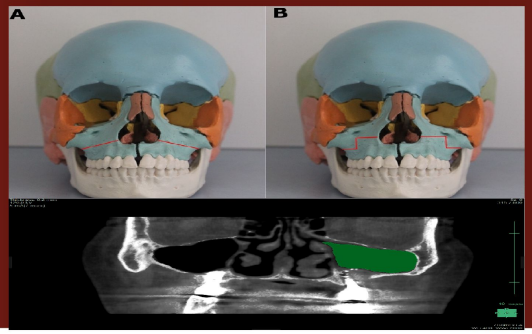
CUMHURIYET DENTAL JOURNAL

The Official Journal of Sivas Cumhuriyet University Faculty of Dentistry



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Cumhuriyet Dental Journal

The Official Journal of the Sivas Cumhuriyet University Faculty of Dentistry. The first issue was published in 1998 and journal's name was changed as Cumhuriyet Dental Journal in 2010. Issues are published quarterly since 2018.

Aims and Scope

Cumhuriyet Dental Journal (CDJ) is an international journal dedicated to the latest advancement of dentistry. The aim of this journal is to provide a platform for scientists and academicians all over the world to promote, share, and discuss various new issues and developments in different areas of dentistry.

CDJ publishes original research papers, reviews, and case reports within clinical dentistry, on all basic science aspects of structure, chemistry, developmental biology, physiology and pathology of relevant tissues, as well as on microbiology, biomaterials and the behavioral sciences as they relate to dentistry.

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INDEXING

CUMHURIYET DENAL JOURNAL

AUTHOR GUIDELINE

Cumhuriyet Dental Journal (CDJ) is the Official Publication of the Cumhuriyet University, Faculty of Dentistry. CDJ accepts original experimental investigations and review articles concerning topics of clinical relevance to the general dental practitioner. Case reports and technique articles will be very critically reviewed in terms of interest to the general dental practitioner and the supporting data provided.

CDJ accepts articles in English. Submitting a paper to CDJ is free of charges. In addition, CDJ has not have article processing charges.

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Review Articles: Although a Review article (particularly following a systematic review) may adhere to the format of the Original Research Article, both Review and Focus Articles need not contain Materials and Methods, Results or Discussion sections, and may instead employ other headings as relevant for the topic addressed.

Case Report: Title, Abstract, Introduction, Case Report, Discussion, Conclusions, Acknowledgements, References, Tables and Figure Legends

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ELEMENTS OF a MANUSCRIPT

1. Title Page

- ***Title page must be*** **uploaded apart from manuscript and should include;**
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3. Keywords

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- This must be presented in a structured format, covering the following subjects, although not under subheadings: succinct statements of the issue in question; the essence of existing knowledge and understanding pertinent to the issue; and the aims and objectives of the research being reported.

5. Materials and methods

- The authors should describe the procedures and analytical techniques and identify names and sources of all commercial products e.g. magnetic attachment (Hyper Slim 5513, Hitachi Metals, Tokyo, Japan)

6. Results

- The authors should refer to appropriate tables and figures and report statistical findings.

7. Discussion

- The authors should discuss the results of the study also state the agreement with other studies and identify the limitations of the present study and suggest areas for future research.

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- The authors should concisely list conclusions that may be drawn from the research and do not simply restate the results.

9.Acknowledgements

- If the work was supported by a grant or any other kind of funding, supply the name of the supporting organization and the grant number.

11. Conflicts of Interest statement

- Specify any potential conflict of interests, or state no conflicts of interest.

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- References must be identified in the body of the article with superscript Arabic numerals after punctuation marks.
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- Figures should be planned to fit the proportions of the printed page (width 17 cm) or one column (width 8 cm) and be legible at this size.
- Figures grouped together should have similar dimensions and be labelled "A, B, C", etc.
- Colour and black-and-white photographs should be created and saved at a minimum of 300 dots per inch (dpi).
- Please name each electronic image file. For example, a Figure 1 in jpeg format should be named fig 1. Multipart figures must be clearly identifiable by the file names: fig 1A, fig 1B, fig 1C, etc.

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To achieve open access to scholarly journal literature, we recommend two complementary strategies.

I. Self-Archiving: First, scholars need the tools and assistance to deposit their refereed journal articles in open electronic archives, a practice commonly called, self-archiving. When these archives conform to standards created by the Open Archives Initiative, then search engines and other tools can treat the separate archives as one. Users then need not know which archives exist or where they are located in order to find and make use of their contents.

II. Open-access Journals: Second, scholars need the means to launch a new generation of journals committed to open access, and to help existing journals that elect to make the transition to open access. Because journal articles should be disseminated as widely as possible, these new journals will no longer invoke copyright to restrict access to and use of the material they publish. Instead they will use copyright and other tools to ensure permanent open access to all the articles they publish. Because price is a barrier to access, these new journals will not charge subscription or access fees, and will turn to other methods for covering their expenses. There are many alternative sources of funds for this purpose, including the foundations and governments that fund research, the universities and laboratories that employ researchers, endowments set up by discipline or institution, friends of the cause of open access, profits from the sale of add-ons to the basic texts, funds freed up by the demise or cancellation of journals charging traditional subscription or access fees, or even contributions from the researchers themselves. There is no need to favor one of these solutions over the others for all disciplines or nations, and no need to stop looking for other.

Open access to peer-reviewed journal literature is the goal. Self-archiving (I.) and a new generation of open-access journals (II.) are the ways to attain this goal. They are not only direct and effective means to this end, they are within the reach of scholars themselves, immediately, and need not wait on changes brought about by markets or legislation. While we endorse the two strategies just outlined, we also encourage experimentation with further ways to make the transition from the present methods of dissemination to open access. Flexibility, experimentation, and adaptation to local circumstances are the best ways to assure that progress in diverse settings will be rapid, secure, and long-lived.

The Open Society Institute, the foundation network founded by philanthropist George Soros, is committed to providing initial help and funding to realize this goal. It will use its resources and influence to extend and promote institutional self-archiving, to launch new open-access journals, and to help an open-access journal system become economically self-sustaining. While the Open Society Institute's commitment and resources are substantial, this initiative is very much in need of other organizations to lend their effort and resources.

We invite governments, universities, libraries, journal editors, publishers, foundations, learned societies, professional associations, and individual scholars who share our vision to join us in the task of removing the barriers to open access and building a future in which research and education in every part of the world are that much morefree to flourish. Submitting a paper to CDJ is free of charges. In addition, CDJ has not have article processing charges.

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The approval of the ethic committee, statement on the adherence to international guidelines mentioned above and that the patients'informed consent is obtained should be indicated in the "Materials and Methods" section and is required for case reports whenever data/media used could reveal identity of the patient. The declaration of the conflict of interest between authors, institutions, acknowledgement of any financial or material support, aid is mandatory for authors submitting manuscript and the statement should appear at the end of manuscript. Reviewers are required to report if any potential conflict of interest exists between reviewer and authors, institutions.

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CONTENTS

ORIGINAL RESEARCH

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Original research

SOFT TISSUE RESPONSE AFTER MAXILLARY STEP SURGERY WITH OR WITHOUT ANS REDUCTION

Neslihan İzgi[1]
*Sibel Akbulut[1]
Nihat Akbulut[2]

ABSTRACT

Objectives: Prediction of the soft tissue profile is an important part of orthognathic surgery planning. Variations in surgical techniques can affect soft tissue response. The current study aimed to determine the effects of maxillary step osteotomy with or without anterior nasal spine (ANS) reduction on the soft tissue response.

Materials and Methods: A total of 24 patients (17 women, 7 men) who underwent maxillary advancement and mandibular set back surgery using maxillary step and bilateral sagittal split ramus osteotomy techniques were included in the study. Then two subgroups were created as ANS reduction positive group (ANSR+) and negative group (ANSR-). Cinch suture and V-Y closure techniques were used in all patients. The lateral cephalometric radiographs which had taken preoperatively and 6-8 months after surgery were recruited. Soft and hard tissue changes were evaluated by using paired samples T-test. Pearson correlation test was used to determine the correlation between hard and soft tissue movements.

Results: Maxillary soft to hard tissue ratios of the ANSR+ group were lower than those in the ANSR- group. The ratios were Pr/ANS: 6% vs 49%, Pr/A: 16% vs 42%, Sn/A: 52% vs 66%, Ls/U1: 31% vs 78%, in ANSR+ and ANSR- groups, respectively.

Conclusions: The maxillary step osteotomy technique may be useful in patients where it is desired to further support the nose tip in an anterior direction. ANS reduction process causes a quite decrease in the soft tissue response of the tip of the nose and the upper lip. The subnasal region is relatively less affected.

Keywords: Orthodontics, orthognathic surgical procedures, cephalometry.

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INTRODUCTION

Orthognathic surgery is a method in the treatment of skeletal deformities in adults. The goal of orthognathic surgery is an improved facial aesthetic with a functional occlusion.[1,2] Therefore, it is essential for the clinician to accurately predict the soft tissue profile after surgery. Although there are many studies on this subject, many different rates have been reported, especially for the maxillary region. In the literature, the reason for that shown as variations in surgical techniques used in the maxilla.[3] Variations in surgical techniques can affect the soft tissue response.[4,5] In a recent study[4] even adjunctive procedures such as V-Y closure and alar base cinch suture have been reported to cause alterations on related soft tissue response. Unfortunately, many studies[6-8] in the literature did not report detailed information about the osteotomy type or the soft tissue techniques used. Therefore, there is a need for studies classified according to each surgical factors such as type of the osteotomy technique, applied soft tissue procedures, or magnitude and direction of surgical movements.[3]

The original Le Fort I osteotomy may be sufficient for mild or moderate midface deficiency correction, especially as an aesthetic approach.[9] Severe midface deficiency has been corrected by using quadrangular Le Fort I osteotomy.[10] Also, some stabilization problems were seen in the original Le Fort I osteotomy. So, less invasive and more stable techniques were searched and developed in later studies.[11-13] The maxillary step technique was firstly described by Bennett and Wolford[14] in 1985 to overcome these disadvantages of the original Le Fort I osteotomy. Later, many modifications were made, and these continue to be used.[9,15] The studies have shown that maxillary step osteotomy and its modifications are more stable than the original Le Fort I osteotomy.

Although there is a tendency for three-dimensional (3D) planning today, reasons such as cost, time investment, and learning curve hamper the 3D planning to enter the routine practice.[16] Moreover, the lateral cephalograms are very useful and feasible in the sagittal profile examination with a low radiation dose. So, this retrospective study aimed to investigate the effects of maxillary step osteotomy technique with and without ANS reduction on the soft tissue response using lateral cephalometric radiographs.

MATERIAL AND METHODS

Ethical approval was granted by the clinical research ethics committee of the Tokat Gaziosmanpasa University (Project number: 19-KAEK-111). The study included 24 patients with skeletal Class III malocclusion who received orthodontic treatment at Tokat Gaziosmapasa University, Department of Orthodontics, and operated in Oral and Maxillofacial Surgery Department of the same university. The mean age of the patients (17 women, 7 men) was 21.6 ± 4.72 years.

The following criteria were used as inclusion criteria;

- Patients who underwent maxillary advancement and mandibular set back surgery without maxillary impaction
- Patients who have lateral cephalometric radiographs with adequate quality, taken just before surgery and 6-8 months after surgery

Exclusion criteria were as follows:

- Patients with a maxillary vertical movement bigger than 3 mm
- Patients who underwent additional surgical interventions such as genioplasty or infraorbital augmentation
- Facial asymmetry patients with occlusal cants in the frontal plane
- Patients with any craniofacial anomaly such as cleft lip and palate
- Patients previously underwent surgical procedures related to maxilla or mandible

Maxillary movements were planned parallel to the Frankfurt horizontal plane, and surgical splints were constructed by using model surgery. Mandibular movements were planned to accommodate maxillary occlusion.

All patients underwent bimaxillary orthognathic surgery by the same surgical team. The maxillary step osteotomy technique[14] was performed in all patients (Figure 1).

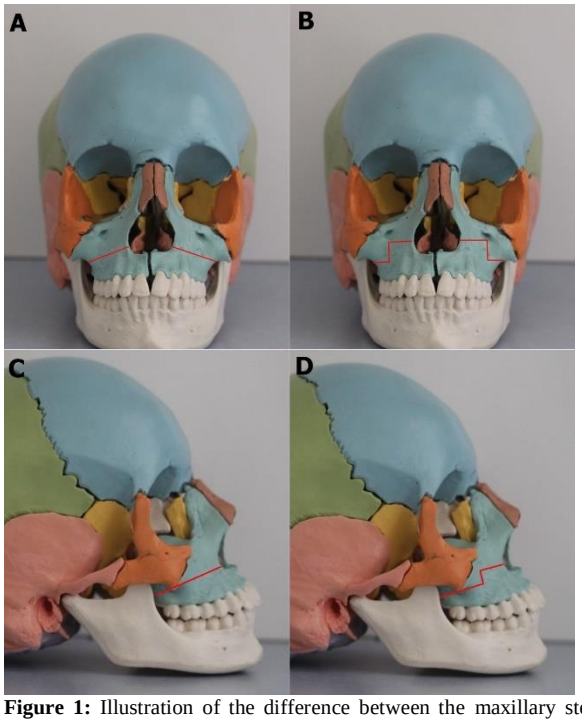

Figure 1: Illustration of the difference between the maxillary step osteotomy line and the original Le Fort I osteotomy (A) Frontal view of the original Le Fort I osteotomy. (B) Frontal view of the maxillary step osteotomy. (C) Lateral view of the original Le Fort I osteotomy. (D) Lateral view of the maxillary step osteotomy.

Then the maxilla was mobilized and repositioned according to the presurgical plan. Fixation was performed via monocortical plates and screws. Under the surgery plan, ANS reduction was performed in 12 of 24 patients (ANSR+ group), while ANS was kept intact in the remaining 12 patients (ANSR- group). Cinch suture[17] and V-Y closure[18] techniques were used in all operations. The cinch suture was performed using a 2/0 absorbable suture and a curved needle. The suture was passed through the lateral nasal muscles and their fibroareolar tissues in a lateral to medial direction. Then, the suture was tied for the approximation of the alar bases and fixed to a hole made in the anterior nasal spine.

Mandibular surgery was performed by bilateral sagittal split ramus (BSSR) osteotomy technique in all patients. Monocortical plates and bicortical screws were used for mandibular fixation. Demonstrative presentation of a patient included in the study was shown in Figure 2.

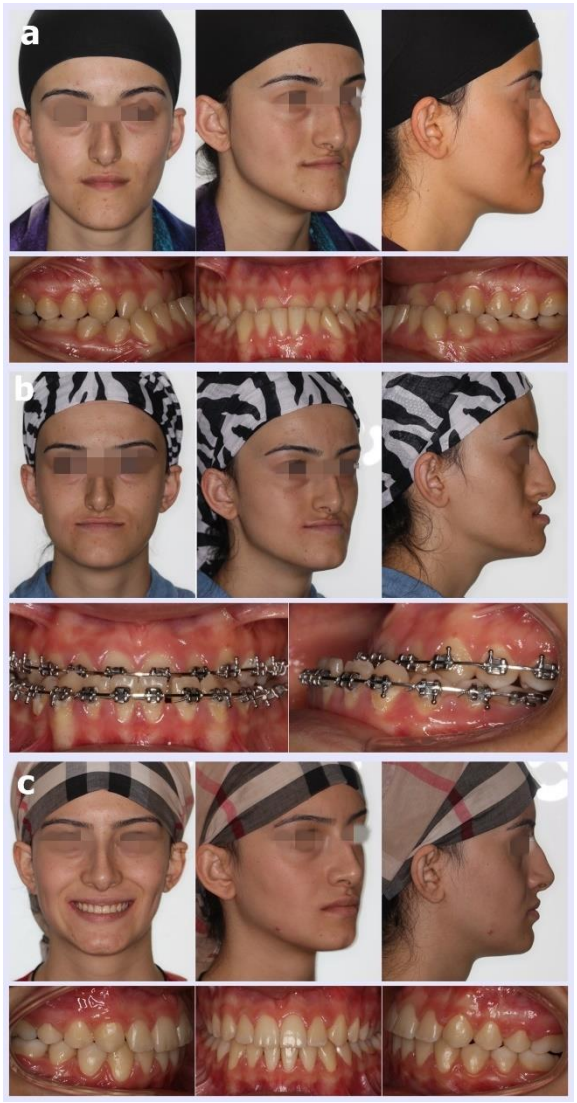

Figure 2: Extraoral and intraoral photographs of a patient included in the study. a: At the beginning of the orthodontic treatment, b: Pre-operative, c: At the end of the treatment.

All lateral cephalometric radiographs were traced using Dolphin Imaging software (Version 11.5, Patterson Dental, CA, USA) by a single examiner (NI). The cephalometric radiographs were evaluated using a modified Legan-Burstone soft tissue analysis method.[19,20] With this method, a horizontal reference line was constructed raised + 7˚ from Sella-Nasion, and a perpendicular line from the Nasion point was used as the vertical reference (Figure 3).

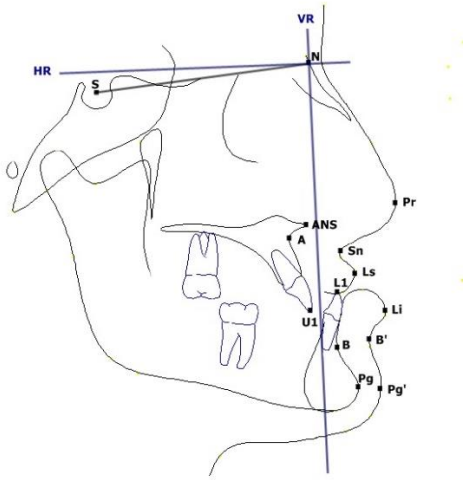

Figure 3: Cephalometric landmarks and reference planes: S indicates Sella, N: Nasion, ANS: anterior nasal spine, A: point A, U1: maxillary incisor tip, L1: mandibular incisor tip, B: point B, Pg: hard tissue pogonion, Pr: pronasale, Sn: subnasale, Ls: upper lip, Li: lower lip, B': soft tissue B point, and Pg': soft tissue pogonion, HR: horizontal reference line, VR: vertical reference line.

