertains to individuals who, due to the progression of periodontitis and disturbed mastication (i.e., older adults) do not consume adequate amounts of fresh F&V. It has been stated that almost 85% of patients currently reporting periodontitis are 65 years or older,[40] which is due to the fact that the number of teeth decreases with age and the remaining teeth get more exposed and sensitive to pathogenic agents. Periodontitis leads to difficulties in the consumption of certain types of foods, especially raw F&V, which are hard to chew. Therefore, in the case of such people, lyophilized F&V products could constitute an interesting approach to the prevention of periodontal diseases, and these products could be recommended as safe adjuncts to nonsurgical periodontal therapy in patients with gingivitis and periodontitis.

Fruit and vegetables are a good source of multiple nutrients, including vitamins A, E and C, and phytochemicals, as well as dietary fiber. All these compounds can affect periodontal health, as they function as antioxidants, antibacterial agents (inhibiting the adhesion of such pathogens as *Streptococcus mutans* to plaque) and enhancers of cell-mediated immunity.[32,41,42] For example, grapefruits are among the richest dietary sources of vitamin C.[39] Two portions of grapefruit provide about 240 mg of vitamin C.[34] The mechanism of action of vitamin C is associated with its antioxidant properties, which help to reduce the production of reactive oxygen radicals, formed during inflammatory processes.[39,43] Staudte et al. stress that adequate intake of vitamin C is crucial in collagen synthesis and in preventing excessive permeability of the gingival tissue.[22]

Berry fruits, such as cranberries, bilberries and blueberries, are also a significant source of flavanols, anthocyanins and proanthocyanidins. These compounds inhibit the formation of biofilm on tooth surfaces, at the same time exhibiting strong antioxidant and anti-inflammatory activity.[34] Yellow and dark green vegetables may also have beneficial effects on periodontal health, mostly because they are a source of antioxidants and may lower pH levels, thus reducing the number of pathogens.[36] Lectins, prostaglandins and thiosulfates contained in onions have anti-inflammatory and antibacterial properties.[44,45] Lupenol present in white cabbage exhibits anti-inflammatory activity.[46,47] Radish is a good source of glucosinolates, which have antioxidant properties.[48] A number of mechanisms have been proposed to explain the relationship between the intake of high-fiber food and periodontal diseases. The protective effect of fiber consists in controlling serum glucose levels and insulin resistance, since diabetes has been unequivocally confirmed as a major risk factor for periodontitis.[24] Moreover, high-fiber foods mechanically remove plaque from tooth surfaces.[49]

Our study has several strengths. Our systematic review was based on 8 cross-sectional studies, as well as on 2 prospective studies and 1 retrospective cohort study, all of them conducted on various populations, which allowed us to conclude that higher intake of F&V is positively associated with the periodontal health status. However, this systematic review also has several limitations. Firstly, the studies included in the systematic review used different periodontal disease indices, which made the results of those studies difficult to compare. Secondly, different studies used different methods of dietary assessment, such as 24-hour recall, food diaries and FFQ. Moreover, in the cohort and cross-sectional studies, either the frequency of F&V intake or the consumption of various fruit (e.g., rich in vitamin C and dietary fiber) and vegetables (e.g., dark green and yellow) was evaluated. Thirdly, there were differences in the classification of F&V across studies. Types of consumed F&V differed according to geographical locations. These factors could affect our results. Fourthly, there were only a few dietary intervention studies that might confirm the effect of F&V as an adjunctive measure in the management of periodontal diseases. Therefore, more high-quality dietary intervention studies,

focusing on different age groups, but with special attention paid to older age groups, are required to confirm our findings. Dietary advice for the prevention of oral diseases also has to be a part of routine patient education practices. However, we should also highlight that there is growing awareness among dental professionals of the beneficial effects of adequate diets on the periodontal tissue condition. According to Kelly and Moynihan, 66% of the surveyed dentists stated that an adequate, well-balanced diet significantly affected the progression of periodontal diseases.[50] Most respondents declared that the intake of vitamin C was significantly associated with improved periodontal health (70.2%), with the recommended level of F&V intake ranking 2nd (64.3%).

This systematic review suggests that the consumption of F&V, at least 5 servings per day, especially dark green and yellow vegetables (spinach, broccoli, yellow peppers, and carrots) and some other vegetables (cabbage, radishes, onions), as well as fruit rich in vitamin C (black currants, grapefruits, oranges) and dietary fiber (bananas, apples, pears, berries, and plums) may prevent the progression of periodontal diseases, especially periodontitis, and even tooth loss. Moreover, incorporation of specific F&V (berries, citrus fruit) into the diet or, alternatively, their lyophilized forms, and nutritional education activities seem to support the standard of care therapy of gingivitis and periodontitis. However, further observational and well-designed experimental studies, with homogeneous periodontal status outcomes, are needed to confirm these findings. Furthermore, professional dietetics care for periodontal patients should be an integral component of the healthcare program.

References

1. Woźniewicz M, Nowaczyk PM, Kurhańska-Flisykowska A, et al. Consumption of cranberry functional beverage reduces gingival index and plaque index in patients with gingivitis. *Nutr Res*. 2018;58:36–45.
2. Mariotti A, Hefti AF. Defining periodontal health. *BMC Oral Health*. 2015;15(Suppl 1):S6.
3. Jin LJ, Lamster IB, Greenspan JS, Pitts NB, Scully C, Warnakulasuriya S. Global burden of oral diseases: Emerging concepts, management and interplay with systemic health. *Oral Dis*. 2016;22:609–619.
4. Caton JG, Armitage G, Berglundh T, et al. A new classification scheme for periodontal and peri-implant diseases and conditions – introduction and key changes from the 1999 classification. *J Periodontol*. 2018;89(Suppl 1):1–8.
5. Marsh PD, Bradshaw DJ. Dental plaque as a biofilm. *J Ind Microbiol*. 1995;15:169–175.
6. Yang H, Xiao L, Zhang L, Deepal S, Ye G, Zhanga X. Epidemic trend of periodontal disease in elderly Chinese population, 1987–2015: A systematic review and meta-analysis. *Sci Rep*. 2017;7:45000.
7. Iwata T, Yamato M, Ishikawa I, Ando T, Okano T. Tissue engineering in periodontal tissue. *Anat Rec (Hoboken)*. 2014;297:16–25.
8. Pihlstrom BL, Michalowicz BS, Johnson NW. Periodontal diseases. *Lancet*. 2005;366:1809–1820.
9. Dahiya P, Kamal R, Gupta R. Obesity, periodontal and general health: Relationship and management. *Indian J Endocr Metab*. 2012;16:88–93.
10. Patel R. The state of oral health in Europe. Report commissioned by the Platform for Better Oral Health in Europe. 2012. http://www.oralhealthplatform.eu/wp-content/uploads/2015/09/Report-the-State-of-Oral-Health-in-Europe.pdf. Accessed February 25, 2018.
11. Palmer CA. Important relationships between diet, nutrition, and oral health. *Nutr Clin Care*. 2001;4:4–14.
12. Moynihan PJ. The role of diet and nutrition in the etiology and prevention of oral diseases. *Bull World Health Organ*. 2005;83:694–699.
13. Van der Putten GJ, Vanobbergen J, De Visschere L, Schols J, de Baat C. Association of some specific nutrient deficiencies with periodontal disease in elderly people: A systematic literature review. *Nutrition*. 2009;25:717–722.
14. Small L, Anderson, D, Melnyk, BM. Prevention and early treatment of overweight and obesity in young children: A critical review and appraisal of the evidence. *Pediatr Nurs*. 2007;33:127,149–152,155–161.
15. Shamseer L, Moher D, Clarke M, et al.; PRISMA-P Group. Preferred reporting items for systematic review and meta-analysis protocols (PRISMA-P) 2015: Elaboration and explanation. *BMJ*. 2015;350:g7647.
16. Zimmer S, Kirchner G, Bizhang M, Benedix M. Influence of various acidic beverages on tooth erosion. Evaluation by a new method. *PLoS ONE*. 2015;10:e0129462.
17. Scottish Intercollegiate Guidelines Network. Critical appraisal notes and checklists. http://sign.ac.uk/methodology/checklists.html. Accessed February 25, 2018.
18. Downs SH, Black N. The feasibility of creating a checklist for the assessment of the methodological quality both of randomised and non-randomised studies of health care interventions. *J Epidemiol Community Health*. 1998;52:377–384.
19. Wells GA, Shea B, O'Connell D, et al. The Newcastle-Ottawa Scale (NOS) for assessing the quality of nonrandomised studies in meta-analyses. 2008. http://www.ohri.ca/programs/clinical_epidemiology/nosgen.pdf. Accessed February 25, 2018.
20. Modesti PA, Reboldi G, Cappuccio FP, et al.; ESH Working Group on CV Risk in Low Resource Settings. Panethnic differences in blood pressure in Europe: A systematic review and meta-analysis. *PLoS ONE*. 2016;11:e0147601.
21. Wickham CA, Carbone ET. Who's calling for weight loss? A systematic review of mobile phone weight loss programs for adolescents. *Nutr Rev*. 2015;73:386–398.
22. Staudte H, Sigush BW, Glockmann E. Grapefruit consumption improves vitamin C status in periodontitis patients. *Br Dent J*. 2005;199:213–217.
23. Tomofuji T, Furuta M, Ekuni D, et al. Relationships between eating habits and periodontal condition in university students. *J Periodontol*. 2011;82:1642–1649.
24. Schwartz N, Kaye EK, Nunn ME, Spiro A, Garcia RI. High-fiber foods reduce periodontal disease progression in men aged 65 and older: the Veterans Affairs normative aging study/dental longitudinal study. *J Am Geriatr Soc*. 2012;60:676–683.
25. Bawadi HA, Khader YS, Haroun TF, Al-Omari M, Tayyem RF. The association between periodontal disease, physical activity and healthy diet among adults in Jordan. *J Periodontal Res*. 2011;46:74–81.
26. Amaliya A, Laine ML, Delanghe JR, Loos BG, Van Wijk AJ, Van der Velden U. Java project on periodontal diseases: Periodontal bone loss in relation to environmental and systemic conditions. *J Clin Periodontol*. 2015;42:325–332.
27. Rivas-Tumanyan S, Campos M, Zevallos JC, Joshipura KJ. Periodontal disease, hypertension, and blood pressure among older adults in Puerto Rico. *J Periodontol*. 2013;84:203–211.
28. Dodington DW, Fritz PC, Sullivan PJ, Ward WE. Higher intakes of fruits and vegetables, β-carotene, vitamin C, α-tocopherol, EPA, and DHA are positively associated with periodontal healing after nonsurgical periodontal therapy in nonsmokers but not in smokers. *J Nutr*. 2015;145:2512–2519.
29. Blihnaut JB, Grobler SR. High fruit consumption and the periodontal status of farm workers. *Clin Prev Dent*. 1992;14:25–28.
30. Yamori M, Njelekela M, Mtabaji J, Yamori Y, Bessho K. Hypertension, periodontal disease, and potassium intake in nonsmoking, nondrinker African women on no medication. *Int J Hypertens*. 2011;2011:695719.
31. Nielsen SJ, Trak-Fellermeier MA, Joshipura K, Dye BA. Dietary fiber intake is inversely associated with periodontal disease among US adults. *J Nutr*. 2016;146:2530–2536.
32. Chapple ILC, Milward MR, Ling-Mountford N, et al. Adjunctive daily supplementation with encapsulated fruit, vegetable and berry juice powder concentrates and clinical periodontal outcomes: A double-blind RCT. *J Clin Periodontol*. 2012;39:62–72.