The measured soft tissue landmarks were pronasale (Pn), subnasale (Sn), labrale superior (Ls), labrale inferior (Li), soft tissue B point (B'), and soft tissue Pogonion (Pog'). And the hard tissue landmarks were anterior nasal spine (ANS), point A (A), upper incisor tip (U1), lower incisor tip (L1), B point (B), and pogonion (Pog). The distances of hard and soft tissue landmarks to the vertical reference line were measured on pre- and post-surgical cephalograms. The differences were recorded as the amount of soft or hard tissue movements.

Three weeks later, to assess the repeatability of the measurements, pre- and postoperative lateral cephalograms of 9 patients who were randomly selected were retraced by the same researcher.

Statistical Analysis

Statistical analysis of the data was carried out using the SPSS statistical software package (SPSS Inc. version 19.0) (IBM, Somers, NY, USA). The means, standard deviations, and differences between time points were calculated. The changes between time points were analyzed with paired samples T-test. Pearson correlation test was used to evaluate the correlations between soft and hard tissue parameters. Dahlberg[21] formula $\sqrt{(\Sigma d^2/2n)}$ was used to assess intraexaminer repeatability. The level of significance was set at $P<0.05$.

RESULTS

The intraexaminer reliability was high with an error of ≤ 0.34 mm in linear measurements, and an error of ≤ 0.24° in angular measurements.

The mean and standard deviations of the measurements and the changes between time points of all patients were given in Table 1.

Table 1. The cephalometric changes after orthognathic surgery in all included patients

	T1		T2		T2-T1		
	Mean	SD	Mean	SD	Mean	SD	p
SNA (º)	78.82	6.03	82.68	5.7	3.86	1.95	**0.00***
SNB (º)	84.33	5.59	81.92	5.49	-2.4	1.52	**0.00***
ANB (º)	-5.51	2.8	0.77	2.43	6.28	2.1	**0.00***
Wits (mm)	-13.06	3.76	-4.42	3.11	8.64	2.98	**0.00***
Overjet (mm)	-7.27	2.82	2.85	0.96	10.13	2.55	**0.00***
Overbite (mm)	1.31	2.64	1.75	1.2	0.44	2.47	0.39
Nasolabial angle(º)	103.66	9.89	104.29	9.5	0.62	6.72	0.65
Mentolabial angle(º)	142.03	12.27	135.22	11.73	-6.8	11.06	**0.01***
ANS-VR(mm)	0.72	6.52	4.15	5.43	3.42	2.48	**0.00***
A-VR (mm)	-4.4	6.48	-0.26	5.63	4.14	1.93	**0.00***
U1-VR (mm)	-0.37	8.31	5.02	8.02	5.4	2.55	**0.00***
L1-VR (mm)	6.89	8.74	2.44	7.71	-4.45	3.22	**0.00***
B-VR (mm)	1.95	10.26	-1.76	9.41	-3.72	3.44	**0.00***
Pg-VR (mm)	4.69	11.35	1.96	10.43	-2.72	4	**0.00***
Pr-VR (mm)	29.08	4.85	30.51	4.54	1.42	1.51	**0.00***
Sn-VR (mm)	13.36	5.87	15.95	5.4	2.58	2.03	**0.00***
Ls-VR (mm)	14.28	7.71	17.58	7.21	3.3	2.95	**0.00***

Li-VR(mm)	19.41	9.44	15.62	8.67	-3.79	4.01	**0.00***
B'-VR(mm)	13.06	10.49	9.32	9.76	-3.74	3.63	**0.00***
Pg'-VR (mm)	15.34	11.29	12.5	10.36	-2.84	4.18	**0.00***

*indicates p<0.05

Statistically significant increase in overjet, ANB, SNA, and Wits; a significant decrease in SNB and mentolabial angle were found (p <0.05). There was no statistically significant change in the overbite and nasolabial angle. The advancement amount of point A, U1-tip, and ANS were found to be 4.14±1.93 mm, 5.4±2.55 mm, and 3.42±2.48 mm, respectively. The amounts of setback were 3.72±3.44 mm at point B, 4.45±3.22 mm at L1-tip, and 2.72±4 mm at Pog.

The cephalometric differences between ANSR+ and ANSR- groups in different time points were given in Table 2.

Table 2. The maxillary cephalometric differences between ANSR+ and ANSR- groups

	ANSR+ Mean±SD	**ANSR- Mean±SD**	**p**
ANS-VR			
T1	0.86±5.60	0.60±7.59	0.92
T2	3.19±5.00	5.12±5.90	0.40
T2-T1	2.33±2.01	4.52±2.51	**0.02***
A-VR			
T1	-3.91±5.32	-4.90±7.68	0.72
T2	-0.38±4.82	-0.14±6.56	0.92
T2-T1	3.52±1.54	4.76±2.16	0.12
U1-VR			
T1	0.97±7.41	-1.72±9.26	0.44
T2	6.33±7.07	3.72±9.00	0.44
T2-T1	5.36±2.39	5.44±2.83	0.94
Pr-VR			
T1	29.13±5.20	29.04±4.72	0.96
T2	29.95±4.59	31.07±4.62	0.55
T2-T1	0.82±1.11	2.03±1.66	**0.04***
Sn-VR			
T1	13.94±6.09	12.78±5.87	0.64
T2	15.99±5.09	15.91±5.92	0.97
T2-T1	2.05±1.61	3.12±2.33	0.20
Ls-VR			
T1	15.42±7.39	13.16±8.19	0.49
T2	17.91±6.54	17.27±8.11	0.83
T2-T1	2.49±2.61	4.11±3.18	0.19

*indicates p<0.05

The groups were found to be similar regarding all cephalometric values at T1. The changes in ANS-VR and Pr-VR values of the ANSR+ group were statistically smaller than the ANSR- group (ANS-VR: 2.33 vs. 4.52; Pr-VR: 0.82 vs. 2.03) between T2 and T1.

Maxillary soft to hard tissue ratios in the ANSR+ group were smaller than those in the ANSR- group. Pr/ANS: 6% vs 49%, Pr/A: 16% vs 42%, Sn/A: 52% vs 66%, Ls/U1: 31% vs 78%. (Table 3).

Mandibulary soft to hard tissue ratios were as follows: Li/L1: 103% vs 101%, B'/B: 99% vs 129%, and Pg'/Pg: 122% vs 120%, in ANSR+ and ANSR- groups, respectively. (Table 3).

Table 3. Correlations and soft to hard tissue movement ratios (S/H) in the ANSR+ and ANSR- groups.

ANSR+ Group				
Soft Tissue Variable	Hard Tissue Variable	r	p	S/H
Pr	ANS	0.259	0.42	0.06
Pr	A	0.720	**0.01***	0.16
Sn	A	0.787	**0.00***	0.52
Ls	U1	0.803	**0.00***	0.31
Li	L1	0.923	**0.00***	1.03
B'	B	0.974	**0.00***	0.99
Pg’	Pg	0.985	**0.00***	1.22
ANSR- Group				
Pr	ANS	0.482	0.11	0.49
Pr	A	0.534	**0.07***	0.42
Sn	A	0.472	0.12	0.66
Ls	U1	0.840	**0.00***	0.78
Li	L1	0.845	**0.00***	1.01
B'	B	0.969	**0.00***	1.29
Pg’	Pg	0.975	**0.00***	1.20

*indicates $p<0.05$

DISCUSSION

Unlike most similar studies in the literature, the maxillary step osteotomy was used in the current study. To our knowledge, this is the first study that evaluates the soft to hard tissue ratios in this osteotomy technique. And the present study revealed that the maxillary step technique supports the tip of the nose much more than the original Le Fort I. Soft to hard tissue ratios related to the nose tip were reported between 16% and 35% in the literature.[6,7,22,23] Whereas, relatively high Pr/ANS and Pr/A ratios (49%, 42%, respectively) were found in the ANSR- group of the current study. So, the maxillary step osteotomy technique can be preferred in patients with a nasal hump. Supporting our findings, in a recent study[9], modified Le Fort I step osteotomy was found to be effective for improvement of paranasal flatness in maxillary deficiency.

The current study also showed that ANS reduction considerably affects the soft tissue response of the nose tip. Pr/ANS and Pr/A ratios in the ANSR- group, were quite higher than those in the ANSR+ group (Pr/ANS: 0.49 vs. 0.06; Pr/A:0.42 vs. 0.16). So, the clinician should examine the preoperative nose profile well and decide whether ANS reduction should be administered or not. Also, it should be noted that these soft to hard tissue rates will vary based on the amount of ANS reduction.

Another finding of the current study is that ANS reduction has an impact not only on the nose tip but also on other soft tissues such as the upper lip and the subnasal region. In the ANSR- group, the upper lip to upper incisor ratio (Ls/U1) was 78%, while this ratio is halved and becomes 31% in the ANSR+ group. This effect might have occurred via the musculus depressor septi nasi. When ANS is remained intact, the tip of nose is further supported anteriorly. This leads the columella plane to rotate in the anti-clockwise direction,[24] and the musculus depressor septi nasi pulls the upper lip forward and upward. On the

other hand, when ANS reduction is performed, the upper lip loses this support in the anterior direction.

Soft tissue ratios in the mandible were consistent with other studies in the literature.[6,7,25-28] The correlations of soft to hard tissue movement in the mandible were more reliable than in the maxilla. This can be explained by before mentioned variations in maxillary surgical techniques such as the amount of ANS reduction, osteotomy type, or the soft tissue techniques used.

The current study has some limitations. The major limitation is the limited number of patients. Because patients with differences in surgical techniques involving hard or soft tissue were excluded from the study. The patients with the same type of osteotomy, the same direction of movement (pure maxillary advancement and mandibular setback without vertical movement), the same additional soft tissue techniques, and the same fixation technique were recruited in the current study. This effort restricted the number of patients included. Another limitation is the lack of an original Le Fort I group, including the same adjunctive surgical techniques.

CONCLUSIONS

The maxillary step osteotomy technique may be useful in patients where it is desired to further support the nose tip in an anterior direction. ANS reduction process causes a quite decrease in the soft tissue response of the tip of the nose and the upper lip. Specific studies for each surgical technique with an adequate number of patients in the maxilla are still needed.

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ÖZ

Amaç: *Yumuşak doku profilinin tahmini, ortognatik cerrahi planlamanın önemli bir parçasıdır. Cerrahi tekniklerdeki değişiklikler yumuşak doku yanıtını etkileyebilir. Bu çalışma, anterior nasal spina (ANS) redüksiyonlu veya redüksiyonsuz basamaklı maksiller osteotominin yumuşak doku yanıtı üzerindeki etkilerini belirlemeyi amaçlamıştır.* ***Gereç ve Yöntemler:*** *Çalışmaya basamaklı maksiller osteotomi ve bilateral sagittal split ramus osteotomisi kullanılarak, maksiller ilerletme ve mandibular geri alma cerrahisi uygulanan toplam 24 hasta (17 kadın, 7 erkek) dâhil edildi. Daha sonra ANS redüksiyon pozitif (ANSR+) ve negatif grup (ANSR-) olmak üzere iki alt grup oluşturuldu. Tüm hastalarda chin sütür ve V-Y kapama teknikleri kullanılmıştır. Ameliyat öncesi ve ameliyattan 6-8 ay sonra alınan lateral sefalometrik radyografiler arşivden toplandı. Yumuşak ve sert doku değişiklikleri, eşleştirilmiş T-testi kullanılarak değerlendirildi. Sert ve yumuşak doku hareketleri arasındaki korelasyonu belirlemek için Pearson korelasyon testi kullanıldı.* ***Bulgular:*** *ANSR+ grubunun maksiller yumuşak/sert doku oranları ANSR- grubundan daha düşüktü. ANSR+ ve ANSR- gruplarında oranlar Pr/ANS:% 6'ya karşı % 49, Pr/A:% 16'ya karşı % 42, Sn/A:% 52'ye karşı % 66, Ls/ U1:% 31'e karşı % 78 olarak bulunmuştur.* ***Sonuçlar:*** *Basamaklı maksiller osteotomi tekniği, burun ucunun anterior yönde daha fazla desteklenmesinin istendiği hastalarda faydalı olabilir. ANS redüksiyon işlemi, burun ucu ve üst dudağın yumuşak doku yanıtında azalmaya neden olur. Subnazal bölge nispeten daha az etkilenir.* ***Anahtar kelimeler:*** *Ortodonti, ortognatik cerrahi işlemler, sefalometri.*

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Original research

COMPARISON OF PANORAMIC, LATERAL SKULL PROJECTION AND CBCT IMAGES IN DETECTION OF MANDIBULAR CONDYLE FRACTURES

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ABSTRACT

Objectives: Condyle fractures constitute 17.5–52% of all mandibular fractures. Our first aim was to investigate whether Panoramic Radiography or Lateral Skull Projection images with lower radiation dose can be used instead of Cone Beam Computed Tomography in the diagnosis of vertical condylar fractures. The second aim of the study was to compare observers' capabilities in diagnosing these fractures.

Materials and Methods: A sample consisting of 15 fresh cadaver mandibles with 30 condyles frozen within 24 hours post-mortem was randomly selected. Vertical fractures from the lateral 2/3 of the condyle head with 0.5 (10 condyles) and 1mm (10 condyles) thickness were created using a fret saw. After creating condyle fractures, digital panoramic, LSP, and CBCT images were acquired. Two dentomaxillofacial radiologists with 15 years of experience, two dentomaxillofacial radiologists with five and seven years of experience, and two newly graduated dentists have evaluated the images. The success of the observers in diagnosing the vertical condyle fracture in each imaging method, intra-observer and inter-observer agreement was evaluated.

Results: The success of all dentists in determining the condyle fractures using LSP images was higher than the success they achieved using panoramic images, but the sensitivity values of LSP and panoramic radiographs for detecting vertical condyle fractures were found to be below 50%. Using different imaging options with CBCT, all diagnoses made by new graduates and dentomaxillofacial radiologists with five and 15 years' experience were 100% compatible with the gold standard (AC1: 1 (1–1)).

Conclusions: For the diagnosis of vertical condyle fractures, conventional techniques (panoramic and lateral jaw imaging methods) were found to be insufficient.

Keywords: Cone beam computed tomography, imaging, mandibular condyle, vertical fracture.

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INTRODUCTION

Condyle fractures have an important percentage of all jaw fractures. 80% of the cases are unilateral, occurring mainly between the ages of 20 and 39 years. The male/female ratio is 3:1. These fractures are mostly caused by indirect forces transmitted from a distant point to the condylar area.[1-3] According to Widmark[4] and Santler[5], fractures of the mandibular condylar process are the most common fractures in the mandible and maxillofacial region. Condyle fractures can occur as a result of direct or indirect trauma. The formation of bone displacement with the fracture depends on the direction, degree and region of the force during the trauma, as well as the current occlusion and dental condition of the patient.[1,4,5]

The diagnosis of mandibular condyle fractures is made by clinical and radiographic evaluations. Difficulty opening the mouth, malocclusion, and edema in the peripheral part of the auricula may be clinical signs of mandibular condyle fractures.[6]

The correct diagnosis of mandibular condyle fractures is made through radiographic evaluations. Conventional extraoral radiographic techniques such as panoramic and lateral skull projection (LSP) are used for the diagnosis and postoperative follow-up of condyle fractures. [7] However, the superimposition of structures could make fracture diagnosis difficult. This is a significant disadvantage in the imaging of high condylar fractures because the treatment outcome depends on the position of the fracture line, the comminution of the proximal fragments, and the shortening of the mandibular ramus.[8,9] Moreover, nondisplaced fractures of the mandibular condylar head may be difficult, if not impossible, to detect on a panoramic image.[10]

Computed tomography (CT) provides a clear visualization of maxillofacial structures without superimposition of anatomical structures. The clinical utility of the CT scan is particularly evident when evaluating condyle fractures, as the degree of displacement in these areas can be subtle.[11] However, CT has disadvantages; it can be unhealthy due to high radiation, overcosting, and large area requirement.[12-15] CBCT scanning is frequently used in dentistry and has advantages such as low radiation dose, low cost, time efficiency and high spatial resolution when compared to CT.[16]

There is only one study that has compared the diagnostic accuracy of CT and CBCT in experimentally created condylar fractures.[17] Three-dimensional imaging does not have a routine indication for every patient, therefore, in our study, we investigated whether panoramic radiography or LSP images with lower radiation dose can be used in the diagnosis of vertical condylar fractures. The second aim of the study was to compare observers' capabilities in diagnosing these fractures.

MATERIALS AND METHODS

Sample: This study was performed with local ethical committee approval (……. University, Project no: D-DA19/05). A sample consisting of 15 fresh cadaver mandibles with 30 condyles frozen within 24 hours post-mortem was randomly selected. The sample was defrosted 24 hours before making the scans. A 1.5 cm red wax material was used as a soft tissue equivalent.

Creating Vertical Condyle Fractures: Vertical fractures from the lateral 2/3 of the condyle head with 0.5 mm (10 condyles) and 1 mm (10 condyles) thickness were created using a fret saw. The fracture line depths were 2 mm.

Panoramic, Lateral Skull and CBCT Assessments: All digital panoramic images were acquired using the same machine (Veraviewpocs 2D, Morita, Japan) with the following exposure parameters: 64–66 kVp; 6–9 mA; and 10 s. The isolated mandibles were positioned with the occlusal plane perpendicular to the floor.

All LSP images acquired using the image receptor were positioned parallel to the mandibles' midsagittal plane.

A CBCT system (3D Accuitomo 170, Morita, Japan) was used to scan the sample. The technical parameters for 3D Accuitomo 170 and Iluma were 90 kV, 5 mA, 17.5 s). Three different fields of view (FOV; 60x60, 80x80, 100x100 mm)

were used. The isolated mandibles were positioned with the occlusal plane perpendicular to the floor.

Assessments of Images and Observers: As observers, two dentomaxillofacial radiologists with 15 years of experience, two dentomaxillofacial radiologists with five years of experience, and two newly graduated dentists evaluated the images. The images were re-evaluated at 1 month interval. The success of the observers in diagnosing the vertical condyle fracture in each imaging method, intra-observer and inter-observer agreement were evaluated.

Statistical Analysis: Statistical analysis of the data collected in the study was made with the SPSS (Version 22, SPSS Inc., Chicago, IL, USA) package program. Intra-observer agreement percentages will be calculated for three different imaging methods. Also, the inter-observer agreement level was evaluated with GWET AC1 statistics instead of Cohen's kappa statistics, which were affected by prevalence. The compliance levels of physician diagnoses with the gold standard for three different imaging methods were also evaluated with the GWET AC1 statistics. Also, sensitivity and selectivity values were calculated to evaluate the success of diagnoses made by the observers using three different devices. Compliance statistics were used to provide information on the distribution of diagnostic differences between observers. Sensitivity and specificity were used to provide information about the ability of the observers to diagnose vertical condyle fractures with 0.5 mm and 1.00 mm thickness. The GWET AC1 values were interpreted as follows: <0.01 means no compliance; 0.01–0.20 means insignificant agreement; 0.21–0.40 means poor agreement; 0.41–0.60 means moderate agreement; 0.61–0.80 means sufficient agreement; and 0.81–1.00 is interpreted as the existence of perfect fit. The statistical significance level was accepted as $P<0.05$.

RESULTS

The intra-observer agreement according to imaging methods is given in Table 1.

Table 1. The intra-observer agreement according to imaging methods.

		Panoramic	LSP	CBCT (60x60)	CBCT (80x80)	CBCT (100x100)
Newly graduated Dentists	%	73.3%	80%	100%	100%	100%
	Agreement*	0.65 (0.38–0.92)	0.62 (0.33–0.92)	1 (1–1)	1 (1–1)	1 (1–1)
Dentomaxillofacial Radiologists with 5-year experience	%	90%	93.3%	100%	100%	100%
	Agreement*	0.88 (0.75–1.02)	0.89 (0.73–1.04)	1 (1-1)	1 (1-1)	1 (1-1)
Dentomaxillofacial Radiologists with 15-year experience	%	90%	93.3%	100%	100%	100%
	Agreement*	0.88 (0.75–1.02)	0.89 (0.73–1.04)	1 (1-1)	1 (1-1)	1 (1-1)

*Gwet's AC1 coefficients and their 95% confidence intervals.
LSP: Lateral Skull Projection.

When the intra-observer agreement was evaluated according to imaging methods, the most successful compliance was the evaluations made using CBCT, followed by the evaluations made using LSP and panoramic images, respectively. The inter-observer agreement level of evaluations using CBCT, LSP and panoramic images was sufficient.

The compliance of physician diagnoses with the gold standard according to imaging methods is given in Table 2.

Table 2. The compliance of physician diagnoses with the gold standard according to imaging methods.

		Panoramic		LSP		CBCT (60x60)		CBCT (80x80)		CBCT (100x100)	
		Sens		Spec	Sens	Spec	Sens	Spec	Sens	Spec	Sens	Spec
Newly graduated dentist A	%	20%		90%	50%	100%	100%	-	100%	-	100%	-
	Agreement*	−0.28 (−0.68 – 0.11)		0.33 (−0.01 – 0.68)	1 (1–1)		1 (1–1)			1 (1–1)		
Newly graduated dentist B	%	5%		80%	50%	80%	100%	-	100%	-	100%	-
	Agreement*	−0.32 (−0.73 – 0.08)		0.20 (−0.16 – 0.57)	1 (1–1)		1 (1–1)			1 (1–1)		
Dentomaxillofacial radiologist with 5-year experience A	%	0%		90%	35%	90%	100%	-	100%	-	100%	-
	Agreement*	−0.28 (−0.71 – 0.15)		0.07 (−0.30 – 0.44)	1 (1–1)		1 (1–1)			1 (1–1)		
Dentomaxillofacial radiologist with 5-year experience B	%	10%		100%	40%	100%	100%	-	100%	-	100%	-
	Agreement*	−0.12 (−0.54 – 0.30)		0.20 (−0.16 – 0.57)	1 (1–1)		1 (1–1)			1 (1–1)		
Dentomaxillofacial radiologist with 15-year experience A	%	5%		100%	35%	100%	100%	-	100%	-	100%	-
	Agreement*	−0.16 (−0.59 – 0.27)		0.14 (−0.23 – 0.51)	1 (1–1)		1 (1–1)			1 (1–1)		
Dentomaxillofacial radiologist with 15-year experience B	%	10%		80%	40%	90%	100%	-	100%	-	100%	-
	Agreement*	−0.28 (−0.68 – 0.11)		0.13 (−0.23 – 0.50)	1 (1–1)		1 (1–1)			1 (1–1)		

*Gwet's AC1 coefficients and their 95% confidence intervals
Sens: Sensitivity, Spec: Specificity, LSP: Lateral Skull Projection.

According to imaging methods, when the agreement between all dentists' diagnoses and the gold standard was evaluated, the most successful agreement was that of the evaluations made using CBCT, followed by the evaluations made using LSP and panoramic images, respectively (Figure 1a, b, c).

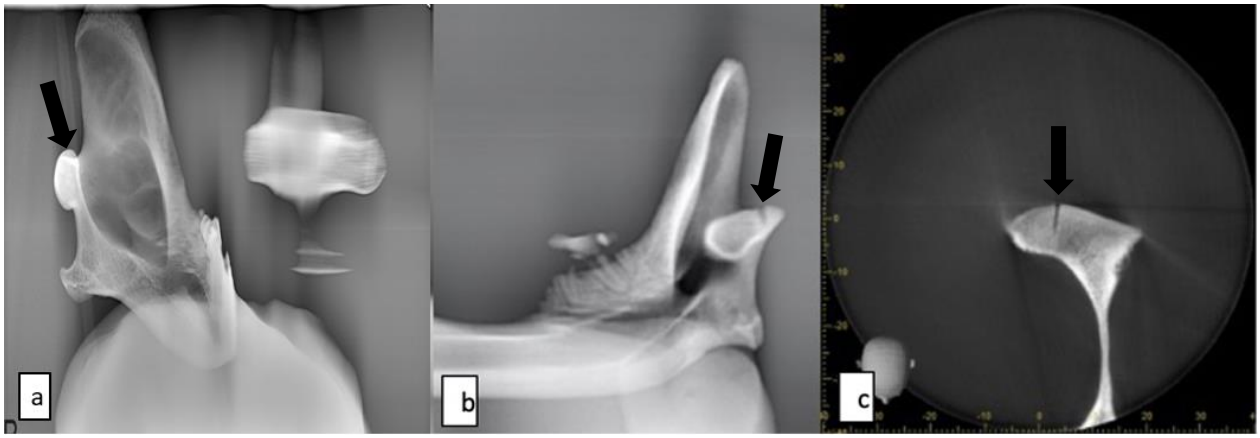

Figure 1(a,b,c). Panoramic, LSP and CBCT images with vertical condyle fractures were seen.

The consistency of the evaluations made with LSP and panoramic images with the gold standard were insufficient.

According to the vertical condyle fracture thickness, the compliance of physician diagnoses with the gold standard for panoramic and LSP images is given in Table 3.

Table 3. The compliance of physician diagnoses with the gold standard for panoramic and LSP according to vertical condyle fracture thickness.

Fracture thickness		Panoramic Sens	Spec	LSP Sens	Spec
0.5 mm	Newly graduated dentist A	20%	90%	50%	100%
	Newly graduated dentist B	0%	80%	50%	80%
	Dentomaxillofacial radiologist with 5-year experience A	0%	90%	30%	90%
	Dentomaxillofacial radiologist with 5-year experience B	0%	100%	40%	100%
	Dentomaxillofacial radiologist with 15-year experience A	0%	100%	30%	100%
	Dentomaxillofacial radiologist with 15-year experience B	10%	80%	40%	90%
1 mm	Newly graduated dentist A	20%	90%	50%	100%
	Newly graduated dentist B	10%	80%	50%	80%
	Dentomaxillofacial radiologist with 5-year experience A	0%	90%	40%	90%
	Dentomaxillofacial radiologist with 5-year experience B	20%	100%	40%	100%
	Dentomaxillofacial radiologist with 15-year experience A	10%	100%	40%	100%
	Dentomaxillofacial radiologist with 15-year experience B	10%	80%	40%	90%

1. Sens: Sensitivity, Spec: Specificity
2. LSP: Lateral Skull Projection

When the success of physician diagnoses in detecting 0.5 and 1 mm thick fractures according to imaging methods was evaluated, it was seen that LSP was more successful than panoramic, but the sensitivity values obtained as a result of both methods were at a very low level—below 50%. When the success of observers' diagnoses in detecting intact condyles compared to the gold standard was evaluated, it was seen that the specificity values were high, since the majority of both intact and broken condyles were diagnosed as intact.

DISCUSSION

The rate of condyle fractures among all jaw fractures is between 17.5% and 52%.[18] Sawazaki et al.[19] reported that 14% of maxillofacial trauma patients sustained at least 1 condylar fracture and, of all mandibular fractures, condylar fractures accounted for 50.09%. There are many different classifications and imaging methods for mandibular condylar fractures used in the literature. The anatomical level of the fractures can be divided into three regions: (A) condylar head (in the capsule), (B) condylar neck (extra-capsule), and (C) subcondylar zone.[3,20-23] There are two types of fractures in general: intra-capsular and extra-capsular. A fracture is classified as either not displaced, deviated, displaced (with medial or lateral overlap or complete separation) or dislocated (outside glenoid fossa), and condylar head fractures can be categorized by horizontal, vertical, and compression types.[3,21-25] The main theme of this report is vertical fractures.

While two different X-ray views can be performed for mandibular fractures: a postero-anterior view, generally used for angle and ramus fractures; bilateral oblique view, used to analyse the angle and horizontal branch of the mandible. For the diagnosis of condyle fractures CBCT, CT and other conventional extraoral radiographic techniques as panoramic, posteroanterior skull projection (PASP), LSP, an angled antero-posterior view called reverse Towne view, useful in case of displacement of condylar fragments; have been used in oral and maxillofacial radiology.[26] In our study, we compared three different imaging methods for condyle fractures.

Conventional radiographs are routinely used for the examination of the mandibular condyle. However, overlapping structures can prevent images from being interpreted properly.[27] Intra-

capsular fractures of the mandibular condyle and fractures in the higher part of the condylar process are difficult to see on plain films. Depending on the position, the image may overlook the displacement of bone fragments, distorting the correct diagnosis.[28] The LSP and panoramic images will provide the essential preliminary information, but these will not be sufficient for critical evaluation of the TMJ itself because of the superimpositions of surrounding structures. The mandibular condyle may be superimposed on panoramic radiographs by the zygomatic process, maxillary tuberosity, and the pterygoid process of the sphenoid bone.[29,30] In the present study, it was found that sensitivity values of LSP and panoramic radiographs were at a very low level below 50% for detecting vertical condyle fractures. We think that this may be due to the superimpositions formed in this region.

CT is a convenient method to diagnose the condylar process that is not seen in conventional radiographs.[31,32] In recent years, CBCT is a modern imaging technique with the advantages of low-level metal artifacts and low radiation dose, which may be more efficient and economical than CT.[18] Moreover, CBCT has been reported to be superior to panoramic radiography, especially in detecting condylar and coronoid fractures and fractures in the anterior part of the mandible.[30]

In the literature, there are many studies comparing 3-dimensional imaging with 2D imaging in detecting condyle fractures. Costa et al.[18] evaluated 2D-CT and 3D-CT examinations of patients with mandibular condyle fractures. They noted that 2D-CT and 3D-CT reconstruction images produced similar information for the diagnosis of mandibular condyle fractures, but 3D-CT was better than 2D-CT at imaging the position and displacement of bone fragments. Raustia et al.[6] reported that both the anteroposterior and mediolateral displacement direction of the fractured condyle were better seen on CT than conventional radiographs. Choudhary et al.[33] evaluated the diagnostic quality of CBCT images and compared them with conventional images from patients with maxillofacial trauma. They stated that the detection of fracture lines on the midface and mandibular condylar region is signifcantly enhanced using CBCT when compared with conventional radiographs.

Even Sukegawa et al.[34] offer a new approach. After their study, they reported that the use of intraoperative CBCT in the hybrid operating room for condylar fractures is the most beneficial approach because they requires more accurate intraoperative diagnosis.

The present study evaluated panoramic, LSP and CBCT imaging as effective techniques for the diagnosis of vertical condylar fractures. In our study, similar to other studies, we found that CBCT is the best imaging technique for the diagnosis of vertical fractures. When the success of physicians detecting 0.5 and 1 mm fractures according to imaging methods was evaluated, it was seen that the lateral imaging method was more successful than the panoramic method, but the sensitivity values obtained as a result of both methods were very low (below 50%).

Şirin et al.[17] compared CT and CBCT imaging of displaced and non-displaced fractures using sheep heads. The kappa values for the intra-observer agreement of Observer 1 varied between 0.56 and 0.92 (moderate to excellent) for CT and between 0.64 and 0.92 (good to excellent) for CBCT in their study. Observer 2 had similar scores for both imaging modalities: 0.57–0.92 for CT and 0.79–0.92 for CBCT. The kappa values for the two observers revealed good to excellent agreement for CT and CBCT (0.62–0.98 and 0.60–0.97, respectively).[17] In our study, the agreement between the diagnoses made by the newly graduated dentists using panoramic and LSP was substantial (AC1: 0.65, 0.62, respectively). The agreement between dentomaxillofacial radiologists with five years of experience using panoramic and LSP imaging was almost perfect (AC1: 0.88, 0.89, respectively). The consistency between the dentomaxillofacial radiologists with 15 years of experience using the panoramic imaging method was sufficient (AC1: 0.80), and the agreement between them using LSP was almost perfect (AC1: 0.89). Compliance percentages of new graduates and dentomaxillofacial radiologists with five years

and 15 years of experience with panoramic images were 73.3%, 90%, and 90%, respectively; the agreement percentages of their diagnoses of LSP images were 80%, 93.3%, and 93.3%, respectively.

For Şirin et al.[17], the kappa values obtained in comparison with the gold standard were 0.69–0.97 for CT and 0.68–0.96 for CBCT. Furthermore, CT and CBCT were in good to excellent agreement, as the kappa values were 0.64–0.94 for the interpretation of the reconstructed images. In our study, all of the diagnoses made by new graduates and dentomaxillofacial radiologists with five and 15 years' experience using CBCT with different fields of view (60x60, 80x80, 100x100) were 100% compatible with the gold standard. On the other hand, Librizzi et al.[35] compared CBCT images using different voxel sizes and FOVs to identify condylar erosions. They reported that the CBCT images acquired with a 6-inch FOV at 0.2-mm voxel size were significantly better than the images acquired with a 12-inch FOV at 0.4-mm voxel size.

Although there are many studies on imaging condylar fractures in the literature, to the best of our knowledge this is the first study that focused on vertical fracture imaging. In this study the vertical condyle fractures were created experimentally and therefore patient related artefacts such as movement were not considered. It may be a potential limitation of the study.

CONCLUSIONS

For the diagnosis of vertical condyle fractures, conventional techniques (panoramic and lateral jaw imaging methods) were found to be insufficient. CBCT, which is frequently used in the three-dimensional imaging of the maxillofacial region, is excellent for the diagnosis of these fractures. Moreover, all observers accurately diagnosed all vertical condyle fractures using CBCT images. Therefore, it is recommended to use CBCT for the diagnosis of vertical condyle fractures, despite the high radiation disadvantage.

CONFLICTS OF INTEREST

No conflicts of interest.

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Original research

IMPACT OF TOOTH LOCATION ON THE TREATMENT OF MULTIPLE GINGIVAL RECESSIONS WITH CONNECTIVE TISSUE GRAFT ASSOCIATED WITH A CORONALLY ADVANCED FLAP

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ABSTRACT

Objectives: Coronally advance flap (CAF) effectiveness has been extensively evaluated, but little information is available regarding the effect of tooth position. This study aimed to evaluate the influence of tooth location on the outcomes of CAF with subepithelial connective tissue graft (SCTG) in the treatment of gingival recessions defects (GRs).

Materials and Methods: Nineteen patients with a mean age of 36.3 ±7.6 years (11women, 8 men), each contributing Miller Class I and II GRs, were selected. Forty-four defects were treated with a combination of a CAF and a SCTG. Gingival recession depth (RD), gingival recession width (RW), probing depth (PD), and clinical attachment level (CAL) were recorded at baseline and 12 months postoperatively

Results: The mean root coverage from baseline to 1year post-surgery was 89 % for the maxillary GRs and 68 % for the mandibular GRs. RD and RW were decreased in both groups from baseline to 12 months ($p<0.001$), but the difference between groups was not statistically significant. Both treatments showed satisfactory root coverage esthetic scores (maxillary teeth 8.2 ±1.3 and in mandibular teeth 7.6 ± 1.1).

Conclusions: The findings of the current study have shown that the CAF is an effective procedure for the treatment of multible GRs. Besides, the two groups (maxillary and mandibular GRs) showed similar significant improvements from baseline to 12 months evaluations.

Keywords: Connective tissue, gingival recession, surgical flaps, tooth.