33. Zare Javid A, Seal CJ, Heasman P, Moynihan PJ. Impact of a customized dietary intervention on antioxidant status, dietary intakes and periodontal indices in patients with adult periodontitis. *J Hum Nutr Diet*. 2014;27:523–532.
34. Widén C, Coleman M, Cariten S, Karlgren-Andersson P, Renvert S, Persson GR. Consumption of bilberries controls gingival inflammation. *Int J Mol Sci*. 2015;16:10665–10673.
35. Tanaka K, Miyake Y, Sasaki S, et al. Relationship between intake of vegetables, fruit and grains and the prevalence of tooth loss in Japanese women. *J Nutr Sci Vitaminol (Tokyo)*. 2007;53:522–528.
36. Yoshihara A, Watanabe R, Handa N, Miyazaki H. A longitudinal study of the relationship between diet intake and dental caries and periodontal disease in elderly Japanese subjects. *Gerodontol*. 2009;26:130–136.
37. AlJehani YA. Risk factors of periodontal disease: Review of the literature. *Int J Dent*. 2014;2014:182513.
38. Nanri H, Yamada Y, Itoi A, et al. Frequency of fruit and vegetable consumption and the oral health-related quality of life among Japanese elderly: A cross-sectional study from the Kyoto-Kameoka Study. *Nutrient*. 2017;9:e1362.
39. Moynihan PJ. The role of diet and nutrition in the etiology and prevention of oral diseases. *Bull World Health Organ*. 2005;83:694–699.
40. White D, Tsakos G, Pitts NB, et al. Adult Dental Health Survey 2009: Common oral health conditions and their impact on the population. *Br Dent J*. 2000;213:567–572.
41. La VD, Howell AB, Grenier D. Cranberry proanthocyanidins inhibit MMP production and activity. *J Dent Res*. 2009;88:627–632.
42. Bonifait L, Grenier D. Cranberry polyphenols: Potential benefits for dental caries and periodontal disease. *J Can Dent Assoc*. 2010;76:a130.
43. Iwasaki M, Moynihan P, Manz MC, et al. Dietary antioxidants and periodontal disease in community-based older Japanese: A 2-year follow-up study. *Public Health Nutr*. 2013;16:330–338.
44. Wilson EA, Demming-Adams B. Antioxidant, anti-inflammatory, and antimicrobial properties of garlic and onions. *Nutr Food Sci*. 2007;37:178–183.
45. Corzo-Martinez M, Corzo N, Villamiel M. Biological properties of onions and garlic. *Trends Food Sci Tech*. 2007;18:609–625.
46. Lin JY, Li CY, Hwang IF. Characterization of the pigment components in red cabbage (*Brassica oleracea* L. var.) juice and their anti-inflammatory effects on LPS-stimulated murine splenocytes. *Food Chem*. 2008;109:771–781.
47. Saleem M. Lupeol, a novel anti-inflammatory and anti-cancer dietary triterpene. *Cancer Lett*. 2009;285:109–115.
48. Lugasi A, Dworschak E, Blazovics A, Kocsis I, Kéry A. Antioxidant and free radical scavenging properties of squeezed juice from black radish (*Raphanus sativus* L. var. niger) root. *Phytother Res*. 1998;12:502–506.
49. Kondo K, Ishikado A, Morino K, et al. A high-fiber, low-fat diet improves periodontal disease markers in high-risk subjects: A pilot study. *Nutr Res*. 2014;34:491–498.
50. Kelly SA, Moynihan PJ. Attitudes and practices of dentists with respect to nutrition and periodontal health. *Br Dent J*. 2008;205:E9.

Oral findings in Rett syndrome: An update and review of the literature

Zmiany w jamie ustnej w zespole Retta – przegląd współczesnego piśmiennictwa

Edoardo Bianco[A–C,E,F], Denise Rota[D,F]

Department of Surgery and Translational Medicine, University of Milano-Bicocca, Milan, Italy

A – research concept and design; B – collection and/or assembly of data; C – data analysis and interpretation;
D – writing the article; E – critical revision of the article; F – final approval of the article

Dental and Medical Problems, ISSN 1644-387X (print), ISSN 2300-9020 (online) *Dent Med Probl.* 2018;55(4):441–445

Address for correspondence
Edoardo Bianco
E-mail: eduardowhite@gmail.com

Funding sources
None declared

Conflict of interest
None declared

Received on July 5, 2018
Reviewed on September 7, 2018
Accepted on October 25, 2018

Published online on December 17, 2018

Abstract

Rett syndrome is a progressive pediatric neurodevelopmental disorder, predominantly affecting females, characterized by a seemingly normal prenatal and perinatal period, followed by neurodevelopmental stagnation, and then rapid regression.

The purpose of this study was to provide an update of the literature on the oral aspects of Rett syndrome and their possible treatment in patients suffering from this pathology. After an electronic and manual search in MEDLINE (PubMed) and the Cochrane Library, 12 articles were found, for a total of 142 patients affected by Rett syndrome. A high prevalence of bruxism, anterior open bite, ogival palate, sucking habits, and difficulties in maintaining oral hygiene was noted. There were also oral findings related to the pharmacological treatment, which included xerostomia, glossitis, erythema multiforme, gingival hyperplasia, dysphagia, and lingual paralysis. It is important for the dentist to know what problems related to the oral cavity can be encountered in a patient diagnosed with Rett syndrome and what preventive measures can be applied.

Key words: autism, bruxism, Rett syndrome, oral manifestations

Słowa kluczowe: autyzm, bruksizm, zespół Retta, objawy w jamie ustnej

Cite as
Bianco E, Rota D. Oral findings in Rett syndrome: An update and review of the literature. *Dent Med Probl.* 2018;55(4):441–445. doi:10.17219/dmp/99203

DOI
10.17219/dmp/99203

Introduction

Rett syndrome is a progressive pediatric neurodevelopmental disorder, which was first described by Andreas Rett in 1966. It is an X chromosome-linked condition, which almost exclusively affects females. The estimated prevalence of the disorder ranges from 1:10000 to 1:15000 in newborns.[1]

Rett syndrome is a neurodegenerative disease, characterized by a seemingly normal prenatal and perinatal period and healthy development for 6–18 months, followed by a period of neurodevelopmental stagnation, and then rapid regression: loss of previously acquired speech, cognitive skills, purposeful hand skills, and active play interest. A further deterioration of cognitive abilities leads to autistic-like attitudes, mental delay and motor disturbances like ataxia, apraxia and tremor. Seizures, stereotypical movements of the hands, hyperventilation, and periods of apnea when awake are also common.[2–4] Progressive muscle atrophy of the distal arms and legs, weight loss, growth retardation, and kyphosis can also be found.[2,3]

In 1999, some mutations in the methyl-CpG-binding protein 2 gene (*MeCP2*, a transcriptional regulator gene) were identified as the causes of the condition, even if some rarer mutations in other genes could be found, particularly in *CDKL5* in the infantile seizure onset variant and *FOXG1* in the congenital variant.[5–8]

Only a few studies on the oral signs and symptoms of Rett syndrome can be found, and there are no up-to-date literature reviews on the oral manifestations in these patients. The purpose of this study was to provide an update of the literature on the oral aspects of Rett syndrome and their possible treatment in patients suffering from this pathology.

Material and methods

An electronic search in MEDLINE (PubMed) and the Cochrane Library of publications from January 1985 to September 2017 was performed using the following search terms: [rett syndrome] AND [oral OR dental OR dentist OR bruxism]. Moreover, a manual search of the bibliographies of all full text articles was also conducted.

The selected studies had to meet the following inclusion criteria:

– publications in English and Italian in the dental literature;
– case reports, case series and reviews that clearly describe the oral manifestations or dental feedback or problems related to dentistry in patients with Rett syndrome, or clinical case studies with the description of the provided dental treatment.

Research papers that did not clearly describe the signs and symptoms of Rett syndrome, or did not specify the provided dental treatment were excluded from the study.

Results

The research identified 12 articles, for a total of 142 patients affected by Rett syndrome.

It was decided that case reports would also be included in the review, since, taking into consideration the scarcity of studies on this topic, it was regarded important to make the spectrum of cases to be reviewed as wide as possible.

The first analyzed case of dental treatment applied to patients with Rett syndrome, described in the literature, regarded the endodontic treatment of a superior central incisor, performed under general anesthesia in a 12-year-old patient.[9] The treatment was implemented after a facial trauma, which occurred during a seizure. Among the analyzed articles, this was the only one that reported dental treatment caused by a facial trauma in a patient with Rett syndrome.[9]

Pagnacco et al. presented the case of a 5-year-old girl with caries of the deciduous dentition, dental wear and abundant sialorrhea[10]; in this case, dental treatment was also carried out under general anesthesia due to the impossibility of providing care on an outpatient basis.

What is clear from our analysis is that the most frequent oral manifestations in Rett syndrome are bruxism, multiple cavities and drooling.

Coleman et al., in a 1988 study, reported evidence of bruxism in 95% of 63 patients with Rett syndrome, as well as atypical swallowing in 65% of cases and hypersalivation in 84%.[11]

Buccino and Weddell, in a case report, emphasized the absence of decay in a 4-year-old child, in whom, however, there were signs of abrasion over all the teeth (particularly of the upper and lower anterior sector teeth) and mobility of grade 2 of teeth 51 and 61 due to bruxism and finger sucking.[12] These authors also reported hypersalivation, drooling and ogival palate. The prevention of oral disease was the only recommendation made – establishing control of bruxism and traumatism, improving oral hygiene with the help of the parents, daily application of topical fluoride gel or rinses, and frequent follow-up visits.

Peak et al. found bilateral hypertrophy of the masseters and bruxism with widespread signs of abrasion in a 5-year-old patient.[13]

Furthermore, Magalhães et al., in 13 patients, found bruxism as the only oral symptom of Rett syndrome, without evidence of carious lesions, but with dental abrasion and muscular dysfunction as a consequence of grinding.[14] In their study, they tried subjecting patients to acupuncture sessions, performed on a weekly basis for an average of 3 years and 4 months in order to reduce grinding habits, but concluded that it was impossible to evaluate the effectiveness of the therapy.

In a case report of a 5-year-old girl, Alpoz et al. showed radiographically an enlargement of the joint space around the temporomandibular joint (TMJ), presumably linked to a considerably retracted position

of the condyles due to the loss of the vertical dimension, resulting from the strong occlusion.[15] They treated her with a soft splint, and even a special design of the splint was developed in order to avoid the anterior mandibular movement.

A study of 17 girls affected by Rett syndrome conducted by Ribeiro et al. showed signs of gingivitis with considerable plaque accumulation as well as thumb sucking habits in all patients, and also bruxism in 82% of cases, non-physiological dental abrasion (more common in the anterior deciduous teeth) in 71%, carious lesions in 59%, ogival palate in 53%, oral breathing in 41%, infant swallowing in 29%, jaw lateralization in 12%, and open bite in more than 80% of cases together with bruxism and finger sucking.[3] A single finding by the authors of migrant glossitis in one of the patients cannot be confidently related to Rett syndrome.

Other case reports and studies also highlighted the abovementioned signs.[1,4,16,17]

The most comprehensive systematic review of the dental literature on the subject was presented by Fuertes-González et al., who listed all the oral findings in 35 patients: xerostomia, stomatitis, glossitis, erythema multiforme, sialorrhea, dysgeusia, gingivitis, parotid gland swelling, periodontal abscesses, sinusitis, dysphagia and tongue paralysis due to drugs, digital-manual sucking/nibbling, bruxism, oral breathing, tongue thrusting, dribbling, mandibular lateralization, gingivitis, caries, high-arched palate, open bite, traumatism, dental wear, sialorrhea, and masseter hypertrophy.[18]

In the analyzed studies, great attention was paid to the need for prevention.[19] Patients with Rett syndrome present with severe psychomotor delay, autistic attitudes and loss of ability to perform controlled voluntary movements. All this results in a difficult management of the patient in terms of providing dental treatment by the dentist and maintaining oral hygiene at home. Therefore, in these patients, prevention procedures are essential. The dentist must implement preventive procedures with frequent follow-ups to monitor bruxism and the onset of possible caries and abrasion. On the other hand, the role of the parents is to ensure fundamental home-based prevention regarding oral hygiene, including frequent application of fluoride gels or systemic fluoride prophylaxis.[6] Even a diet with few cariogenic foods can help to control carious disease.[1]

Deep carious lesions associated with pain may necessitate follow-up sessions of the compromised teeth under general anesthesia or sedation.[4]

To reduce the problems related to bruxism, associated with dental abrasion and muscular dysfunction, Magalhães et al. suggests the use of modified daytime and nocturnal bites.[14] The upper dental elements are covered to reproduce the myocentric occlusion and the posterior margin of the bite extends posteriorly to the hard palate. Many authors recommend using a resin bite exclusively during the day, since the sucking habits (oro-digital habits) and the severe degree of mental delay could make it dangerous to use at night.[12,15] Moreover, these bites cannot be used in patients with deciduous dentition.[13] In such a case, Chattopadhyay and Arora advise parents to organize frequent visits to the dentist to check the progression of grinding and the hypertrophy of the masseters, and assess the possibility of introducing a bite at an appropriate time.[1] Friedlander et al. also consider the possible use of myorelaxants or benzodiazepines to control grinding in the most severe cases.[19]