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INTRODUCTION

Gingival recession (GR) is defined as the opening of the root surface to the oral cavity by the displacement of the gingiva towards the apical of the cementoenamel junction.[1,2] This condition affects a large part of the population, regardless of the standard of oral hygiene.[3] The etiology of GR in today's dentistry is multifactorial, It is thought that the effect of more than one factor at the same time and their cumulative effects lead to GRs.[4] GRs could be related to a large variety of predisposing precipitating and predisposing factors: plaque-induced gingival diseases,[5] aberrant frena,[5] traumatic toothbrush,[6] tooth malposition,[3] orthodontic treatment,[7] improper flossing[8] and iatrogenic. Aesthetic problems, dentin hypersensitivity, and accompanying with a carious or noncarious cervical lesion are the major indications for the treatment of these GRs and have been extensively documented in the literature that GR can be treated satisfactorily with several root coverage procedures (RCP).[9-11]

Several alternative substitutes to connective tissue have been tested in overcoming to eliminate the problems associated with a second surgical site[12-14] but meta-analyzes have shown that subepithelial connective tissue grafts (SCTG) can be accepted as the gold standard procedure for GR treatment.[10,15,16] Consensus opinion on the treatment of GR clearly shows that SCTG based procedures lead to the best clinical results because of their excellent percentages of root coverage and the enhanced possibility of complete root coverage, as well as significant increase in keratinized tissue width when comprised with most of the other procedures.[10, 17]

Due to the high success rate in root closure from past to present, the most preferred one is CAF surgery.[18,19] This technique aims to cover the root surface based on the principle of sliding the gingiva to the coronal direction at the apical of the GR.[20] The predictable closure of multiple GRs still represents one of the most challenging situations in aesthetic plastic periodontal surgery.[21] Anatomical variations such as the larger avascular surface due to the size of the surgical area, weaker blood supply, the position of the tooth roots, shallow vestibules, and differences in gingival recessions depth are the factors that make the surgery and wound healing difficult.[22,23]

Given the effects of tooth location on the results of root coverage techniques, it is of foremost importance to understand the true probability of achieving a complete root coverage after treatment with SCTG+CAF in maxillary and mandibular defects. Although, there are several studies related to the effect of SCTGs for the treatment of localized GRs[24-26], there is limited information regarding the use of subepithelial connective tissue graft plus coronally advanced flap (SCTG+CAF) for the treatment of multiple GRs. Considering the effects of the depth of the vestibular fornix, flap tensions, flap thickness, and mucogingival phenotypes on the results of periodontal plastic surgery, the hypothesis of the study stated that the percentage of root coverage is greater in the maxilla than mandibula in the treatment of multiple gingival recessions with CAF+SCTG. Thus, this retrospective study aimed to evaluate the clinical outcomes of SCTG+CAF in the treatment of multiple GRs concerning the tooth location

MATERIAL AND METHOD

Written informed consent was obtained from all subjects included in the surgical treatment with an agreement to use their data for the clinical trials in accordance with the Helsinki Declaration 1975 as revised 2000. The study was approved by the Clinical Research Ethics Board of Akdeniz University Faculty of Medicine (70904504/745).

This study was carried out on 44 GRs in 19 patients (11 females and 8 males, aged 31–43 years) Data were collected by evaluation of records of patients treated with SCTG+CAF for GRs in Akdeniz University Faculty of Dentistry Department of Periodontology Antalya Turkey, between 2018 and 2019 and controlled 12 months follow-up period.

Clinical measurements:

Demographic details, age and sex were recorded. The following clinical measurements were performed at baseline and 12 months follow-up postoperatively by a single calibrated, blinded

examiner (ZA) using a periodontal probe (UNC 15 Periodontal probe; Hu-Friedy, Leimen, Germany): 1)plaque index (PI)[27], 2)gingival index (GI),[28] 3) Probing depth (PD), measured from the marginal gingiva to the bottom of the gingival sulcus; 4) Clinical attachment level (CAL), recorded from the CEJ to the bottom of the gingival sulcus; 5) Recession depth (RD), measured from the CEJ to the marginal gingiva.[29] 6) Recession width (RW): measured from one border of the defect to another at the CEJ.[30]

Esthetic evaluation:

After 12 months, experienced independent specialist (ZA) evaluated the esthetic outcome of surgery. Root coverage esthetic score (RES) system assessed five variables as follows: 1)gingival margin (GM) level: zero-point = failure of root coverage; 3 point = partial root coverage; and 6 point = complete root coverage; 2) marginal tissue contour: zero-point = irregular gingival margin; 1 point = proper marginal contour; 3) soft tissue texture: zero-point = presence of scar of keloid-like appearance; 1 point= absence of scar; 4) Mucogingival Junction (MGJ) alignment: zero-point= MGJ not aligned with MGJ on adjacent teeth; 1 point= MGJ aligned with MGJ on adjacent teeth; and 5) gingival color: zero-point = color of tissue varies from gingival color on adjacent teeth; 1point=normal color and integration with adjacent soft tissues. The excellent RES score was 10 point and worst was zero point, which equivalent to unsuccessful root coverage.

Initial therapy:

Before surgery, all subjects received oral hygiene instructions to modify their habits associated with the etiology of GRs. Phase I periodontal therapy (consisting of ultrasonic scaling and polishing) was performed.

Surgical technique:

Both surgical operations have been conducted by one operator with plastic periodontal surgery clinical experience (NAK). The envelope type of CAF technique was performed which was proposed by Zucchelli and De Sanctis[31] in 2000. After local anesthesia, a horizontal incision was made to involve one more tooth on each border of the GRs related teeth to be operated for easing the coronal repositioning of the gingival tissue to the mucogingival junction. The horizontal incision of the envelope flap was composed of oblique interdental submarginal incisions to design the external surgical papilla (SP), incisions which continued with the sulcular incision at the GRs defects. Every single SP was displaced concerning the anatomic papilla by the oblique interdental submarginal incisions. Briefly, the SP, which are mesial to the midline of the flap were displaced more distally and apically, while the SP which are distal to the midline of the flap was shifted in a more mesial and apical position. Split thickness approach of SP was done till the sulcular area, incisions were carried out keeping the scalpel parallel to the root surface. The full-thickness flap of the gingival tissue under the exposed root was dissected apical position to exposed 3-4 mm alveolar bone and the fragment of the flap critical for root coverage with more thickness was prepared. At last, the most apical fragment of the flap was dissected in a split-thickness approach to facilitate the coronal shift of the gingival tissue. The root surfaces were planed gently with periodontal curettes. Facial gingival tissue of the remaining interdental papillae was de-epithelialized to create connective tissue beds to which the SPs were sutured. A sharp dissection into the vestibular sulcus mucosa was made to prevent muscle tension. The SCTG was harvested from the palate between the canine and the 1st molar area using a surgical knife. The SCTG, about 1 to 1.5mm thick, was positioned in the recipient site to cover the exposed root surface. Absorbable (Coated Vicryl, Ethicon, Johnson&Jonhnso, Belgium) subperiosteal sutures were used to secure the graft in the recipient site; then the envelop type CAF flap was shifted coronally and sutured using 5-0 propylene sutures (Ethicon, Johnson and Johnson Intl, St. Stevens, Woluwe, Belgium) to cover the SCTG completely. Sling sutures were carried out to achieve a complete adaptation of the flap on the exposed root surfaces and to fix each SP over the interdental recipient site.

Post-Surgical Protocol

Analgesics (flurbiprofen 100mg, two times daily) and antibiotics (amoxicillin, 1g, two times daily)

were prescribed for all patients after the surgical procedure. The patients were told to rinse their mouths twice a day with a mouthwash containing 0.12% Chlorhexidine the day after the procedure. It was explained that brushing the areas with avoiding any mechanical trauma. After 10 days, the sutures in the surgical areas were removed.

According to the standard formula, percentages of root coverage [(100×(baseline recession depth –1-year follow-up recession depth)) /baseline recession] and full root coverage have been determined.[12] The patients were called for post-operative controls at the 1st and 12th months to evaluate the surgical site, professionally perform supragingival cleaning, and explain oral hygiene procedures.

Statistical analysis

The sample size was calculated with an assumed power of 85% to detect a minimum clinically significant difference in RD of 1 mm (using = 0.05) and a standard deviation of 1.1 mm. Descriptive statistics were expressed as mean±standard deviation. The normality of the data was tested by using a Shapiro-Wilk test. All data were not normally distributed and the Wilcoxon test was used to detect significant differences within and between each group before and after therapy. At baseline, the statistical significance of differences in clinical parameters and percentages of root coverage between two groups was analyzed using the Mann-Whitney U test. The baseline clinical periodontal parameters were accepted covariates and Univariant analysis was used to evaluate differences between study groups.

RESULTS

Nineteen patients (mean age 36.3±7.6, 31–43 years, 11 females and 8 males) completed all examinations throughout 12 months. In these patients, 44 Miller Class I or II recession-type defects were treated. All recipient sites in both groups were uneventfully healed concerning the postoperative period.

There was no statistically significant difference between the for patients with mandibular GRs and maxillar GRs in gender at baseline. (Table 1).

Table 1: Clinical measurements at baseline and 1 year post-surgery.

	Baseline Mean±SD	1 year Mean±SD	Baseline versus 1 year *p-value*
PI maxillary teeth	0.77±0.43	0.32±0.42	0.527
PI mandibular teeth	0.59±0.50	0.50±0.50	0.180
p-value	0.075	0.132	_
GI maxillary teeth	0.75±0.46	0.71±0.49	0.202
GI CAF mandibular teeth	0.25±0.46	0.57±0.53	0.414
p-value	0.201	0.225	_
PD (mm) maxillary teeth	1.75±1.03	1.74±0.64	0.137
PD (mm) mandibular teeth	1.71±0.49	1.28±0.48	0.206
p-value	0.431	0.647	_
CAL (mm) maxillary teeth	4.87±2.23	2.25±1.03	**<0.001**
CAL (mm) mandibular teeth	4.00±0.81	2.0±1.41	**<0.001**
p-value	0.189	0.382	**_**
RD (mm) maxillary teeth	3.12±1.95	0.37±0.74	**<0.001**
RD (mm) mandibular teeth	2.28± 0.95	0.71±0.95	**<0.001**
p-value	0.165	0.767	**_**
RW (mm) maxillary teeth	4.37±1.41	0.75±1.38	**<0.001**
RW (mm) mandibular teeth	3.14±0.89	1.28±1.70	**<0.001**
p-value	0.010	0.455	_

p<0.05 indicates statistically significant differences. PI: plaque index, GI: gingival index, PD: probing depth, CAL: clinical attachment level, RD: recession depth, RW: recession width.

The average percentage of root coverage was 76% for the mandibular GRs and 93% for the maxillary GRs. Moreover, the percentage of sites with complete root coverage was 57% and 76% respectively (Figure 1). The professional esthetic evaluation recorded the two groups presented similar RES after 12 months (in maxillary teeth 8.2± and in mandibular teeth 7.6±1.1).

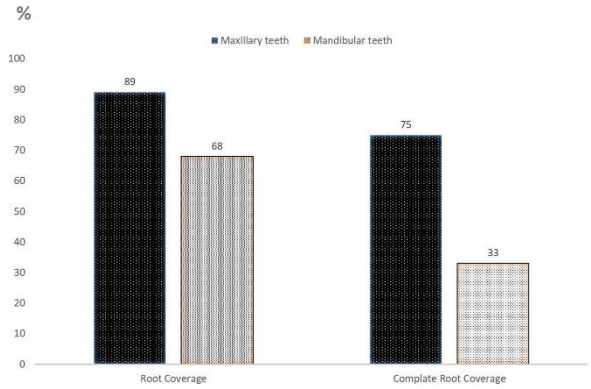

Figure 1. The percentage of root coverage and the percentage of root surfaces showing complete root coverage 1 year.

For patients with mandibular GRs, mean RD decreased from 2.28±0.95 mm to 0.71±0.95 mm, mean RW decreased from 3.14±0.89 mm to 1.28±1.7 mm, and mean CAL decreased from 4±0.81 mm to 2 ± 1.41 mm (Table 1). For patients with maxillary GRs, mean RD decreased from 3.12± 1.95 mm to 0.37± 0.74 mm, mean RW decreased from 4.37±1.41 mm to 0.75±1.38 mm, and mean CAL decreased from 4.87±2.23 mm to 2.25 ± 1.03 mm. (Table 1). For both groups, statistically significant improvements were found for RD, RW, CAL from baseline to 12 months ($P<0.05$) (Table 1).

Differences between patients with maxillary or mandibular GRs at baseline and 12 months follow-up were presented in Table1. Between groups, no statistically significant differences were found in baseline measurements. ($P>0.05$) Similarly, the differences between groups at the 12-month follow-up were not found statistically significant for all parameters ($P>0.05$). (Figure 2 and 3)

Figure 2: Multiple gingival recession treatment of the maxillary lateral incisor, canine, first premolar and mandibular lateral incisor, canine, first premolar with CAF. **a**. Preoperative view of recession,

Figure 2b. 12 months postoperative

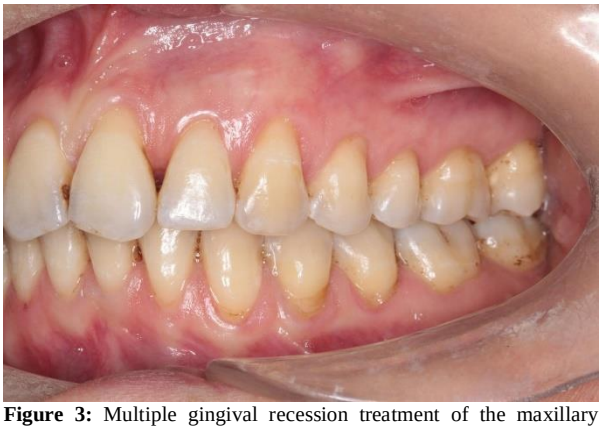

Figure 3: Multiple gingival recession treatment of the maxillary lateral incisor, canine, first premolar and mandibular lateral incisor, canine, first premolar, second premolar with CAF+ SCTG. **a.** Preoperative view of recession,

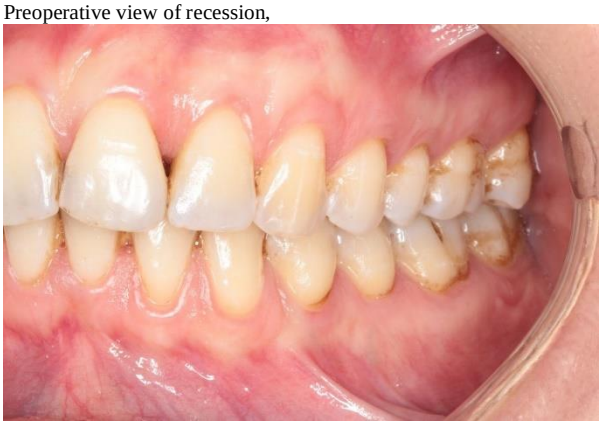

Figure 3b. 12 months postoperative.

DISCUSSION

The combination of CAF surgery with a subepithelial connective tissue graft was found to be a successful treatment to cover multiple GRs in the current study. A significant improvement in all clinical parameters was observed when the 12 months measurements were compared to the baseline values. While the mean root coverage was 89% in maxillar GRs and 68% in mandibular GRs at the postoperative results from the beginning to the last 12 months, full root coverage was obtained in 75% in maxillar GRs and 33% in mandibular GRs.

CAF therapy alone provides an average root coverage of 55-91% and is still a viable option when it comes to treating GRs.[15] The results of the present study seem to be similar to the values published by da Silva *et al*.[32] and Jepsen *et al.*[33] after treatment of the GRs with CAF+SCTG (75.3 and 72.0%, respectively). In this study, multiple GRs in the maxillary and mandibular teeth were included and the root coverage percentage was 72.2%. This percentage was detected as 89% in maxillar GRs and 68% in mandibular GRs. Evidence in the published literature has shown that the CAF + SCTG combination is the most effective and predictable surgical procedure for closing GRs defects.

The percentage of sites with complete root coverage was 33% for the mandibular sites and 75% for the maxillary sites These data lower than those reported by de Sanctis *et al*.[34] CAF+SCTG for mandibular recessions. Moreover, this data similar to published by Zucchelli *et al*.[29] for maxillary teeth. In this study, full root coverage was obtained in 22 (50%) of the 44 GR regions. Full root coverage could not be achieved in posterior teeth, possibly associated with short papilla.

The results of previous studies agree with the findings of a significant increase in CAL and a non-significant difference in PD.[31,34] Through a combination of epithelial down growth and connective tissue attachment, these findings are associated with the graft attachment to the root surface.[35]

The CAF approach was not used with vertical incisions in this study because it was proposed that better clinical results could be obtained by improved vascularization.[29] The preservation of major gingival vessels within the flap, histologically demonstrated by Mormann, increases the nutrition of the graft.[36] To our knowledge no studies are comparing the results of the treatment of an GRs of maxillary and mandibular defects without vertical releasing incisions.

Although this CAF+SCTG procedure appeared to be more effective for the maxillary than mandibular multiple recession defects, there was no statistically significant difference. Therefore, further studies with different flap designs will give an idea to clinicians.

CONCLUSIONS

Combination of the CAF surgery and SGTG was found to be as an efficient procedure to cover multiple GR defects. Much research is needed to increase the effectiveness of this CAF and SCTG procedure, especially in multiple GRs in the mandibular regions. More long-term studies with larger sample sizes are needed to evaluate the efficacy of these techniques

CONFLICTS OF INTEREST STATEMENT

The author declares no conflict of interest in this study.

ÖZ

Koronal Pozisyone Flep ile İlişkili Bağ Dokusu Grefti ile Çoklu Dişeti Çekilmelerinin Tedavisinde Diş Konumunun Etkisi

Amaçlar: *Koronale pozisyone flep (KPF) etkinliği kapsamlı bir şekilde değerlendirilmiştir, ancak diş pozisyonunun etkisine ilişkin çok az bilgi mevcuttur. Bu çalışma, dişeti çekilme defektlerinin (DÇ) tedavisinde subepitelyal bağ dokusu grefti (SBDG) ile KPF'nin sonuçlarına diş lokasyonunun etkisini değerlendirmeyi amaçlamıştır.* ***Gereç ve Yöntemler:*** *Ortalama yaşı 36,3 ± 7,6 yıl olan (11 kadın, 8 erkek) her biri Miller Sınıf I ve II DÇ'si olan 19 hasta seçildi. Kırk dört defekt, KPF ve bir SBDG kombinasyonu ile tedavi edildi. Dişeti çekilme derinliği (ÇD), dişeti çekilme genişliği (ÇG), sondllama derinliği (SD) ve klinik ataçman seviyesi (KAS) başlangıçta ve ameliyat sonrası 12. ayda kaydedildi.* ***Bulgular:*** *Başlangıçtan ameliyat sonrası 1 yıla kadar ortalama kök kapanması, maksiller DÇ'ler için %89 ve mandibular GR'ler için %68 idi. ÇD ve ÇG her iki grupta da başlangıçtan 12 aya azaldı (p <0,001), ancak maksiller ve mandibular dişler arasında istatistiksel olarak anlamlı bir fark yoktu. Her iki tedavi de tatmin edici estetik sonuçlar gösterdi (RES, üst çene dişlerinde 8,2 ± 1,3 ve alt çene dişlerinde 7,6 ± 1,1).* ***Sonuçlar:*** *Bu çalışmanın bulguları, KPF'nin çoklu DÇ'lerin tedavisi için etkili bir prosedür olduğunu göstermiştir. Ayrıca, iki grup (Alt çene ve üst çene DÇ'leri), başlangıç değerinden 12 aya kadar değerlendirmelere benzer anlamlı iyileşmeler gösterdi.*

Anahtar Kelimeler: *Bağ dokusu, dişeti çekilmesi, cerrahi flepler, diş.*

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Original research

EVALUATING THE EFFECT OF DIFFERENT LASER TYPES ON DENTIN FRACTURE RESISTANCE

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*Hüseyin Gürkan Güneç[2]
Faruk Haznedaroğlu[3]

ABSTRACT

Objectives: The aim of this in vitro study was to use fracture testing methods to evaluate the impact of the use of different laser types–particularly diode, Nd:YAG and Er:YAG lasers–on dentin fracture resistance.