Furthermore, in their study, Friedlander et al. point at another oral manifestation in Rett syndrome – the possible erosion of the surfaces of the teeth, caused by the exposure to acids, consequent upon gastroesophageal reflux, quite common in patients with Rett syndrome.[19] Among the 12 analyzed studies, only that of Di Bona shows no evidence of diurnal or nocturnal grinding; therefore, it can be concluded that this clinical sign can be found in almost all patients with Rett syndrome.[9]

Ten studies out of 12 investigated the presence or absence of caries, and multiple cavities were found in 37.2% of patients (29 patients out of 78). These results are indicative only. In the case of younger patients, caries may not yet have arisen because of their early age or the patients simply benefited from excellent oral hygiene put into practice by their caretakers. It should also be noted that in some cases there might be no signs of bruxism due to the young age of the patients. What can be gathered from our review is that, due to the difficulty of obtaining adequate compliancy as well as the possible presence of gastroesophageal reflux, these patients are at a higher risk of developing caries than the rest of the healthy pediatric population. Bruxism seems to be a common finding in a high percentage of patients.

Drooling, deep bite and ogival palate are not reported in all the studies; therefore, a reliable statistical analysis of these problems is difficult. It is not possible to provide accurate data on the percentage of caries, since the patients' age is not a homogeneous variable; consequently, a statistical comparison cannot be made. Moreover, in the analyzed studies, the diagnostic approach to the various dental problems is not uniform.

Discussion

There are 2 types of oral manifestations associated with Rett syndrome: those related to drugs taken by patients and those derived from Rett syndrome itself.

Among the latter, which are not pathognomonic for the syndrome but rather accompany it, and their prevalence in Rett syndrome patients is higher as compared to the healthy population, we found mainly bruxism, anterior open bite, ogival palate, sucking habits, and difficulties in maintaining oral hygiene (Table 1).

Table 1. Oral manifestations in Rett syndrome in the analyzed studies

Authors	Number of patients	Age [years], for groups – median (IQR)	Oral manifestations
Di Bona 1985[9]	1	12	traumatism
Alpoz et al. 1999[15]	1	5	bruxism
Chattopadhyay and Arora 2014[1]	1	4.5	digit sucking, phalangeal wounds and wasting, poor control of the tongue, difficulties with swallowing, caries, grinding
Bathla et al. 2010[16]	1	8	grinding, high-arched palate, dental attrition, caries
Magalhães et al. 2002[14]	13	9 (3–16)	bruxism
Buccino and Weddell 1989[12]	1	4.25	high-arched palate, bruxism, digit sucking
Ribeiro et al. 1997[3]	17	7.33 (2.7–12.7)	digital-manual sucking/nibbling, bruxism, oral breathing, tongue thrusting, dribbling, mandibular lateralization, gingivitis, caries, high-arched palate, open bite
Peak et al. 1992[13]	1	5	bruxism, masseter hypertrophy
Pagnacco et al. 1988[10]	1	5	caries of the deciduous dentition, dental wear, abundant sialorrhea
Fuertes-González et al. 2011[18]	35	6.8 (2.7–21.0)	xerostomia, stomatitis, glossitis, erythema multiforme, sialorrhea, dysgeusia, gingivitis, parotid gland swelling, periodontal abscesses, sinusitis, dysphagia and tongue paralysis due to drugs, digital-manual sucking/nibbling, bruxism, oral breathing, tongue thrusting, dribbling, mandibular lateralization, caries, high-arched palate, open bite, traumatism, dental wear, masseter hypertrophy
Janas and Osica 2015[4]	1	18	grinding, bruxism, difficulties with chewing and swallowing, neglect of oral hygiene, oral inflammation with hypertrophic gingiva, pulp gangrene
Coleman et al. 1988[11]	63	data not available	bruxism, atypical swallowing, hypersalivation

IQR – interquartile range.

The events related to the pharmacological therapies to which these patients are subjected (mainly anxiolytic and anticonvulsant) include xerostomia, glossitis, erythema multiforme, gingival hyperplasia, dysphagia, and lingual paralysis.[1,19]

It is important for the dentist to know what problems related to the oral cavity can be encountered in a patient diagnosed with Rett syndrome and what preventive measures can be applied. To date, there has been no specific type of dental treatment that could be used in these patients; however, prevention is essential. Grinding and the presence of multiple cavities are the most frequent dental findings.

Grinding (more frequently diurnal rather than nocturnal) should be monitored over time to evaluate wear of the dental elements and to decide whether to intervene with a bite.[14,19] Caries prevention often needs to be done with the help of parents due to the patients' mental delay. Topical fluoride applications are recommended to reduce the risk of caries, as are frequent checks by the attending dentist.[11,17]

When it is necessary to intervene, the literature describes the use of mouth props to secure a degree of stability and oral opening, in order to facilitate dental exploration and/or treatment. As regards behavioral management, some authors suggested the application of certain techniques used in autism (routines and the avoidance of noise).[13]

Some authors used sedation with nitrous oxide,[15] while others combined it with sublingual midazolam.[17] In turn, some investigators used general anesthesia,[11,12] due to the medical risk and the lack of the patient's cooperation needed for correct dental treatment.[19]

References

1. Chattopadhyay S, Arora R. The ironies of human mind: A case of Rett syndrome. *Ethiop J Health Sci*. 2014;24:171–174.
2. Cianfaglione R, Clarke A, Kerr M, Hastings RP, Oliver C, Felce D. Ageing in Rett syndrome. *J Intellect Disabil Res*. 2016;60:182–190.
3. Ribeiro RA, Romano AR, Birman EG, Mayer MP. Oral manifestations in Rett syndrome: A study of 17 cases. *Pediatr Dent*. 1997;19:349–352.
4. Janas A, Osica P. Dental issues in Rett syndrome. *Dev Period Med*. 2015;19:478–481.
5. Hagberg B, Hanefeld F, Percy A, Skjeldal O. An update on clinically appreciable diagnostic criteria in Rett syndrome. Comments to Rett Syndrome Clinical Criteria Consensus Panel Satellite to European Paediatric Neurology Society Meeting, Baden-Baden, Germany, 11 September 2001. *Eur J Paediatr Neurol*. 2002;6:293–297.
6. Amir RE, Van den Veyver IB, Wan M, Tran CQ, Francke U, Zoghbi HY. Rett syndrome is caused by mutations in X-linked *MECP2*, encoding methyl-CpG-binding protein. *Nat Genet*. 1999;23:185–188.
7. Bienvenu T, Chelly J. Molecular genetics of Rett syndrome: When DNA methylation goes unrecognized. *Nat Rev Genet*. 2006;7:415–426.
8. Matsuishi T, Yamashita Y, Takahashi T, Nagamitsu S. Rett syndrome: The state of clinical and basic research, and future perspectives. *Brain Dev*. 2011;33:627–631.
9. Di Bona MC. Hospital dentistry for a child with Rett's syndrome. *Spec Care Dent*. 1985;5:62–63.

10. Pagnacco A, Ferrara M, Vangelisti R, Randon C. Rett syndrome: A "new" and rare disease. A clinical case [in Italian]. *Dent Cadmos*. 1988;56:93–95.
11. Coleman M, Brubaker J, Hunter K, Smith G. Rett syndrome: A survey of North American patients. *J Ment Defic Res*. 1988;32:117–124.
12. Buccino MA, Weddell JA. Rett syndrome – a rare and often misdiagnosed syndrome: Case report. *Pediatr Dent*. 1989;11:151–157.
13. Peak J, Eveson JW, Scully C. Oral manifestation of Rett's syndrome. *Br Dent J*. 1992;172:248–249.
14. Magalhães MH, Kawamura JY, Araújo LC. General and oral characteristics in Rett syndrome. *Spec Care Dent*. 2002;22:147–150.
15. Alpoz AR, Ergul N, Oncag O. Bruxism in Rett syndrome: A case report. *J Clin Pediatr Dent*. 1999;23:161–163.
16. Bathla M, Chandna S, Bathla JC. Rett's syndrome: Diagnostic and therapeutic dilemma. *Ger J Psych*. 2010;13:157–160.
17. Fuertes-González MC, Silvestre FJ. Oral health in a group of patients with Rett syndrome in the regions of Valencia and Murcia (Spain): A case-control study. *Med Oral Patol Oral Cir Bucal*. 2014;19:e598–e604.
18. Fuertes-González MC, Silvestre FJ, Almerich-Silla JM. Oral findings in Rett syndrome: A systematic review of the dental literature. *Med Oral Patol Oral Cir Bucal*. 2011;16:e37–e41.
19. Friedlander AH, Yagiela JA, Paterno VI, Mahler ME. The pathophysiology, medical management and dental implications of fragile X, Rett, and Prader–Willi syndromes. *J Calif Dent Assoc*. 2003;31:693–702.