Materials and Methods: Ninety human maxillary incisors were used. The teeth were divided into three experimental groups and three control groups, each containing 15 samples. The laser treatments were a diode laser for experimental group 1, a Nd:YAG laser for experimental group 2, and an Er:YAG laser for experimental group 3. The teeth were then dried and obturated using the AH-Plus sealer and RevoS AS40 gutta percha (GP). Control group 1 was obturated as in the experimental groups but without laser application; control group 2 was instrumented but not obturated; and negative control group 3 had no procedure performed at all. All samples were fixed in acrylic blocks and were subjected to fracture tests using an Autograph Universal Testing Machine. The results were analysed using IBM SPSS Statistics 22 software, one-way ANOVA test and Tukey's HSD test (to identify groups that cause a difference), with $p<0.05$ indicating statistical significance.

Results: The applied force was significantly lower for control group 2 than for the Er:YAG laser or negative control groups ($p<0.05$). The remaining groups showed no statistically significant differences ($p>0.05$)

Conclusions: The findings presented here support the conclusions that the use of Nd:YAG, Er:YAG and diode lasers in endodontic treatments has no negative impact on dentin fracture resistance and that these lasers can be used safely.

Keywords: Endodontics, laser, fracture resistance, dentin, disinfection.

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INTRODUCTION

The purpose of endodontic treatment is to sustain the function of teeth that have pulpal and/or periapical disease in a biocompatible manner. To succeed in this purpose, irrigation, instrumentation and three-dimensional hermetic obturation, known as the "endodontic triad", should be performed.[1,2]

Irrigation of the root canal system, also called chemo-mechanic preparation, is an important stage of the triad. This stage involves the use of irrigation solutions and medications, in addition to mechanical preparation. The objective of chemo-mechanic preparation is to eliminate microorganisms, vital/necrotic pulp and hard-tissue remains from the root canal system.[3-6] Studies show that, regardless of the method used for chemo-mechanic preparation, complete elimination of all the microorganisms from the system is not possible.[7-9] The reasons for this may be the extremely complicated anatomy of the root canal system or the microorganisms' resistance to traditional disinfecting agents.[10-12] Consequently, the search for a more effective disinfectant continues.

The use of lasers in endodontics, as in many other medical disciplines, has become more popular in recent years, and many studies have been conducted on this subject. Laser systems are now used in disinfection of the root canal system and of root canal instrumentation, as well as in endodontic surgery and endodontic retreatment.[13-21]

One of the commonest failures in endodontically treated teeth is the presence of cracks or fractures. Studies show that the materials and methods used in instrumentation, disinfection and obturation can negatively affect dentin fracture resistance and promote tissue loss on teeth.[22-24] The goal of the present in vitro study was to use fracture-testing methods to evaluate the impact of the use of different laser types, specifically diode, Nd:YAG and Er:YAG lasers, in combination with the traditional irrigation protocols and instrumentation, on dentin fracture resistance.

MATERIALS AND METHODS

This study was evaluated at the meeting numbered 03 in 2014 and approved by the Istanbul University Faculty of Medicine Clinical Research Ethics Committee (2014/277-368).

Ninety recently extracted, caries-free, single-root, single-canal human maxillary incisors were used. The remains of soft tissue were eliminated using a scalpel, and hard tissue was eliminated using a periodontal curette. The teeth were then refrigerated at +4 ºC in distilled water until use.

The anatomy of the root canals and the dimensions of the teeth were determined by cephalometric radiography, viewing all teeth together. Round shaped roots with similar dimensions (in terms of bucco-lingual and mesio-distal dimensions) were selected. For this purpose, the mesio-distal and bucco-lingual widths of the teeth were measured with a digital calliper (Mitutoyo Corp, Tokyo, Japan). Teeth with mesio-distal widths of 11 ± 1 mm and bucco-lingual widths of 10 ± 1 mm teeth were included in the study.

The crowns of the samples were removed and standardised to a 12 mm length at the cemonto-enamel junction. Fifteen of the samples were set aside to serve as a negative control group which received no procedure at all, and the remaining 75 were instrumented and irrigated using the same protocol. The endodontic working length was determined as 1 mm short of the apical foramen. Instrumentation was performed using Revo-S Ni-Ti rotary files (Micro Mega, France) and the X-Smart endo-motor (Dentsply, United Kingdom). Initially, a 3 mm instrumentation of the coronal side was performed using an Endoflare (Micro-Mega, Besancon, France). The roots were kept constantly filled with NaOCl (2.5%) throughout the instrumentation and were irrigated after every instrument using an endodontic irrigation syringe tip (Endo-Eze, Ultradent, South Jordan, UT) and 2 mL of NaOCl (2.5%). Subsequently the SC1, the first instrument of the Revo-S system, was used up to two-thirds of the working length, back and forth, with no pressure applied and with the parameters of 300 rpm and 1.5 Ncm of torque. The instrument was not present in the root canal for more than 10 seconds at a time. Following the use of the SC1, the next instruments (SC2, SU, AS30, AS35 and AS40) were used at the same working length and instrumentation was completed. All the instruments

were used at 300 rpm and 1.5 Ncm of torque in back-and-forth movements of 1–2 mm. The final irrigant was 5 mL of NaOCl (2.5%), followed by EDTA (17%) (Vista Dental, Wisconsin, USA), which was allowed to remain in the root canal system for 1 minute. Finally, 5 mL of NaOCl (2.5%) was again used to neutralise the EDTA. A total irrigant volume of 29 mL was maintained in all the samples. Finally, all the samples were irrigated with 5 mL of distilled water and then incubated at 37 °C in distilled water.

A power calculation was performed using an F test: Fixed effects, one-way analysis (G*Power 3.1 software; Heinrich Heine University, Dusseldorf, Germany), with $\alpha = 0.05$ for calculating the required sample size. The results indicated that the required sample size for six groups is 90 for an effect size of 0.45 and 0.90 actual power. Therefore, for each subgroup, at least 15 samples were required. Fifteen of the 90 samples received no procedure except the removal of their crowns and were labelled as the negative control group. The remaining 75 were randomly divided into five groups, including three experimental groups and two control groups, based on the procedures performed on them (Table 1).

Table 1: Experimental groups and systems

Groups	Instrumentation	Irrigation	Final Irrigation	Laser	Obturation Technique
Group 1	Revo-S AS40	2.5% NaOCl	17% EDTA 2.5% NaOCl	Diode	Single cone GP
Group 2	Revo-S AS40	2.5% NaOCl	17% EDTA 2.5% NaOCl	Nd:YAG	Single cone GP
Group 3	Revo-S AS40	2.5% NaOCl	17% EDTA 2.5% NaOCl	Er:YAG	Single cone GP
Control 1	Revo-S AS40	2.5% NaOCl	17% EDTA 2.5% NaOCl	Not applied	Single cone GP
Control 2	Revo-S AS40	2.5% NaOCl	17% EDTA 2.5% NaOCl	Not applied	Not applied
Negative Control	No	No	No	Not applied	Not applied

Group 1 (Diode Laser): These samples underwent the diode laser treatment after the final irrigation. The root canal system was filled with distilled water during the laser application. The diode laser (Gigaa Optronics Technology Co. Ltd., China) had a 200 µm fibre-optic tip and was used in continuous mode at 1.5 W and a wavelength of 810 nm. The laser application was performed at one single time from the apical to the coronal areas, with the tip placed at the working length and moved back to the coronal area over the course of 20 seconds. The laser application samples were then obturated with the single-cone gutta-percha method. The root canal system was initially dried using the Revo-S AS40 paper-point (Micro Mega, France). As a sealing agent, resin-based AH-Plus (Dentsply, DeTrey, Germany) was used according to the manufacturer's instructions. A sealer was applied to the root canal system using a Lentulo spiral filler (Pastinject, Micro Mega, France) placed 4 mm shorter than the working length and run at a speed of 500 rpm. For obturation, the Revo-S AS40 gutta percha (Micro Mega, France) was used. The apical 4–5 mm of the gutta percha was smeared with sealing agent and placed in the root canal at the designated working length. Any excess gutta percha was removed using a heated excavator at 1 mm under the canal orifice, and that 1 mm space was then filled with temporary filling material (Coltosol, Coltene; Whaledent Inc., Altstaetten, Switzerland).

Group 2 (Nd:YAG Laser): These samples underwent the Nd:YAG laser treatment (Fotona Laser, Ljubljana Slovenia, EU) after the final irrigation. The root canal system was filled with distilled water during the laser application. The Nd:YAG laser was used at 10 Hz and 1.5 W, with a 200 µm fibre-optic tip moved in a helicoidal fashion. The laser application was performed in the system for four times for 5 seconds at a time at intervals of 20 seconds, for a total of 20 seconds of laser application. The fibre-optic tip was applied from the apical to the coronal areas, at the working

length. The device was activated at the working length. Obturation then was performed as in group 1.

Group 3 (Er:YAG Laser): These samples underwent Er:YAG laser treatment (Fotona Laser, Ljubljana Slovenia, EU) following the final irrigation. The root canal system was filled with distilled water during the laser application. The Er:YAG laser was used at 10 Hz and 1 W with a 400 μm fibre-optic tip (PIPS, Fotona). The fibre-optic tip was placed at the working length and used in helicoidal movements. During the application, the laser was activated five times for 5 seconds at a time at 20 second intervals for a total of 25 seconds of laser application. The device was activated at the working length. Obturation was then performed as in group 1.

Control Group 1 (Obturated Teeth): The samples were obturated as described for experimental groups 1, 2 and 3 but without prior laser application.

Control Group 2 (Instrumented Teeth): The samples were instrumented as in the experimental groups 1, 2, 3 and control group 1 but were not obturated.

Negative Control Group (No procedure): The samples had no procedure performed on them at all. All the samples were incubated for 14 days at 37 °C and 100% humidity.

Preparation of the samples for fracture testing

The samples were placed in acrylic blocks to enable fixing onto the Universal Testing Machine. The periodontal ligament was simulated through this process, as described below.[25,26]

A key model for the acrylic blocks was obtained by preparing model stone blocks of 10 mm× 5 mm×20 mm. C-type silicone impressions were taken of these model stones, and a key model was obtained for the acrylic blocks. All the samples were then covered in a single layer of aluminium foil to create spacing for the silicone material that would be used to simulate the periodontal ligament.[25]

The acrylic resin used in the key model was prepared as instructed by the manufacturer (Imicryl, Konya, Turkey). The samples were then placed in the resin parallel to their vertical root axis, with 5 mm of the root remaining out of the resin. After resin polymerisation, the samples were removed from the resin and the aluminium foil around the tooth was removed. The space remaining within the block was filled with Express XT Light Body Quick (3M ESPE, Germany) impression material using an applicator tip. The samples were placed inside this silicone material and any excess silicone was removed using a spatula.

The samples were fixed after the polymerisation was completed. The silicone material between the sample and the acrylic block served as a simulator for periodontal ligament. The positions of the samples inside the acrylic block were as shown in Figure 1.

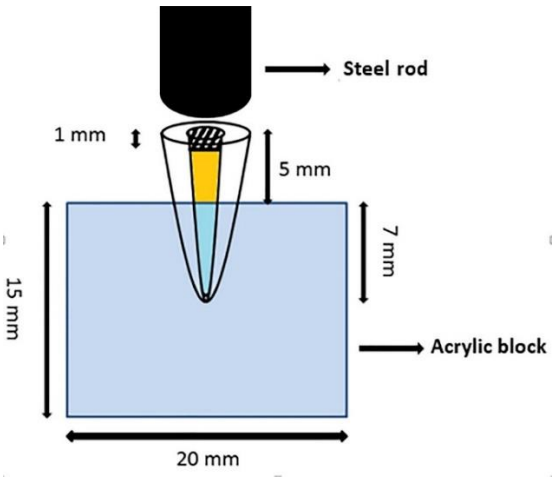

Figure 1. Positions of samples in acrylic block

Fracture Test

Fracture testing was performed using the Universal Testing Machine (Autograph AG-IS; Shimadzu Co., Kyoto, Japan).[27] Force was applied through a steel rod with a 5 mm diameter round tip.[28] Prior to the application of force, the round tip of the steel rod was confirmed to be in full contact with the sample at the centre of the coronal surface, and the steel rod was verified as being perfectly vertical and parallel to the root axis (Figure 2). The exact value of the fracture force was recorded in newtons.

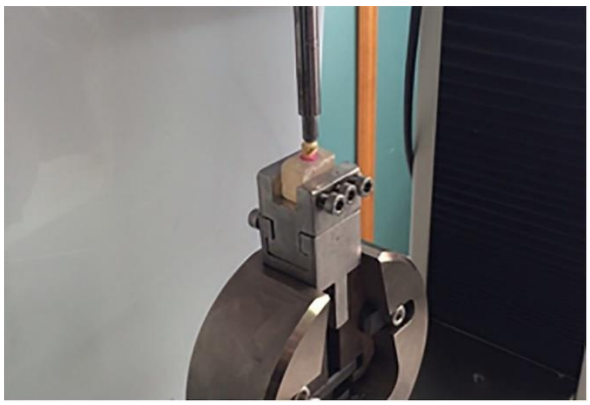

Figure 2. Fitting the acrylic block on the test device

Statistical Analysis

IBM SPSS Statistics 22 software was used to evaluate our findings. The Kolmogorov-Smirnov test was used to evaluate the normal distributions of the study data, and the parameters were confirmed to be normally distributed. A cross-group comparison of the parameters was performed using the one-way ANOVA** test, and the Tukey HDS test was used to determine the group responsible for the difference in the data. The significance was evaluated as $p<0.05$.

RESULTS

The force applied to control group 2 (instrumented, but not obturated) was significantly lower than the force applied to group 3 (Er:YAG laser) ($p<0.05$) and to the negative control (no procedure) ($p=0.011$; $p<0.05$). The remaining groups showed no statistically significant differences (Table 2) ($p>0.05$).

Table 2: Average Force Value(N)

Experimental Groups	Mean±SD	P value*
Diode laser	724.79 ± 170.52	<0.018*
Er:YAG laser	775.18 ± 190.12	
Nd:YAG laser	719.73 ± 211.14	
Control 1 (obturated teeth)	767.77 ± 140.71	
Control 2 (instrumented teeth)	598.84 ± 73.32	
Negative control (no procedure)	808.56 ± 176.16	

* p<0.05 **One-way ANOVA Test

DISCUSSION

Previous studies performed to evaluate the success of endodontic treatments have shown that vertical and horizontal fractures are among the most common causes of failure. Two studies determined vertical fracture rates of 8.8% and 13.4% for teeth that had been extracted due to endodontic failures.[29,30] Resistance to dentin fracture is reduced by NaOCl, which dissolves organic tissue.[31,32] For this reason, we treated all samples in all groups with the same volume of NaOCl during irrigation. The currently available treatments using laser systems may assist in endodontic treatments by reducing the number of microorganisms in the root canal system and removing the smear layer.[33-36]

The use of a diode laser at 1.5 W in all operation modes and at 3 W in pulse mode for 20 seconds is safe for endodontic treatments.[37] The 810 nm diode laser is safe to use at a power of up to 3 W even with thin root canal walls.[38] In light of these findings, we used the 810 nm diode laser at 1.5 W power in continuous mode for 20 seconds.

Some researchers have reported that applying a Nd:YAG laser to samples infected with *Enterococcus faecalis* at 1.5 W for 20 or 25 seconds resulted in a statistically significant decrease in the amount of bacteria in the samples. The Nd:YAG laser is also safe to use at 1.5 W power for 20 seconds.[39,40] According to these findings, we used the Nd:YAG at 10 Hz and 1.5 W for 20 seconds.

Studies by Schoop *et al.*[41] demonstrated that the Er:YAG laser need not be used at more than 1 W to eradicate most of the endodontic bacterial species. Furthermore, SEM imaging showed that samples treated with a laser at 1 W laser in the root canal system had clearly observable dentin tubules, while the smear layer was completely removed. The thermal changes caused by the use of lasers at

4 Hz, 6 Hz and 10 Hz frequencies had no negative impact on dentin, and the thermal increase caused by Er:YAG laser was within acceptable limits.[42,43] For these reasons, we used the Er:YAG laser at 10 Hz and 1 W power for a total of 25 seconds.

The findings of the present study revealed no statistically significant differences in the dentin fracture resistance between groups treated with a diode laser, Nd:YAG laser or Er:YAG laser and control group 2 ($p>0.05$). In parallel with these findings, Braun *et al.*[44] and Faria *et al.*[45] found that laser application with different parameters (970-nm, 1.5 W/100 Hz and 3 W/100 Hz) also had no effect on dentin fracture resistance, even if the irrigation solutions varied. However, opposite results were reported by Karatas *et al.*[46] after the use of a diode laser at 3 W/100 Hz. This result may be related to the presence of EDTA solution in the root canal when the laser was applied. Similar results were observed in the study of Ayrancı *et al*.[47]

In the current study, control group 2 showed significantly lower dentin fracture resistance compared to the negative control group ($p<0.05$). Control group 1 showed values between control group 2 and the negative control group, but no significant differences were detected between control group 1 and either group ($p>0.05$). These findings were consistent with those of Sandıkçı and Kaptan,[48] who concluded that instrumentation renders a tooth physically weaker.

The groups that were instrumented and obturated (diode laser, Nd:YAG laser, Er:YAG laser and control group 1) showed no statistically significant difference in their average fracture force values. Conversely, the samples that were obturated and treated with the Er:YAG were significantly more resistant to fracture than were the teeth that were instrumented but not obturated (control group 2) ($p<0.05$). The studies by Hibst and Keller[49] and by Firoozmand *et al.*[50] concluded that Er:YAG laser application does not cause a thermal increase capable of morphological dentin changes. In the present study, we considered that the cause of this difference might be the obturation in the Er:YAG group, which would increase the fracture resistance over that found in the teeth that were not obturated.

The findings of the current study show that laser systems do not have a negative impact on dentin fracture resistance. This may be related to the fact that lasers do not change the dentin structure if they are not used at a high-power output.

CONCLUSIONS

The findings of this study indicate that the use of lasers (diode, Er:YAG, or Nd:YAG lasers) in endodontic practice, in conjunction with traditional final irrigation protocols to eliminate the smear layer, does not negatively impact dentin fracture resistance. Consequently, these lasers can be used safely. Further study of these lasers in more intense uses, such as instrumentation, would be useful for predicting their effects in other situations.

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Original research

EFFECT OF TRIBOCHEMICAL SURFACE TREATMENT TECHNIQUE ON THE PUSH-OUT BOND STRENGTH OF NOVEL CAD/CAM POST RESTORATIONS

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ABSTRACT

Objectives: The purpose of this study was to investigate the effect of tribochemical surface treatment (TBC) on the push-out bond strength (PBS) of novel CAD/CAM post materials to root canal dentin.

Materials and Methods: Fifty-two freshly extracted human maxillary central incisors were selected and endodontically treated. The teeth were randomly divided into 7 groups according to the post material used: fiber-reinforced composite post as control (FRC), zirconia (ZR), lithium disilicate (LDS), zirconia-reinforced lithium silicate (ZLS), nano-ceramic (RMC_CE), nanoparticle-filled (RMC_LU), and polymer-infiltrated-ceramic (RMC_EN). Then the posts, except FRC, were randomly assigned into two sub-groups according to the surface treatment technique used: Control (no treatment), TBC (CoJet). Following post space preparation, posts were cemented with dual-cure self-adhesive resin cement. A total of 156 sections were obtained (n=12), 3 sections on each root of the tooth. The PBS test was performed for each slice and the results were analyzed by using two-way ANOVA and Tukey HSD tests (α=0.05). The fracture modes were examined.

Results: The lowest PBS values were obtained for ZR post groups that untreated (17.24±1.33 MPa) and tribochemical coated (23.09±2.16 MPa) (p<0.05). The highest PBS values were obtained for untreated RMC_CE (42.45±2.42 MPa) and RMC_LU (45.22±2.32 MPa) groups (p=0.215) and, tribochemical coated RMC_CE (43.55±2.63 MPa) and RMC_LU (45.38±2.59 MPa) groups (p=0.821). Significant differences were observed between the remaining post groups (p<0.05). Tbc has been significantly increased the PBS values of LDS, ZLS, and ZR post groups (p<0.05). Adhesive failure was the most common failure mode. (n=78).

Conclusion: The results of this study proved that the PBS values of the CAD/CAM RMC post groups were higher than the FRC, ZR, LDS, and ZLS post groups, and TBC increased the PBS values of all CAD/CAM post groups.

Keywords: CAD-CAM, post-restorations, push-out bond strength, surface treatment.

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INTRODUCTION

Intracanal post-and-core restorations are required to ensure long-term restorative success in endodontically treated teeth where more than 50% of the coronal structure is damaged.[1] Post systems can be classified as cast, prefabricated, and milled according to the technique used.[2] Cast or prefabricated metallic posts have been used for decades. However, metal-free post materials have become more common due to the increasing esthetic demands of the patients.[3] Prefabricated fiber-reinforced composite (FRC) post materials show an elastic modulus (about 20 GPa) similar to dentine (about 18.6 GPa), which reduces the fracture probability of weakened root compared to metal posts.[2,4] In parallel with the development of Computer-Aided Design/Computer-Aided Manufacture (CAD/CAM) technology, various materials are available, such as metal, glass fiber, zirconia, ceramics, resin-composites, and hybrid materials, as post-and-core restorations. Zirconia (Y-TZP) materials are popular for post restorations especially in the anterior region due to aesthetic reasons instead of metallic posts.[5] Besides, they have higher fracture strength, toughness, and chemical stability than FRC post systems.[6-8] Previous studies have reported that the fracture resistance of endodontically treated teeth may be increased by using Y-TZP post restorations by their superior physical and mechanical features.[7,8] However, the higher elasticity modulus of Y-TZP material (about 300 GPa), when compared to the dentin, is the main disadvantage that may cause unfavorable force distribution and root fracture.[9] Another disadvantage of the Y-TZP post is the difficulty in removing it from the root canal when a failure occurs with the indication of retreatment.[6,7] Furthermore, Y-TZP has inadequate bonding capacity to resin-based materials and dentine tissue.[4] Due to these disadvantages, different CAD/CAM restorative materials, especially with lower elasticity modulus than Y-TZP, are investigating for post-and-core restorations in the anterior region.

Lithium disilicate (LDS) glass-ceramic CAD/CAM restorative materials with the elastic modulus of 90-100 GPa have been successfully used in clinics for many years.[10] The proven clinical performance of LDS encourages the manufacturers to development of its modifications such as reinforcing with polycrystalline ceramics. Zirconia-reinforced lithium silicate (ZLS), such as VITA Suprinity (VITAZahnfabrik, Bad Sackingen, Germany), is one of the current commercial examples, which combines the superior characteristics of glass-ceramic and Y-TZP materials. Besides their superior mechanical properties, they have provided exceptional aesthetics results due to their similar optical features with natural dentition and show an elastic modulus of 70 GPa.[6,10]

Recently, the CAD/CAM resin matrix ceramic (RMC) materials, which include the composite resin nano-ceramic (RMC_CE, Cerasmart, GC Dental Products, Tokyo, Japan), nanoparticle-filled ceramic (RMC_LU, Lava Ultimate, 3M ESPE, Seefeld, Germany) and polymer-infiltrated-ceramic-network (RMC_EN, Vita Enamic, Vita Zahnfabrik, Bad Sackingen, Germany), have been developed to combine the positive features of both ceramics and polymers. RMCs have some superiorities compared to ceramic materials such as easier milling and adjustment, similar elasticity modulus to dentin (10~20 GPa), higher fatigue or fracture resistance, fewer crack propagations, better stress distribution, and less wear for opposing teeth.[6,11] While most of these restorative materials are already being used as core material, their performance as a post-and-core restoration has not been evaluated.

In addition to the good mechanical features of the post material, the bonding strength to root dentin is also an important criterion for the post-and-core restorations. The achievement of long-term successful bonding is influenced by various factors, such as the type, shape, size, and surface of posts, adhesive coupling agent, resin cement, and the surface of root dentin.[12] However, there is little information about the currently available CAD/CAM post materials bonding strength to the root dentin. Therefore, in this study, the push-out bond strength (PBS) of post materials (with and without additional surface treatment) to root dentin that fabricated with currently available CAD/CAM restoratives have been evaluated. The null hypothesis of this study was that the PBS of CAD/CAM post restorations would

not differ with the type of material and also with additional surface treatments.

MATERIAL AND METHODS

The present study was permitted by the Local Clinical Research Ethics Committee of the Ordu University (#2020/232). The sample size of the PBS test was calculated using a power analysis (G*Power 3.1.9.2, Düsseldorf, Germany) that an alpha error probability of 0.05 and a power of 97.05%. It has been shown by power analysis that 10 samples (effect size = 0.408) were required for each test group.

Fifty-two freshly extracted single-rooted human permanent maxillary incisor teeth with no cracks, caries, restoration, and no shorter roots than 12 mm were selected. All teeth were decoronated 2 mm coronal to the cement-enamel junction using a diamond bur (SWS Dental, İzmir, Turkey) under copious water maintaining root length at 10 mm. The remaining root canals of the tooth were prepared up to size R50 file with the Reciproc system (VDW, Munich, Germany). The root canals were irrigated with 5 mL 5% sodium hypochlorite and 5mL of 17% ethylenediaminetetraacetic acid, between the use of each canal instrument. The final irrigation has been performed with 5 mL distilled water and dried with absorbent paper tips (Reciproc Paper Point, VDW, Munich, Germany). The root canals were obturated with a gutta-percha (VDW, Munich, Germany) and AH Plus sealer (Dentsply, Konstanz, Germany) via lateral condensation. The access openings of the canals were also sealed with a temporary filling material (Cavit, 3M ESPE, Neuss, Germany) and all specimens were kept in 100% humidification for 7 days at 37°C. The filling material in root canals has been removed with a Peeso Reamer canal drill set up to size #3 (Mani, ZZlinker, Shingai), leaving only a 3-mm apical root filling intact. The final shapes of the root canals were enlarged with the FRC post systems drill set (Cytec Blanco, Hahnenkratt GmbH, Königsbach, Germany) up to a blue drill with a diameter of 1.8 mm at the coronal part. Then, the root canals were irrigated with 5 mL distilled water and dried.

The FRC post with a diameter of 1.8 mm at the coronal part and a length of 20 mm has been shortened to the length of 10 mm from the coronal part and served as the control group. One of the FRC post specimens has been digitally scanned using a dental lab scanner (Ceramill map600, Amann Girrbach, Koblach, Austria), and the digital post design performed using CAD software (Ceramill Mind, Amann Girrbach, Koblach, Austria) for the fabrication of other post specimens. Then the CAD/CAM post specimens have been manufactured using a milling machine (Ceramill Motion 2, Amann Girrbach, Koblach, Austria) from the CAD/CAM blocks listed in Table 1.

Table 1. The post materials (composition), manufacturers, and lot numbers of the test groups.

Group	Material (Composition)	Manufacturer	Lot Number
FRC	Cytec Blanco; glass fiber post system (60% glass fiber, 40% epoxy resin matrix)	Hahnenrratt GmbH,	027656
LDS	IPS e.max CAD; lithium disilicate-reinforced glass-ceramic block (SiO_2-Li_2O-K_2O-MgO-P_2O_5- Al_2O_3)	Ivoclar Vivadent	U49077
ZLS	Vita Suprinity; zirconia-reinforced lithium silicate glass-ceramic (SiO_2-Li_2O-K_2O-P_2O_5-Al_2O_3-ZrO_2-CeO_2)	Vita Zahnfabrick	47610
ZR	In Coris TZI; high-translucent monolithic zirconia block (99% ZrO_2-HfO_2-Y_2O_3, <.5% Al_2O_3, <.5 %SiO_2)	Sirona Dental Systems	2014211887
RMC_CE	Cerasmart; composite resin nano-ceramic RMC block (71 wt% SiO_2-barium glass, 29 wt% UDMA, DMA, Bis-MEPP)	GC Dental Products	1410071
RMC_LU	Lava Ultimate; nanoparticle-filled RMC block (80 wt% SiO_2-ZiO_2, 20 wt% Bis-GMA, UDMA, Bis-EMA, TEGDMA)	3M ESPE	3314A2
RMC_EN	Vita Enamic; polymer-infiltrated-ceramic-network RMC block (86 wt% SiO_2-Al_2O_3-Na_2O-K_2O-B_2O_3-ZrO_2-CaO, 14 wt% UDMA, TEGDMA)	Vita Zahnfabrick	68251

UDMA: Urethane dimethacrylate; DMA: Dodecyl dimethacrylate; Bis-MEPP: 2, 2-Bis (4-methyacryloxypolyethoxyphenyl) propane; Bis-GMA: Bisphenol-A-glycidyl methacrylate; Bis-EMA: Bisphenol-A-ethoxylate glycidyl methacrylate; TEGDMA: Triethylene glycol dimethacrylate.

After the milled post specimens' dimensions have been controlled, the LDS and ZLS post specimens crystallized, and the Y-TZP post specimens (ZR) sintered according to the manufacturer's introductions. Then, each post group was randomly divided into two subgroups according to surface treatment procedures; no further treatment was applied, and the tribochemical silica-coated (TBC). TBC was not applied to the FRC post system that was selected as the control group. The TBC CAD/CAM post specimens have been tribochemical coated with silica-modified 30 µm aluminum oxide (SiO_x-Al_2O_3) (Cojet Sand, 3M ESPE, Seefeld, Germany) under 2.5 bar pressure for 15 seconds using an intraoral sandblaster (Prophyflex 3, KaVo Dental GmbH, Biberach, Germany). A 3 methacryloxypropyltrimethoxysilane coupling agent (3M Espe Sil, Minnesota, USA) was applied onto the surface of all CAD/CAM post specimens and waited for 5 min to dry according to the manufacturer's recommendations.

A self-etch bonding agent (Clearfil SE Bond 2, Kuraray Noritake Dental, Okayama, Japan) was applied onto the root dentin of each group according to the manufacturers' instructions [Clearfil SE Bond 2 Primer applied using the micro brush (20 s) and dried with mild air (5 s), the mixture of Clearfill SE Bond 2 Bond and Clearfil DC Activator applied using the micro brush and dried with mild air]. A dual-cure self-adhesive resin cement (Panavia SA Plus, Kuraray Noritake Dental, Tokyo, Japan) has been loaded into the root canal using automix tips according to the manufacturers' instructions and the post specimens were quickly seated into the root canals under finger pressure. The excess cement was partially light-cured for 5 seconds with an LED light-curing unit (Valo Led, Ultradent, South Jordan, USA) at 1000 mW/cm^2 for easy removal, and the remainder light-cured for 40 seconds top of the post. All specimens were stored at 100% humidity in an incubator at 37°C for 24 hours. Then, the roots of the tooth were perpendicularly embedded into an auto-polymerizing acrylic resin block (Panacryl, Arma Dental, Istanbul, Turkey) using a cylindrical Teflon mold (Ø=25 mm, h = 20 mm). The acrylic blocks horizontally cut into six slices using a precision cutting machine (Mecatome T180, Presi Metallography, Eybens, France) under copious water to obtain 1-mm sections. The 2nd, 4th, and 6th slices were selected for the PBS test (N=156, n=12) and the apical side of each slice was marked.

Each root slice has been mounted on a universal testing device (AGS X, Shimadzu Corp., Tokyo, Japan) and subjected to increasing load at a crosshead speed of 0.5 mm/min in the apical-coronal direction until failure occurred. A load of failure was recorded in Newton (N), and the PBS values were converted to MegaPascal (MPa) by dividing the failure load to the bonded area (mm^2). The total bonding area was calculated as $(\pi(r1 - r2)\sqrt{(r1 + r2)^2 \times h^2})$, where π: is the constant 3.14, r1: is the radius of the post from the upper part of the specimen, r2: is the radius of the post from the lower part of the specimen, and h: is the height of the specimen. The mode of failure was assessed at x25 magnification in a stereomicroscope (Leica SP1600, Leica, Wetzlar, Germany), classified into three groups; adhesive (between the post and the cement or the dentin and the cement), cohesive (within the resin cement), and mixed failure (a mixture of adhesive and cohesive).

According to Leneve's homogeneity test, the groups were normally distributed (F = 1.353, p = 0.196). The PBS results were evaluated with the two-way analysis of variance (ANOVA) for descriptive statistics and the effects of independent variables (surface treatment, post type, and their interaction). The mean PBS values (MPa) of the post groups were multiply compared by using the Tukey HSD test (α = 0.05). The pairwise comparisons of the same surface treatment applied post type groups were performed by using the Paired Sample t-test. The PBS values of each post group have been allocated for coronal, middle, and apical regions and these subgroups were multiply compared by using the Tamhane's test. All the computational work was performed using SPSS 20.0 V statistical software (SPSS Inc., Chicago, IL) and significance was evaluated at $p < 0.05$ for all tests.

RESULTS

According to the 2-way ANOVA results post type, surface treatment, and their interactions were significant on the PBS values ($p < 0.001$) (Table 2).

Table 2. Two-way ANOVA results of PBS values.

Source	SS	df	MS	F	P
Post Type (A)	11531.320	6	1921.887	327.830	.000
Surface Treatment (B)	379.600	1	379.600	64.751	.000
A X B	222.682	5	44.536	7.597	.000
Error	838.330	143	5.862		
Total	198737.887	156			

*p<0.05 indicates a significant difference.

The mean, standard deviation (SD) of PBS values (MPa) of test groups, the Tukey HSD multiple comparisons, and pairwise comparisons results according to the Paired Sample t-test are presented in Table 3.

Table 3. The mean, standard deviation (SD) of PBS values (MPa) of test groups with statistical summaries.

Surface Treatment Post Type	N	None	TBC	t-Test*
FRC	12	34.85 (2.41)^{d}	-	
LDS	12	30.39 (2.1)^{c}	34.77 (3.11)^{d}	*P*<.001
ZLS	12	23.46 (2.2)^{b}	30.09 (2.46)^{c}	*P*<.001
ZR	12	17.24 (1.33)^{a}	23.09 (2.16)^{b}	*P*<.001
RMC_CE	12	42.45 (2.42)^{fg}	43.55 (2.63)^{g}	*P*=.300
RMC_LU	12	45.22 (2.32)^{g}	45.38 (2.59)^{g}	*P*=.877
RMC_EN	12	38.39 (2.38)^{e}	39.77 (2.92)^{ef}	*P*=.218

The Tukey HSD comparisons of PBS values (MPa) for the post types in same surface treatment application groups are presented as superscripts and significant differences indicate with different letters (p<0.05). *The pairwise comparisons of PBS values (MPa) for the same surface treatment applied post type groups according to the Paired Sample t-test (p<0.05).

The lowest PBS values were obtained for the ZR post group not only for untreated (17.24 ± 1.33 MPa) but also TBC surface treatment applied (23.09 ± 2.16 MPa) groups (p < 0.05). When untreated post groups were multiply compared; the highest PBS results were obtained for RMC_CE (42.45 ± 2.42 MPa) and RMC_LU (45.22 ± 2.32 MPa) groups with no significant difference (p = 0.215). Significant differences were also observed between the remaining post groups (p<0.05). When TBC surface treatment applied post groups were multiply compared; similarly the highest PBS results were obtained for RMC_CE (43.55 ± 2.63 MPa) and RMC_LU (45.38 ± 2.59 MPa) groups with no significant difference (p = 0.821). Also, significant differences were observed between the remaining post groups (p < 0.05).