Tetrad presentation of non-syndromic odontogenic keratocyst: An uphill diagnostic and therapeutic challenge

Opis przypadku grupy czterech bezobjawowych zębopochodnych torbieli rogowaciejących – złożoność diagnostyczna i lecznicza

Varshini Marimuthu[A–D], Urvashi Ashwin Shetty[A–E], Pushparaja Shetty[A,E,F]

Department of Oral Pathology and Microbiology, the A.B. Shetty Memorial Institute of Dental Sciences, NITTE (Deemed to be University), Deralakatte, India

A – research concept and design; B – collection and/or assembly of data; C – data analysis and interpretation;
D – writing the article; E – critical revision of the article; F – final approval of the article

Dental and Medical Problems, ISSN 1644-387X (print), ISSN 2300-9020 (online) *Dent Med Probl.* 2018;55(4):447–451

Address for correspondence
Urvashi A. Shetty
E-mail: urvashishetty10@gmail.com

Funding sources
None declared

Conflict of interest
None declared

Acknowledgements
We thank Dr. Padmaraj Hegde for supporting us in writing this article.

Received on June 27, 2018
Reviewed on July 25, 2018
Accepted on September 25, 2018

Published online on December 27, 2018

Cite as
Marimuthu V, Shetty UA, Shetty P. Tetrad presentation of non-syndromic odontogenic keratocyst: An uphill diagnostic and therapeutic challenge. *Dent Med Probl.* 2018;55(4):447–451. doi:10.17219/dmp/96272

DOI
10.17219/dmp/96272

Abstract

Odontogenic keratocyst (OKC), in the last decade sceptically referred to as keratocystic odontogenic tumor (KCOT), is known for its subclinical extensive growth potential and significant rate of recurrences. Odontogenic keratocyst, being the third most common cystic lesion (10–20%) of the maxillofacial region, is often recognized as a sporadic lesion and is well-documented in the literature. Multiple presentation of these cysts over a lifetime is relatively uncommon and is usually seen in conjunction with nevoid basal cell carcinoma syndrome (NBCC), orofacial digital syndrome, Noonan syndrome, Ehlers–Danlos syndrome, Simpson–Golabi–Behmel syndrome, or other syndromes. The 'two-hit' hypothesis postulated by Knudson best explains this anomaly, wherein multiple OKCs associated with the syndromes arise as a consequence of the allelic loss in the patched (*PTCH*) gene, mapped to the long arm of chromosome 9q22.3-q31. A partial expression of the gene may result in multiple OKCs (5%) without any related syndromes. Though concurrent occurrence of non-syndromic multiple OKCs is a rare phenomenon, a handful of cases have been documented over the past few years. Adding to this, we report a case of multiple OKCs occurring synchronously and bilaterally in all 4 quadrants in non-syndromic, otherwise healthy persons, which could indicate a shift in trend.

Key words: multiple, odontogenic cysts, keratocyst, non-syndromic

Słowa kluczowe: mnogie, zębopochodne torbiele rogowaciejące, rogowaciejący guz nowotworowy, bezobjawowy

Introduction

Odontogenic keratocyst (OKC) is a distinctive form of developmental odontogenic cyst that deserves special consideration owing to its specific histopathological features and clinical behavior. Odontogenic keratocysts arise from the dental lamina, its remnants or odontogenic basal cell hamartia.[1] Multiple OKCs usually occur at younger age as a component of nevoid basal cell carcinoma syndrome (NBCCS) or Gorlin–Goltz syndrome, orofacial digital syndrome, Noonan syndrome, Ehler–Danlos syndrome, Simpson–Golabi–Behmel syndrome, or other syndromes. The patched (*PTCH*) gene, a tumor suppressor gene located on chromosome 9q22.3-q31, is involved in both sporadic OKCs and OKCs associated with NBCCS.[2] A partial expression of the *PTCH* gene may result in the occurrence of only multiple recurring OKCs, without any associated systemic findings.[3] The term 'multiple' refers to the lifetime history of the patient and not to many cysts present at any one time. Any patient with more than 1 OKC other than a recurrence is generally said to show some other features of the syndrome, albeit only minor anomalies, which may be revealed only during full examination.[4] Contrary to the above statement, we report a case of multiple OKC occurring at one time in all 4 quadrants, without any syndromic features found during systemic examination.

Case report

A 28-year-old female patient was referred from a private clinic to our institution (Department of Oral Pathology and Microbiology, the A.B. Shetty Memorial Institute of Dental Sciences, NITTE (Deemed to be University), Deralakatte, India) to evaluate an incidental finding of cyst in the orthopantomogram (OPG). Three months before the patient reported to our institution, the extraction of the bilateral lower third molars, followed by the drainage of the abscess was carried out, and medical termination of pregnancy was advised due to the spread of infection from the periapical abscess and adverse effects of antibiotics. During extraoral examination, diffuse bilateral swelling of the face was noticed (Fig. 1). Hypertelorism was evident. During intraoral examination, there was no cortical expansion noticed. The orthopantomogram revealed ill-defined radiolucency present bilaterally in the posterior region of the maxilla and the mandible, impacted teeth 18 and 28, and loss of cortication in the anterior ramus of the mandible (Fig. 2).

The presence of syndrome in this patient was ruled out after detailed clinical examination, blood tests, and chest and skull radiograph procedure. In order to enucleate the cyst, the patient was subjected to surgery, supplemented with an intraoral application of Carnoy's solution. There was performed extensive curettage bilaterally, along with the extraction of the embedded teeth on either side. Primary closure was done. The patient had an uneventful post-operative course and was discharged the next day. All the excised cystic lining from the 4 quadrants was sent for histopathological evaluation.

Fig. 1. Clinical picture showing diffuse swelling of the face

The histopathological report revealed that the cystic lining of all 4 lesions was parakeratinized stratified squamous epithelium of uniform 6–8-cell thickness (Fig. 3). The lining epithelium consisted of well-defined columnar basal cells in a palisaded arrangement with polarized nuclei and surface corrugation. The underlying connective tissue capsule showed loose bundles of collagen fibers, inflammatory cells – predominantly lymphocytes, and numerous blood vessels, lined by endothelial cells. Satellite cysts (Fig. 4,5) and epithelial remnants were observed in the connective tissue capsule. In a few areas of the satellite cysts, budding of the basal layer into the connective tissue

Fig. 2. Orthopantomogram (OPG) showing multilocular radiolucency in all 4 quadrants

wall was also noticed. Thus, the final diagnosis was OKC. The patient had been followed up for the subsequent 6months at the time of this report.