While the additional surface treatment with TBC has been increased the PBS values of all CAD/CAM post groups, these differences were statistically significant for LDS, ZLS, and ZR post type groups according to the pairwise comparisons with Paired Sample t-test (p < 0.05).

According to the multiple comparisons of root regions for each post group, the PBS of the coronal region (18.70~47.74 MPa) was significantly higher than the apical region (16.39 ~ 43.42 MPa) for each post group (p<0.05). A significant difference has been detected between the PBS values of coronal and middle regions for untreated ZR and RMC_LU; between the PBS values of middle and apical regions for untreated RMC_CE and RMC_EN and TBC surface treatment applied ZR, ZLS, RMC_LU, RMC_EN post groups (p< 0.05) (Fig. 1).

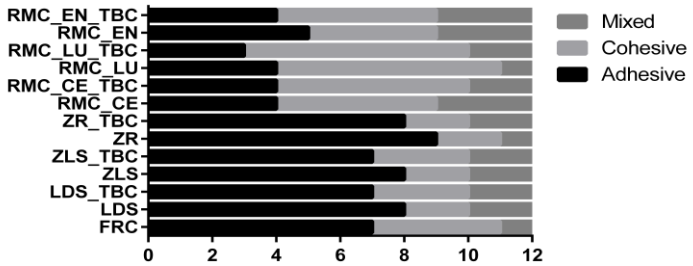

Figure 1. The mean (±SD) of PBS values of root region groups. *Significant differences between the related root region according to the Tamhane's test (p<0.05).

The results of the failure modes of the test groups were presented in Table 4.

Table 4. Failure modes of experimental groups

Groups	Adhesive	Mixed	Cohesive	Total
FRC	7	1	4	12
LDS	8	2	2	12
LDS_TBC	7	2	3	12
ZLS	8	2	2	12
ZLS _TBC	7	2	3	12
ZR	9	1	2	12
ZR_TBC	8	2	2	12
RMC_CE	4	3	5	12
RMC_CE_TBC	4	2	6	12
RMC_LU	4	1	7	12
RMC_LU_TBC	3	2	7	12
RMC_EN	5	3	4	12
RMC_EN_TBC	4	3	5	12
Total	**78**	**26**	**52**	**156**

The most commonly observed failure mode was an adhesive failure (n = 78), followed by cohesive (n = 52) and mix failure (n = 26).

DISCUSSION

In this study, endodontically treated maxillary incisors were restored with FRC and various novel CAD/CAM materials, and the PBS and fracture modes were evaluated. According to the results of the present study, the post type, and also the surface treatment has been affected the PBS values. Therefore, the null hypothesis was rejected.

The developments and researches about the ideal post-restoration material are also focused on the novel CAD/CAM restorative materials. Therefore, the PBS of post restorations made of novel CAD/CAM materials has been evaluated in the present study. The FRC post systems are commonly used for the restoration of endodontically treated, considering their restrictions, thus served as the control group of the present study.

The untreated RMC post groups showed statistically higher PBS values than the FRC post

group. The recently introduced RMC materials have not only the physical and mechanical advantages of ceramics but also improved flexural properties and the higher bonding capacity of composite resins.[11,13] RMC materials have a composite structure that consists of both organic matrix and highly filled ceramic particles with a bridgework silane agent.[13,14] The higher PBS results of RMC materials in the present study may be explained by their mechanical advantages and improved bonding performance. The RMC_EN showed the lowest PBS values compared to RMC_CE and RMC_LU post groups, and no significant differences were obtained between RMC_CE and RMC_LU. The effect of different surface treatments on the bond strength of CAD/CAM fabricated RMC post systems to root canal dentin has been evaluated in a previous study and reported that although no significant difference was observed between post types, while the Cerasmart post group achieved the highest bond strength values (12.54±3.08 MPa), the Vita Enamic post group showed the lowest bond strength values (9.71±1.67 MPa). It has been attributed to the variations in the chemical composition and the inorganic filler ratio of these RMC materials in this previous study.[15] In the present study, the RMC_EN has the highest ratio (86 vol%) of the inorganic filler (porous feldspathic ceramic) contain that strengthened by an interpenetrating polymer matrix when compared to the ratio of RMC_LU (80% by weight) and RMC_CE (71 vol%).[13]

The untreated ZR, ZLS, and LDS post groups have statistically lower PBS values than the FRC post group. On the other hand, the untreated ZR post group has the lowest PBS value (17.24±1.33 MPa) among the all tested post groups. This result could be attributed to the lack of a silica-containing and glass phase of zirconia restorative material that the untreated high crystalline ceramics may not enough bonding performance to resin-based materials. In agreement with this result, the untreated LDS post group showed statistically higher PBS values than the ZLS post group in this study. So, it could be concluded from this result that the increased crystalline content (8-12%), which improves the mechanical behavior of the material, may also weaken the bonding performance of lithium disilicate ceramic materials.[16]

The airborne particle abrasion (sandblasting) with Al_2O_3 particles enhances the bond strength of ceramics by increasing the surface roughness, wettability, and surface energy. Furthermore, the tribochemical silica coating techniques with SiO_x - Al_2O_3 particles, such as the Cojet system (3M ESPE, Seefeld, Germany), not only change the surface morphology but also enhances the chemical connection with bonding agent with the penetrated silica particles and further silane application on the ceramic surface.[17] On the other hand, some studies showed that RMCs should be effectively bonded to the resin-based materials after the hydrofluoric acid (HF) etching technique.[18-21] Since HF etching was declared questionable by the manufacturers of RMC, the TBC surface treatment technique with 30 µm SiOx - Al_2O_3 particles were used for all tested CAD/CAM post materials in this study. After the TBC surface treatment procedure, the silane coupling agents are commonly used to gain additional chemical retention with silica-coated alumina particles which may be buried into the ceramic surface.[22] As expected, the TBC post surface treatment was increased the PBS results of all CAD/CAM post groups. However, this increase was only significant for the LDS, ZLS, and ZR post groups, compared to the untreated ones. According to this result, which was also proven in many previous studies,[23,24] the TBC followed by the silanization technique may significantly increase the bond strength of ceramics by increasing the silica content on the materials, especially for high crystalline ceramics. The RMC materials with integrated polymer components do not require additional TBC surface treatment application, and silanization with a 3-methacryloxypropyltrimethoxysilane coupling agent may be enough to obtain sufficient bond strength results.

In the present study, the PBS values for all groups were significantly higher for the coronal region than the apical region. This situation depends on the density and distribution of the dentil

tubules in different parts of the root. It is known that the dentinal tubules in the coronal region are numerous and larger in diameter than the apical region.[25] It also reduces bond strength in limited access to the apical region.[26]

According to the push-out bond test and failure mode analysis performed in the present study, an adhesive failure between the resin cement and the post interface was the most frequent type of failure reported for LDS, ZLS, and ZR post groups. Cohesive failure within the resin cement was the most frequent type of failure reported for RMC post groups. For the FRC post, the most frequent type of failure was adhesive failure between the resin cement and dentine (Fig. 1).

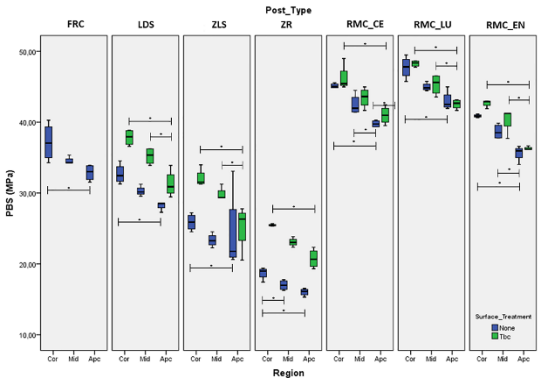

Figure 2. The failure mode of the debonded specimens.

The modes of failures observed in the present study reveal that the surface adhesion properties of the high-density ceramic post systems may be weaker than those of FRC and RMCs post materials, leading to more failures at the interface level between the post and cement.

Various test methods such as microtensile, pull-out and push-out tests can be used to evaluate the bond strength of post restorations to root dentin[27-29].The microtensile test has been highly associated with large data distributions as well as numerous premature failures during sample preparation which is complex and difficult.[30,31] In the pull-out test, regional differences have no effect on the results, as enable the evaluation of the entire root length. Possible failures in the specimen preparation phase can be avoided by not sectioning post cemented roots.[32] However, the bond strength values of the root regions cannot be compared in this test method and a large number of samples are needed. Unlike, in the push-out test it is possible to analyze the cervical, middle, and apical root regions.[29] It is easy to prepare samples and therefore has a low standard deviation rate. The push-out test can provide a more accurate and better estimation of bonding strength because failure occurs in parallel to the bonding area as in oral condition.[31,33] Because of the mentioned advantages, the bond strength of tested post materials to the root dentine had been evaluated using the push-out test in the present study.

The present study has some limitations; PBS of CAD/CAM made post restorations using six different ceramic materials with and without additional surface treatment had been evaluated and compared with FRC posts. The bonding performance of post restorations may significantly improve by using various micromechanical and chemical surface conditioning techniques.[12,15,22] All of the post restorations had been designed in a standard conical shape, smoothbore texture, and a coronal diameter of 1.8 mm. However, the long-term performance of CAD/CAM made post restorations, in various dimensions, design and material parameters may be further investigated in future studies after different surface treatments such as acidic solutions, laser, or plasma applications. In the present study, a chairside type (Cojet) of TBC treatment with 30 µm SiOx - Al_2O_3 particles was used, but a laboratory type TBC treatments (Rocatech or Rocatech Plus) with 50 - 110 µm SiOx-Al_2O_3 particles in various application parameters should be evaluated in future studies. A dual-polymerized and 10-methacryloxydecyl dihydrogen phosphate (MDP) containing bonding agent, and resin cement systems that have been declared with superior bonding results[34,35], were used in the present study. However, other bonding agents and resin cement systems with different application procedures and monomer contain should be evaluated after dynamic, thermal, and hydraulic aging conditions in future studies.

CONCLUSIONS

Within the limitation of this study, the following conclusion should be drawn;

1. The CAD/CAM made RMC post restorations have more sufficient bond strength results to the root dentine than FRC post restorations.

2. Additional TBC surface treatment application is not required for RMC post materials.
3. While the PBS results of LDS, ZLS, and ZR post restorations may be increased with TBC surface treatment, their PBS results were lower than the FRC post group.

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CONFLICT OF INTEREST
The authors declare that they have no competing interest.

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Original research

THREE-DIMENSIONAL CALCULATION OF SINUS AUGMENTATION VOLUME AFTER MAXILLARY SINUS FLOOR ELEVATION

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ABSTRACT

Objective: This study aimed to calculate the volume of the maxillary sinus and grafted part of it with different modes of three-dimensional reconstruction software.

Materials and Methods: This retrospective volumetric cone-beam computed tomography study was carried out on 21 patients/ 36 maxillary sinuses who had undergone maxillary sinus lift surgery using a lateral approach, between 2010 and 2016 at the Department Periodontology. All statistical analyses were performed by using the NCSS (Number Cruncher Statistical System, Kaysville, Utah, U.S.A.) software. P values <0.05 were considered to indicate statistical significance.

Results: The mean volume of the right maxillary sinus cavity was 15.37 cm^3 while for the left it was 15.90 cm^3. There was no statistically significant difference between right and left maxillary sinus volumes ($p>0.05$). An occupied portion of the sinus cavity after lateral sinus floor elevation surgery was approximately 14.87 %. Furthermore, the volume through manual and automatical modes of the software do not affect the results ($p>0.05$). The right and left sides of the maxillary sinus volumes were not different from each other. Gender and measuring mode was not found to be related to volumetric values of the maxillary sinus cavity.

Conclusions: The grafted volume of the sinus cavity was defined as a safe volume in terms of serious complications during and after the surgery.

Key words: Sinus floor elevation, maxillary sinus volume, cone-beam computed tomography, dental implant, Schneiderian membrane.

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INTRODUCTION

The maxillary sinus is the largest of the paranasal sinus with pyramid-shaped cavity between the nasal wall and zygoma.[1] The cavity extends from premolar area to the first molar region, and average volume of it is approximately 12 to15 cm3.[2,3] The pneumatization of the maxillary sinus varies from patient to patient, and increases with age in the edentulous areas towards the alveolar process.[4]

Alveolar bone resorption and sinus pneumatization can compromise immediate implantation in the posterior maxilla.[5] Different sinus floor elevation techniques have been used since 1980 to restore this anatomic deficiency before the implant surgery.[6,7] Among these techniques, lateral sinus floor elevation (LSFE) has been recommended in sites with insufficient residual bone height (RBH).[8] LSFE ensured the reconstruction of bone deficiencies of the sinus cavities with high clinical success rates, allowing implantation in that region safer and more predictable.[9]

Moreover, volumetric knowledge of the maxillary sinus cavity and grafted part of it is crucial for the practitioners in choosing the surgical method and evaluate the success of the procedure. The various effects of LSFE on maxillary sinus physiology were evaluated in this retrospective study. Maxillary sinus physiology might also be affected by the volumetric changes after sinus surgeries. It has been established that the risk of Schneiderian membrane perforations is greatly correlated to the membrane thickness.[10,11] One of research objectives was to analyze the change of thickness of the Schneiderian membrane and gingival thickness before and after LSFE.

Several radiological and clinical studies have reported promising data through panoramic radiography, spiral computerized tomography (CT), cone-beam computed tomography (CBCT), magnetic resonance imaging (MRI) to provide volumetric information of the sinus cavity.[12-15] Among these methods, the application of CBCT in exploring paranasal sinuses has rapidly become a popular tool by supporting scientific and technologic advances.[16] CBCT was accepted very efficient, affordable, and relatively safe method for evaluating maxillary sinus cavity. One of the main points of this study to define a safe volume of the sinus cavity to avoid any serious complications during the surgery. The present radiographic study observed total volume of the sinus cavity and the grafted part of the cavity after LSFE procedure. Another aim of the study is to compare the volumetric values obtained by manual and automatic volumetric measurements.

MATERIAL AND METHODS

Patient selection

The study included the radiographic data of 21 patients, 36 maxillary sinuses. During the period from 2010 to 2016, these patients had undergone CBCT investigations before maxillary sinus lift (MSL) using bone biomaterials at the Department of Periodontology. Fifteen patients (71.4%) underwent bilateral LSFE surgery. LSFE surgeries were carried out at the same department. According to the patients' records, in all sites, pre-surgical bone height was lower than 5mm and a staged surgical approach was necessary.[17,18] Thirty-six maxillary sinuses which underwent maxillary sinus lifting surgeries with the application of bone substitutes were defined as research subjects. Collagenated heterologous bone graft derived (Large granules, 1-2mm, Apatos, Osteobiol®, Tecnoss, Coazze, Italy) was used to fill the antrum. The length of the paced implants into the augmented sinuses were between 10-12 mm. No perforation of the sinus membrane or any other clinical complications such as postoperative sinusitis, ostium obstruction were present in the patient records. The study did not address patient's general health condition at the time of examination and surgery, as well as the elapsed time between tooth loss, MSL and the smoking factor. The study was approved by the Local Research Ethics Committee of YYY (Decision date: 07/11/2017, decision number: 1511), and the protocol of the study was conducted following the principles of the Declaration of Helsinki.

Imaging procedures

Radiological investigation for pre–surgical planning and post–surgical evaluation purposes were performed using CBCT device I–CAT Next Generation (Imaging Sciences International, Hatfield, PA, U.S.A.). All patients were investigated following a unified protocol. All

included patients' second radiographs were taken because of different diagnostic purposes other than the sinus surgery. Radiographic records of the patients showed the same scanning parameters: diameter – 16 cm, height – 13 cm, scanning time – 8 to 9 seconds, power – 120 kV, 5 mA. Images were obtained using 0.3 voxel (three–dimensional image volume unit) size. Images were processed and reconstructed by Three Dimensional (3D) Synapse Software (Fujifilm, Tokio, Japan). Before taking measurements, an image was positioned so that the plane of the hard palate was parallel to the floor while the sagittal plane was perpendicular to the floor. Each volumetric data was measured twice (in automatic (Fig. 1) and in manual mode (Fig. 2) and recorded in cubic centimeters (cm^3).

Figure 1. Total sinus volume measurement and visual construction of the cavity (automatically).

Figure 2. Total sinus volume measurement and visual construction of the cavity (manually).

Statistical analysis

The recorded data were processed using NCSS software (Number Cruncher Statistical System, Kaysville, Utah, U.S.A.). After descriptive and comparative analysis, significance of 5% or less was considered statistically significant. When the data were subjected to normal distribution, analysis of variance (ANOVA) was used for analysis of quantitative differences between two or more groups Student's t–test was performed for analysis of differences between two groups.

RESULTS

Summarization of demographic data led to the conclusion that out of 36 maxillary sinuses included in the study 22 (61.1%) were females and 14 (38.9%) were males. At the time of LSFE surgery, the mean age of patients was 50.9 years (31-66 years). Mean age of females who were included in the study was 49.4 while the mean age of males was 53.7 years.

Inclusion criteria consisted of maxillary CBCT taken both before and after the sinus surgery. The longest time recorded from post–surgery until CBCT re–examination was 5 years. The average time from post–surgery until CBCT re–examination was 2.06 ± 0.749 years.

Mean values and standard deviations of the volumes for the maxillary sinus cavities and for grafts are shown in Table 1 and Table 2. All volumetric assessments were performed not only automatically but also in manual mode using 3D Synapse Software. Although there were small differences between manual and automatic measurements, they were not significant (p>0.05). The total maxillary sinus volume (mean ± SD) measured manually on CBCT images was 15.35 ± 2.9 cm^3. The minimum maxillary sinus volume was 10.91 cm^3 and the maximum was 22.03 cm^3.

Table 1. Volumetric measurements of the sinus cavities.

Measurement Mode	Side	Volume (cm^3) ±SD	Difference (p value)	Difference (p value)
Manual	Right	15.37 (±3.05)	p>0.05	p>0.05
	Left	15.9 (±3.08)		
	Mean	15.35 (±2.9)		
Automatic	Right	15.19 (±3.08)	p>0.05	
	Left	14.98 (±2.87)		
	Mean	15.1 (±2.9)		

Table 2. Volumetric measurements of the grafts.