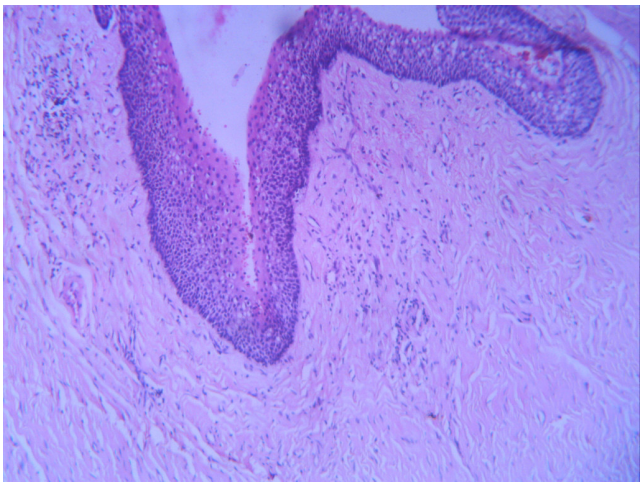

Fig. 3. Section stained with hematoxylin and eosin (H&E) showing cystic lining with palisaded basal cells and surface parakeratinization (×100)

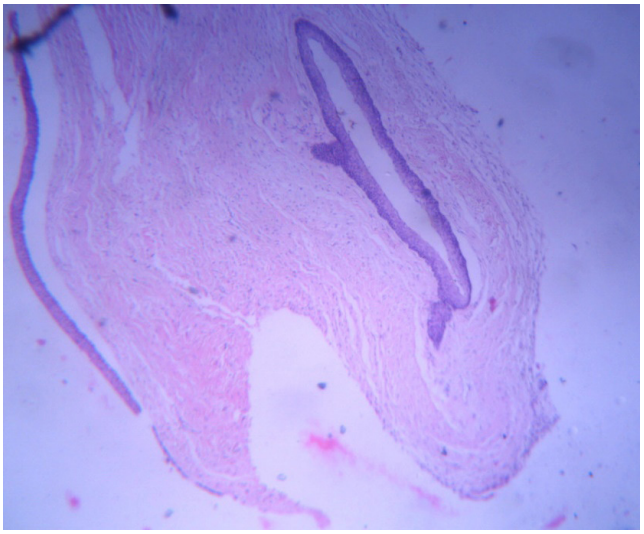

Fig. 4. Section stained with H&E showing a satellite cyst along with budding of the basal layer into the connective tissue wall (×40)

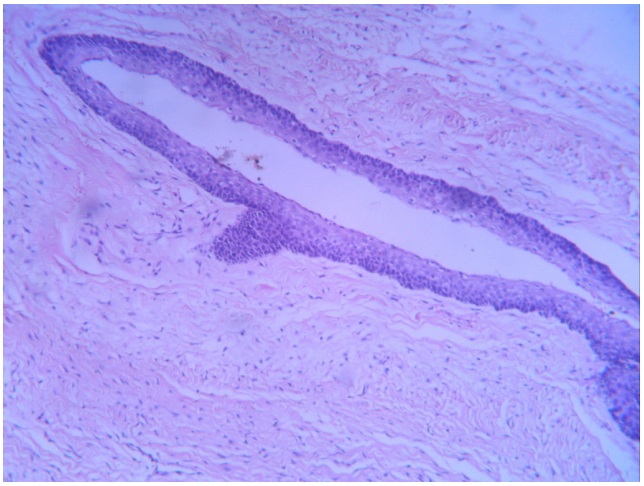

Fig. 5. Section stained with H&E showing a satellite cyst along with budding of the basal layer into the connective tissue wall (×100)

Discussion

Odontogenic keratocyst, in the last decade sceptically referred to as keratocystic odontogenic tumor (KCOT), is deemed an odontogenic cyst of developmental origin.[5] Odontogenic keratocyst was first identified and described in 1876, and further characterized by Phillipsen in 1956.[acc.6] The emphasis on keratinization was considered deceptive, masking other histological characteristics that were actually responsible for the biological behavior of the cysts.[7] In 1963, Hansen pointed out that the designation 'keratocyst' was used invariably to describe any keratin-forming jaw cyst and highlighted the need for specific histological criteria.[acc.4] Studies by Browne (1971) and Forssell and Sainio (1979) showed that the characteristic epithelial lining of OKC was unique, different from the metastatic keratinizations in other jaw cysts, affirming its recognition as a discrete entity.[acc.4]

Odontogenic keratocysts occur over a wide age range from the 1st to the 9th decade, commonly involving the mandible. Sporadic and non-syndromic OKCs are reported to have bimodal age incidence with the 1st peak in the 2nd–3rd decade (15–45 years), and the 2nd peak in the 5th decade or later (55–65 years), with the maxilla commonly involved.[4] In females, the 2nd peak of incidence is often 1 decade earlier as compared to males, but this can vary among races. However, OKCs associated with syndrome show only 1 peak of incidence at the age of 10–30 years.[4] Ours is a case of non-syndromic OKC in a patient of 28 years, probably exhibiting the 1st peak of incidence, thereby mandating long-term follow-up and patient education on the possibility of the 2nd peak of incidence.

A slightly higher prevalence of OKC is reported in males than in females, with a ratio of 1.42. But the male to female ratio in the case of multiple OKCs associated with syndrome is 1:1, indicating its relatively higher incidence in females as compared to sporadic OKCs.[8] This is in contrast to this case report of a female presenting with multiple OKCs without any features in line with syndrome, portraying the rarity of this case and imposing a diagnostic challenge. Odontogenic keratocysts showed a higher incidence rate in Caucasian males than in black males in 2005.[acc.4] This was expected to be reversed in the course of time, taking into consideration the selection bias in the previous studies,[4] but a systematic review by MacDonald-Jankowski from 2010 still showed a relatively lower incidence in South African blacks; they were more prone to ameloblastoma than to OKC.[9]

Multiple OKCs mean the occurrence of these cysts over a lifetime, and only 5% of such cases have been reported in non-syndromic individuals. Hardly a handful of cases showing synchronous presentation of multiple OKCs at one time have been reported in the literature (Table 1).[10–13] Ours may be the next case following.

Table 1. Literature review of multiple non-syndromic odontogenic keratocysts (OKCs) in all 4 quadrants

Study	Age [years]	Gender	Satellite cysts and/or odontogenic remnants
Bartake et al. 2011[10]	20	F	satellite cysts
Kargahi and Kalantari 2013[11]	11	M	–
Kurdekar et al. 2013[3]	23	M	satellite cysts and odontogenic remnants
Maheshwari et al. 2015[12]	20	M	–
Reddy et al. 2016[13]	14	F	satellite cysts

F – female; M – male.

Radiographically, OKCs may occur as unilocular or multilocular radiolucency. Sometimes the unilocular radiolucency appears to have a scalloped border, suggesting unequal growth activity, and is often misinterpreted as multilocular radiolucency. Voorsmit described such types as 'multilobular'.[acc.4] Varied presentations of OKCs in the radiograph are interpreted based on their anatomical locations as follicular keratocyst (envelopmental/replacemental type), extraneous and collateral types. In our case, the cysts in the mandible appeared as multilocular radiolucency and the cysts in the maxilla were of follicular keratocysts associated with impacted teeth 18 and 28.

Nevoid basal cell carcinoma syndrome is associated with a mutation in the *PTCH* gene at 9q22.3-q31. The patched (*PTCH*) gene is a tumor suppressor gene which encodes a transmembrane receptor for the sonic hedgehog pathway in humans, controlling cell patterning and growth of various organs, including tooth development.[14] Knudson's 'two-hit' or 'multiple-hit' hypothesis best explains this mutation, wherein basal cell carcinomas and keratocysts associated with NBCCS emerge as the result of the first hit of the allelic loss of *PTCH* within the precursor cell. Sporadic OKC is an outturn of 2 somatic hits in which the mutations of *PTCH* within locally susceptible cells ultimately result in the allelic loss.[2] The absence of all the manifestations of NBCCS, which may be due to the variability of the *PTCH* gene expression, highlights the need to periodically monitor patients with multiple OKCs.

Biological behavior of OKCs associated with NBCCS is more aggressive and these cysts have higher recurrence rates (63%) compared with solitary keratocysts (37%).[15] Recurrent OKC may develop in 3 different ways: by incomplete removal of the original cyst lining; by retention of daughter cysts, from microcysts or epithelial islands in the wall of the original cyst; or as new OKCs from epithelial offshoots of the basal layer of the oral epithelium. The latter case supports the hypothesis of Shear and Altini (1976), which addresses the possibility of initiating the process of cyst formation by the overlying epithelium under the influence of residual ectomesenchymal inductive activity.[acc.4] The presence of a higher number of satellite cysts, odontogenic epithelial remnants and a higher number of mitotic figures in the epithelium lining of the parent cyst cavity of OKCs associated with NBCCS indicates an inherent genetic potential for proliferation of odontogenic epithelium in syndromic patients.[4] In our case, OKCs presented a bizarre picture of satellite cysts and odontogenic epithelial remnants in almost all of the multiple cysts, making the diagnosis difficult and necessitating periodic follow-ups to elicit recurrences and also delayed presentation of syndromic features, if any.

Treatment of OKC is generally classified as either aggressive or conservative. The goal is to choose the right modality, carrying the lowest risk of recurrence and least morbidity, and, at the same time, restoring the morphology and function of the affected area. Therapeutic interventions of OKC include marsupialization and enucleation, combined with adjuvant cryotherapy with Carnoy's solution, and marginal or radical resection.[16] Voorsmit et al. advocated excision of the overlying mucosa and popularized the use of Carnoy's solution as a chemical fixative.[acc.17] Carnoy's solution contains ferric chloride (dehydrating agent), absolute alcohol (fixative hardening the tissue by shrinkage), chloroform (increasing the speed of fixation), and glacial acetic acid (making the tissue swell and preventing over-hardening), which cauterize and fix the tissues to a predictable time-dependent depth. At the same time, the neurovascular bundle is protected by a coat of vaseline. Its average depth of penetration is 1.54 mm after 5 min of application.[18]

With tetrad OKC presentation being reported only in the present decade, documentation of such cases throws a light on the changing trend in OKC presentation. Thus, it is important to report such cases, taking into account their oddity and perplexing clinical presentation, which pose a diagnostic and therapeutic challenge. Thorough clinical evaluation assisted with appropriate investigations ruled out the presence of syndrome in our case. However, genomic studies were not carried out to determine the presence of syndrome, if any.

Conclusions

The possibility of multiple OKCs should be considered in any patient with OKC. Therefore, careful histopathological and radiological examination of any other existing lesion should be done. Any patient reporting with multiple OKCs should be evaluated thoroughly for the possibility of NBCCS, as OKC may be the first and only manifestation of this syndrome. Furthermore, due to the fact that OKC associated with this syndrome has a higher rate of recurrence than the isolated cases, a very strict follow-up has to be conducted, along with serial screening for the development of malignancies and other complications beside OKCs, for a long period of time. Most important

of all, care should be taken for complete excision and thorough enucleation. The increase in the reported cases of non-syndromic multiple OKCs from 2011 to 2018, in conjunction with the present case report, reflect a change in trend, where multiple OKCs may not necessarily be associated with NBCCS.

References

1. Makarla S, Bavle RM, Muniswamappa S, Narasimhamurthy S. A large extragnathic keratocystic odontogenic tumour. *Case Rep Pathol*. 2015;2015:723010.
2. Sansare K. Response to the critique of „Keratocystic odontogenic tumor: Systematic review with analysis of 72 additional cases from Mumbai, India". *Oral Surg Oral Med Oral Pathol Oral Radiol*. 2013;115:841–842.
3. Kurdekar RS, Prakash J, Rana AS, Kalra P. Non-syndromic odontogenic keratocysts: A rare case report. *Natl J Maxillofac Surg*. 2013;4:90–93.
4. Shear M, Speight PM. Odontogenic keratocyst. In: Shear M, Speight PM. *Cysts of the Oral and Maxillofacial Regions*. Oxford, UK: Blackwell Munksgaard; 2007:6–26.
5. El-Naggar AK, Chan JKC, Grandis JR, Takata T, Slootweg PJ. Odontogenic and maxillofacial bone tumours. In: El-Naggar AK, Chan JKC, Grandis JR, Takata T, Slootweg PJ, eds. *WHO Classification of Tumours of Head and Neck*. 4th ed. Lyon, France: IARC Press; 2017:204–236.
6. Nayak MT, Singh A, Singhvi A, Sharma R. Odontogenic keratocyst: What is in the name? *J Nat Sci Biol Med*. 2013;4:282–285.
7. Lucas RB. *Pathology of Tumours of the Oral Tissues*. 2nd ed. Edinburgh and London, UK: Churchill Livingstone; 1972:361–362.
8. Mehta D, Raval N, Patadiya H, Tarsariya V. Gorlin–Goltz syndrome. *Ann Med Health Sci Res*. 2014;4:279–282.
9. MacDonald-Jankowski DS. Orthokeratinized odontogenic cyst: A systematic review. *Dentomaxillofac Radiol*. 2010;39:455–467.
10. Bartake A, Shreekanth N, Prabhu S, Gopalkrishnan K. Non-syndromic recurrent multiple odontogenic keratocysts: A case report. *J Dent (Tehran)*. 2011;8:96–100.
11. Kargahi N, Kalantari M. Non-syndromic multiple odontogenic keratocyst: A case report. *J Dent Shiraz Univ Med Sci*. 2013;14:151–154.
12. Maheshwari V, Patel N, Jadhav R, Engineer P. Non syndromic odontogenic keratocyst: A case report. *J Dent Med Sci*. 2015;14:64–67.
13. Reddy GV, Reddy MH, Garlapati K, et al. Non-syndromic multiple keratocystic odontogenic tumors: An arduous challenge for oral and maxillofacial specialists. *Int J Case Rep Images*. 2016;7:360–364.
14. Gomes CC, Diniz MG, Gomez RS. Review of the molecular pathogenesis of the odontogenic keratocyst. *Oral Oncol*. 2009;45:1011–1014.
15. Tarakji B, Baroudi K, Hanouneh S, Azzeghaiby SN, Nassani MZ. Possible recurrence of keratocyst in nevoid basal cell carcinoma syndrome: A review of literature. *Eur J Dent*. 2013;7:126–134.
16. Stoelinga PJW. The management of aggressive cysts of the jaws. *J Maxillofac Oral Surg*. 2012;11:2–12.
17. Abdullah WA. Surgical treatment of keratocystic odontogenic tumour: A review article. *Saudi Dent J*. 2011;23:61–65.
18. Tandon P, Saluja H, Shah S, Dadhich A, Sachdeva S. Efficacy of Carnoy's solution as an adjunct to conventional treatment modalities in aggressive bony tumors. *Pravara Med Rev*. 2017;9:26–28.

Impact Factor Listing for Journals on Dentistry (2017)

First part: Journals on General Dentistry (39 titles with IF: 0.619–5.38)

Journal title	Abbreviation	Country of the publisher	Frequency in a year	IF (change vs 2016)
Journal of Dental Research	J Dent Res	USA	12	5.38 (+0.63)
International Journal of Oral Science	Int J Oral Sci	India	4	4.138 (+0.2)
Dental Materials	Dent Mater	UK	6	4.039 (+0.03)
Journal of Dentistry	J Dent	UK	6	3.77 (+0.32)
Molecular Oral Microbiology	Mol Oral Microbiol	Denmark	6	2.853 (–0.05)
Journal of the American Dental Association	J Am Dent Assoc	UK	12	2.486 (+0.33)
Journal of Evidence-Based Dental Practice	J Evid Based Dent Pract	USA	4	2.4 (–0.07)
Clinical Oral Investigations	Clin Oral Investig	Germany	4	2.386 (+0.08)
Archives of Oral Biology	Arch Oral Biol	UK	12	2.05 (+0.3)
Community Dentistry and Oral Epidemiology	Community Dent Oral Epidemiol	Denmark	6	1.992 (–0.3)
International Journal of Computerized Dentistry	Int J Comput Dent	UK	4	1.725 (+0,29)
Oral Surgery, Oral Medicine, Oral Pathology and Oral Radiology	Oral Surg Oral Med Oral Pathol Oral Radiol	USA	12	1.718 (+0.3)
Journal of Applied Oral Science	J Appl Oral Sci	Brazil	4	1.709 (+0.36)
European Journal of Oral Sciences	Eur J Oral Sci	UK	6	1.655 (+0.11)
Head & Face Medicine	Head Face Med	UK	open access	1.606 (+0.23)
BMC Oral Health	BMC Oral Health	UK	open access	1.602 (+0.12)
Journal of Oral & Facial Pain and Headache	J Oral Facial Pain Headache	USA	4	1.538 (–1.24)
Journal of Esthetic and Restorative Dentistry	J Esthet Restor Dent	UK	6	1.531 (+0.26)
Acta Odontologica Scandinavica	Acta Odontol Scand	UK	6	1.522 (+0.29)
Australian Dental Journal	Aust Dent J	Australia	4	1.494 (–0.15)
Odontology	Odontology	Japan	1–2	1.458 (–0.46)
Gerodontology	Gerodontology	UK	2	1.439 (–0.26)
Journal of Public Health Dentistry	J Public Health Dent	USA	4	1.436 (+ 0.06)
Dental Traumatology	Dent Traumatol	Denmark	6	1.414 (+0.01)
International Dental Journal	Int Dent J	UK	6	1.389 (+0.02)
International Journal of Dental Hygiene	Int J Dent Hyg	UK	4	1.38 (+0.02)
British Dental Journal	Br Dent J	UK	24	1.274 (+0.27)
International Journal of Periodontics & Restorative Dentistry	Int J Periodontics Restorative Dent	USA	6	1.249 (+0.14)
Brazilian Oral Research	Braz Oral Res	Brazil	4	1.223 (–0.09)
Dental Materials Journal	Dent Mater J	Japan	6	1.205 (+0.13)
Journal of Craniomandibular Practice & Sleep Practice	Cranio	UK	4	1.094 (+0.22)
Quintessence International	Quintessence Int	Germany	10	1.088 (+0.08)
Journal of the Canadian Dental Association	J Can Dent Assoc	Canada	6	0.978 (+0.46)
Oral Health & Preventive Dentistry	Oral Health Prev Dent	UK	6	0.96 (+0.3)
Community Dental Health	Community Dent Health	UK	4	0.956 (+0.14)
Journal of Oral Science	J Oral Sci	Japan	4	0.853 (–0.02)
Swedish Dental Journal	Swed Dent J	Sweden	6	0.818 (+0.23)
American Journal of Dentistry	Am J Dent	USA	6	0.76
Journal of Dental Sciences	J Dent Sci	China	4	0.619 (+0.12)

Second part: Journals on Specialist Dentistry (52 titles with IF: 0.138–6.22)

Journal title	Abbreviation	Country of the publisher	Frequency in a year	IF (change vs 2016)
Oral Surgery and Maxillofacial Surgery (7 titles)				
Oral Oncology	Oral Oncol	UK	12	4.636 (–0.16)
International Journal of Oral and Maxillofacial Surgery	Int J Oral Maxillofac Surg	Denmark	12	2.164 (+0.25)
Journal of Cranio-Maxillo-Facial Surgery	J Craniomaxillofac Surg	UK	8	1.96 (+0.38)
Journal of Oral and Maxillofacial Surgery	J Oral Maxillofac Surg	USA	12	1.779 (–0.13)
Oral and Maxillofacial Surgery Clinics of North America	Oral Maxillofac Surg Clin North Am	USA	4	1.367 (–0.11)
Cleft Palate-Craniofacial Journal	Cleft Palate Craniofac J	USA	10	1.262 (+0.13)
British Journal of Oral & Maxillofacial Surgery	Brit J Oral Maxillofac Surg	UK	6	1.26 (+0.05)
Revue de Stomatologie et de Chirurgie Maxillo-faciale	Rev Stomatol Chir Maxillofac	France	6	0.441 (+0.19)
Dental Radiology (2 titles)				
Dento Maxillo Facial Radiology	Dentomaxillofac Radiol	UK	8	1.848 (+0.27)
Oral Radiology	Oral Radiol	Japan	2	0.466 (–0.09)
Periodontology and Oral Pathology (8 titles)				
Periodontology 2000	Periodontol 2000	Denmark	3	6.22 (+2.15)
Journal of Clinical Periodontology	J Clin Periodontol	USA	12	4.046 (+0.57)
Journal of Periodontology	J Periodontol	USA	12	3.392 (+0.36)
Journal of Periodontal Research	J Periodontal Res	USA	6	2.878 (+0.21)
Oral Diseases	Oral Dis	Denmark	8	2.31 (+0.2)
Journal of Oral Pathology & Medicine	J Oral Pathol Med	Denmark	10	2.237 (+0.19)
Medicina Oral Patologia Oral y Cirugia Bucal	Med Oral Patol Oral Cir Bucal	Spain	open access	1.671 (+0.52)
Journal of Periodontal & Implant Science	J Periodontal Implant Sci	Korea	6	1.072 (–0.15)
Implant Dentistry (7 titles)				
Clinical Oral Implants Research	Clin Oral Implants Res	Denmark	12	4.305 (+0.68)
Clinical Implant Dentistry and Related Research	Clin Implant Dent Relat Res	USA	4	3.097 (+0.16)
European Journal of Oral Implantology	Eur J Oral Implantol	UK	4	2.809 (–0.76)
The International Journal of Oral & Maxillofacial Implants	Int J Oral Maxillofac Implants	USA	6	1.699 (–0.56)
Implant Dentistry	Implant Dent	USA	6	1.307 (+0.2)
Journal of Oral Implantology	J Oral Implantol	USA	6	1.212 (+0.03)
Implantologie	Implantologie	Germany	4	0.138 (+0.1)
Cariology and Endodontics (6 titles)				
International Endodontic Journal	Int Endod J	UK	12	3.015
Journal of Endodontics	J Endod	USA	12	2.886 (+0.08)
Caries Research	Caries Res	Switzerland	6	2.188 (+0.37)
Operative Dentistry	Oper Dent	USA	6	2.13 (–0.75)
Journal of Adhesive Dentistry	J Adhes Dent	UK	4	1.691 (–0.31)
Australian Endodontic Journal	Aust Endod J	Australia	4	1.371 (+0.54)
Orthodontics (9 titles)				
Orthodontics & Craniofacial Research	Orthod Craniofac Res	UK	4	2.077 (+0.96)
European Journal of Orthodontics	Eur J Orthod	UK	6	2.033 (+0.31)
American Journal of Orthodontics and Dentofacial Orthopedics	Am J Orthod Dentofacial Orthop	USA	12	1.842 (+0.37)
Korean Journal of Orthodontics	Korean J Orthod	Korea	6	1.617 (+0.43)
Angle Orthodontist	Angle Orthod	USA	6	1.592 (+0.23)
Progress in Orthodontics*	Prog Orthod	Germany	open access	1.25
Journal of Orofacial Orthopedics	J Orofac Orthop	Germany	open access	0.907 (+0.15)
Seminars in Orthodontics	Semin Orthod	USA	open access	0.5 (+0.1)
Australian Orthodontic Journal	Aust Orthod J	Australia	3	0.396 (–0.03)

Pediatric Dentistry (4 titles)				
Pediatric Dentistry	Pediatr Dent	USA	7	1.774 (–0.17)
International Journal of Paediatric Dentistry	Int J Paediatr Dent	UK	6	1.383 (–0.15)
European Journal of Paediatric Dentistry	Eur J Paediatr Dent	Italy	4	0.893 (+0.21)
Journal of Clinical Pediatric Dentistry	J Clin Pediatr Dent	USA	4	0.854 (+0.08)
Prosthetic Dentistry (6 titles)				
Journal of Prosthodontic Research	J Prosthodont Res	Netherlands	4	3.306 (+0.74)
Journal of Prosthetic Dentistry	J Prosthet Dent	USA	12	2.347 (+0.25)
Journal of Oral Rehabilitation	J Oral Rehabil	UK	12	2.051 (–0.04)
Journal of Prosthodontics	J Prosthodont	USA	6	1.745 (+0.29)
International Journal of Prosthodontics	Int J Prosthodont	USA	6	1.333 (–0.05)
Journal of Advanced Prosthodontics	J Adv Prosthodont	Korea	4	1.144 (+0.12)
Dental Education (2 titles)				
European Journal of Dental Education	Eur J Dent Educ	UK	4	1.343 (+0.29)
Journal of Dental Education	J Dent Educ	USA	12	1.085 (+0.16)

*Journal has entered the list in 2017.

Annual Contents

No. 1 (January–March)

No. 2 (April–June)

Original papers

Reviews

Clinical cases

No. 3 (July–September)

Original papers

Reviews

Clinical cases

No. 4 (October–December)

Original papers

Reviews

Clinical cases

Roczny spis treści

Nr 1 (styczeń–marzec)

Prace oryginalne

Prace poglądowe

Prace kazuistyczne

Nr 2 (kwiecień–czerwiec)

Prace oryginalne

Prace poglądowe

Prace kazuistyczne

Nr 3 (lipiec–wrzesień)

Prace oryginalne

Prace poglądowe

Prace kazuistyczne

Nr 4 (październik–grudzień)

Prace oryginalne

Prace poglądowe

Prace kazuistyczne

Index of Authors

Dental

and Medical Problems