Measurement Mode	Volume (cm^3) ±SD	Percentage	Difference (p value)
Manual	2.25 (±1.24)	14.87 % (±7.71)	p>0.05
Automatic	2.24 (±1.2)	14.66 % (±7.73)	

The overall average graft volume obtained after the surgery was 2.25 cm^3 (±1.24 cm^3). The occupied space of the sinus cavity by graft biomaterials was calculated (%), as shown in Table 2. The average percentage of the grafted part was 14.87% through manual measurements and 14.66% through automatic measurements.

In pre-surgical CBCT imaging, the mean thickness of the crestal gingiva was 1.09 mm (±0.94). The gingival thickness in the surgical area increased slightly after the surgery, which was not statistically significant (Table 3). The sinus membrane thickness ranged from 0.7mm to 3.2mm in pre-surgical CBCT scans. The mean thickness prior to surgery was 1.62 mm. Following LSFE, mean membrane thickness showed no significant difference from pre-surgical values (Table 3).

Table 3. Analysis of the linear measurements before and after sinus surgery

Parameters	Pre-op. (mm) ±SD	Post-op. (mm) ±SD	Difference (p value)
Schneiderian membrane thickness	1.62 (±1.04)	1.77(±0.72)	p>0.05
Gingival thickness	1.09 (±0.94)	1.29 (±0.47)	p>0.05
Residual bone height	3.14 (±2.38)	---	---
Graft height	---	11.36 (±2.78)	---

All ostiums were detected and most of them maintained their openness after sinus lift surgery. Obstruction of the sinus ostium was observed just in one sinus (2.7 %). The mean buccal bony wall of the maxillary sinus cavity after the surgery was slightly thicker than in pre-surgical CBCT scans (Table 3).

DISCUSSION

According to several clinical studies, the success rate of the sinus elevation procedure for the placement of implants has significantly increased.[16] LSFE with different types of bone grafts has become a remarkable treatment choice for severely atrophic posterior maxilla. This retrospective analysis aimed to evaluate the physiological changes after sinus lifting surgery.

Volumetric and linear measurements of the maxillary sinus cavity have conventionally been measured using cadavers by different authors.[2,19,20] However, "gold standard" for LSFE considered 3D CBCT.[21] Ariji, Uchida and others have measured maxillary sinus volume in humans through the CT images.[4,22,23] Recent years, volumetric measurements have been performed by using CBCT with different modelling software.[16,24,25] In this study, total and grafted volume of the maxillary sinus were examined using manual and automatic mode of the 3D Synapse Software.

The maxillary sinus cavity is described as the largest one between paranasal sinuses and its volume is changing between 8.6 cm^3 and 24.9 cm^3.[3,26] The maxillary sinus volume tends to be increased after the maxillary posterior tooth loss.[27] According to Takahashi *et al.*[28] mean volume of the maxillary sinus was 31.3 cm^3, which was approximately twice as much as the present results. This difference may be explained by the fact that volume measuring methods were totally unlike from each other. The mean volume of the sinus cavity after full growth was calculated as 14.8 cm^3.[29] The mean total sinus volume was around 15 cm^3 in the present results.

There have been a few studies reported graft volume after different types of sinus surgeries.[30-33]

However, this is the first CBCT study in the literature using the current software to investigating the safe volume of the sinus cavity for the grafting. The safe volume after sinus grafting means not to interfere with the osteomeatal unit that hazardous to sinus physiology. In this study, all included patients were performed successfully two-stage lateral sinus floor elevation without any complication. These results confirmed that sinus augmentation with lateral approach is a safe procedure when evaluation of maxillary sinus anatomy by CBCT and 3D elevation of the membrane are performed.

All volumetric measurements of the sinuses were performed twice to compare manual and automatic modes of the software. To the best of our knowledge, no study evaluated the difference between manual and automatical estimated maxillary sinus cavity volumes in the CBCT images. The automatical volume calculation is easier to perform and less time consuming than the manual measurement. Our study showed an excellent convenience between the manual and automatic measuring volumetric data of the sinus cavity. Although such estimation may not be suitable for other software, we believe that this tool might be beneficial for research purposes in further evaluations through this program.

Published studies comparing left and right sinus cavity volumes have produced resemble outcomes. Most of the authors have found no statistical difference between right and left cavity in terms of sinus volume.[4,34] Our results are consistent with other reported studies. In the present study, the mean value of the right sinus cavity volume was 15.37 cm^3, and 15.9 cm^3 for the left side, which showed no statistically significant difference.

In the present study, the authors relied on CBCT exploration in order to evaluate and understand physiological changes after LSFE. Sinus membrane thickness is one of the first post-surgical inflammatory signs inside the maxillary sinus cavity after membrane elevation procedure. The transient swelling of the Schneiderian membrane after the LSFE has already been described by Quirynen *et al.*[35] Membrane thickening was assessed before and after the sinus surgery to understand the effect of the procedure on membrane physiology. The outcomes showed the fully resolution of the early post-surgical inflammatory reaction of sinus membrane after the healing period. These presented results are in excellent agreement with the previous established results by different authors.[36 37]

Some authors reported that healthy Schneiderian membranes are thicker in individuals with a thick gingival biotype than in those with a thin gingival biotype.[11,38] However, our results showed no correlation between the membrane thickness and crestal gingival thickness.

Sample size might be a major limitation of this retrospective study. Moreover, the current study may be considered as standardized since they were only augmented with bone grafts without implant placement. Further studies can be designed to achieve valuable data about graft volumes used with different surgical techniques.

CONCLUSIONS

The present study showed that in posterior maxillary regions with insufficient bone height, the LSFE technique could achieve a predictable outcome for implant surgery. According to the results of this retrospective study, approximately 14.87% of the sinus cavity is occupying by graft materials after sinus elevation surgery, which considered as a safe volume. There were no significant difference between pre-surgical and post-surgical CBCT scans according to sinus membrane thickness and patency of osteomeatal unit. Nevertheless, this retrospective radiographic study confirmed that sinus augmentation surgery is a safe procedure in a long term when carefully planned and all inflammatory reactions totally subsides after the healing period.

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Original research

THREE-DIMENSIONAL VOLUMETRIC/LINEAR ANALYSIS AND AXIAL CLASSIFICATION OF ROOT RESORPTIONS USING CONE BEAM COMPUTED TOMOGRAPHY: A RETROSPECTIVE STUDY

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Dilara Nil Gunacar[2]
Taha Emre Kose[2]

ABSTRACT

Objectives: The purpose of this study was to investigate the volumetric-linear analysis and to present a new axial classification of root resorptions using cone beam computed tomography (CBCT).

Materials and Methods: A total of 43 teeth with root resorption (external cervical resorption (ECR) (n=27), external replacement resorption (ERR) (n=4) and internal root resorption (IRR) (n=12)) from 34 patients were included in this study. On CBCT images of teeth, the volume of total tooth and resorption for the volumetric analysis, the widest lengths of resorptions and the amount of thinnest dentin thickness around them for the linear analysis were measured, and volumetric/linear measurements were compared according to age and gender. In addition, the eight regional axial classification was performed, and these regions were compared. Data were evaluated using Shapiro-Wilk, Pearson's r., Kruskal-Wallis and Dwass-Steel-Critchlow-Fligner post-hoc tests. Significance was set at p=0.05 for statistical analysis.

Results: No significant difference was found between the volumetric and linear measurements of ECRs, ERRs, and IRRs. No difference between genders in volumetric and linear measurements of ECRs and IRRs, except total tooth volume, was higher in males than in females in ECRs ($p<0.05$). With increasing age in ECRs, the buccal dentin thickness increased, and bucco-lingual length and total tooth volume decreased ($p<0.05$). In axial classification, ECRs were mostly found in lingual, while IRRs and ERRs did not show regional differences.

Conclusions: Although root resorptions had different localizations and classifications, they did not differ in terms of volumetric and linear measurements due to having similar nature. Using CBCT imaging, the volumetric/linear analysis and axial classification of resorptions, and demographic differences according to these parameters can help clinicians in understanding the nature of resorption and in determining appropriate management.

Keywords: Classification, cone beam computed tomography, endodontics, root resorption.

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INTRODUCTION

Root resorption (RR) is the loss of hard dental tissue as a result of clastic activities.[1] RR can be classified in association to the surface of the root as internal or external. Internal root resorption (IRR) has been defined as intraradicular or apical with regard to location.[2] External root resorption can be also subdivided into surface resorption (SR), external inflammatory resorption (EIR), external cervical resorption (ECR), external replacement resorption (ERR), and transient apical breakdown resorption (TAP).[3]

IRR especially occurs as a result of pulpal inflammation; however, external resorption types have different etiologies such as orthodontic treatment, cysts, trauma, etc.[1,2] Oval or round in shape, IRR radiographically appears like a well-defined, ballooning out of the pulpal root canal.[4] ECR that has a traceable root canal typically appears as an irregular radiolucency. In the reparative stage, the appearance of the lesion creates a mixed image due to the accumulation of calcific tissue.[5]

An accurate diagnosis is essential for establishing an appropriate treatment plan for root resorptions.[4] Radiographic evaluation is a suitable method for the exact diagnosis.[6] It is reported that 60-70% of mineralized tissue loss is required to determine resorption with conventional radiographs.[7] Periapical (PA) radiographs have limitations in comprehending the size and location, and in determining the relationship of the resorption area with surrounding tissues.[8,9] Due to these limitations of PAs, cone beam computed tomography (CBCT) presents the three-dimensional (3D) representations of hard tissues feature, the high-quality imaging, and the fast scanning. Moreover, CBCT provides an advantage in comprehensive and accurate evaluation of resorbed areas, as it ensures cross-sectional assessment in sagittal, axial, coronal, and multiplanar planes.[10]

In 1999, Heithersay proposed four classes in PA radiography according to the extent of ECR. Resorption can range from class 1, a small cervical lesion with shallow penetration into dentin, to class 4, a lesion extending beyond the coronal third of the root.[11] This classification is valid if ECR is limited to the proximal aspect of the tooth. However, it also fails to describe the circumferential and pulpal involvement of the lesion and to predict treatment plans.[12,13] In recent years, 3D classification of ECR has been proposed using CBCT by Patel *et al.*[12] This new classification takes into account the ECR height, circumferential spread, and proximity to the root canal.[12] Nevertheless, it does not give any information about the localization of resorptions in axial section.

CBCT has recently become popular in the measurement of remaining dentin thickness and the volume of resorptions.[13,14] The increase in the 3D width and volume of the root resorption or the decrease in the thickness of the dentin around it can decrease the fracture resistance of tooth and the success of treatment. To the best of our knowledge, the study evaluating the 3D width and classifying the localization in axial section of root resorptions using CBCT could not be found in the literature search. Additionally, previous studies evaluating resorption using CBCT have generally investigated ECR lesions, not ERR, IRR.[13,15] In 3D images, volumetric measurements such as the volume of resorption, and/or linear measurements (i.e. the widest length of resorptions, the thinnest dentin thickness around them) can help the physician to understand the nature and the differentiation of root resorption and to provide an advantage in the treatment decision.

Thus, this retrospective study had two aims. The first was to investigate the volume of ECRs, ERRs, IRRs, and total tooth, the widest length of these resorptions, and the amount of thinnest dentin thickness around them, and to compare the age and gender distribution according to these parameters. The secondary aim was to establish the eight regional settlement classifications in axial sections of CBCT and to compare the percentages in these regions of ECRs, ERRs, and IRRs.

MATERIALS AND METHODS

In this retrospective study, we evaluated patients' CBCT images with root resorption obtained between January 2017 and January 2020 in the

Department of Oral and Maxillofacial Radiology, Recep Tayyip Erdoğan University, Faculty of Dentistry. This study was registered with www.clinicaltrials.gov/ (Identification number: NCT04617301) after approval (Number: 2020/98) by the Ethics Committee of the Recep Tayyip Erdoğan University Faculty of Medicine, and we followed the guidelines of the Helsinki Declaration in this investigation.

Case Selection

Cases of resorption, who had previously received CBCT for a definitive diagnosis and treatment plan, were included in the study. Patients who met the following criteria were excluded: those presenting pathologic lesions, congenital/ developmental anomalies or teeth with root canal filling, and those whose CBCT scans failed to present satisfactory quality. Additionally, SR, TAP, and EIR cases were excluded because their true dimensions could not be completely determined before resorption. Radiographic features of resorption were defined in the images of 34 patients in accordance with these criteria. A total of 43 teeth with ECR (n=27), ERR (n=4), and IRR (n=12) were identified from 34 patients.

Linear/Volumetric Analysis and Axial Classification

The following parameters were registered: Gender, age, tooth number, and resorption type. For the linear measurements, the widest corono-apical length was made on sagittal sections where the tooth axis was perpendicular to the ground plane (Figure 1).

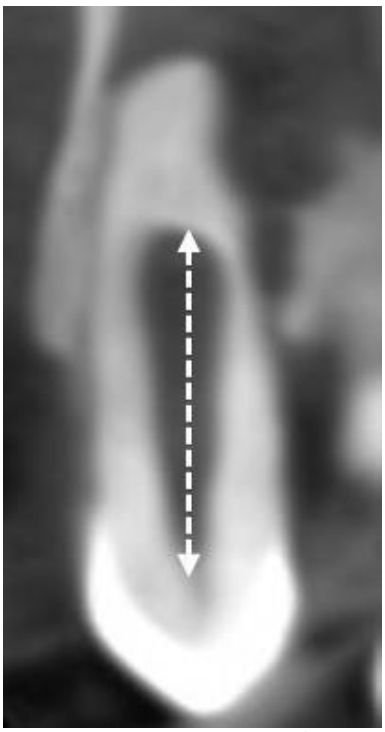

Figure 1. Linear measurement of the corono-apical length of the resorption area in sagittal slice of internal resorption case.

On axial sections, the width of the resorbed area (mesio-distal length and bucco-lingual length) (Figure 2A) and the thinnest dentin thickness (buccal, distal, mesial and lingual/palatinal) (Figure 2B) were measured.

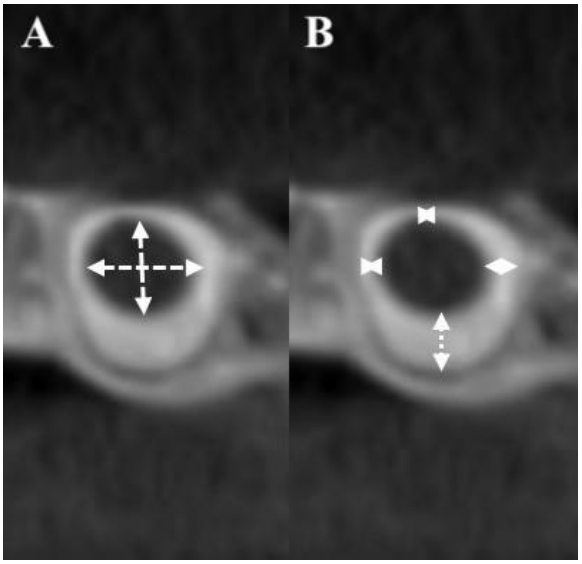

Figure 2. (A) Linear measurements of the mesio-distal and bucco-lingual width of resorption area, and **(B)** the thinnest dentin thickness around the resorption area in axial slice of internal resorption case.

For the volumetric assessment, volume calculations of total tooth and resorbed area were made with ITK-SNAP program (Figures 3A and 3B).

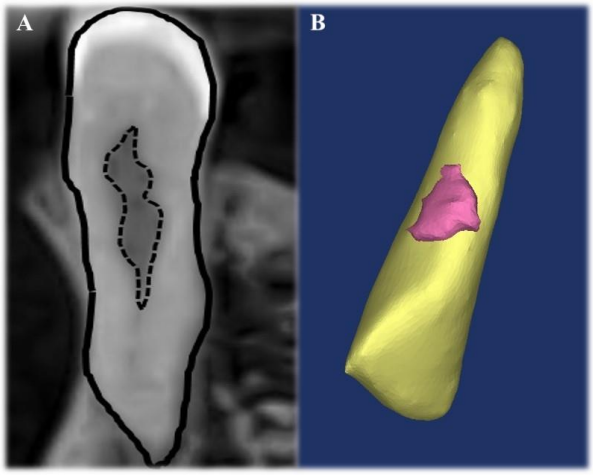

Figure 3. (A) Volumetric measurements of resorption and total tooth areas in a cross-sectional slice obtained from CBCT images of internal resorption case. **(B)** 3D reconstruction of resorption area and total tooth obtained during volumetric calculation with ITK-SNAP program in external cervical resorption case.

The apical reference point was the radiographic apex of the root and the coronal reference point was cusp tip(s) or incisal edge of tooth for the total volume. The total volume to resorption volume ratio was calculated after volumetric measurements. At the same time, the axial slice which showed the widest resorption area of the tooth was divided into eight parts and regional settlement classification was performed (Figure 4).

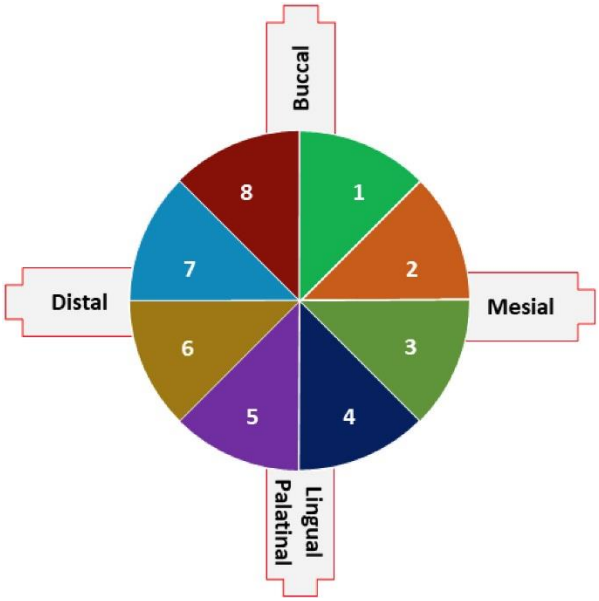

Figure 4. Eight regional settlement classification in the axial slice which showed the widest resorption area of the tooth in CBCT images.

Height and Patel et al.'s ECR Classification

In ERR or IRR, at sagittal and coronal slice, which showed the longest corono-apical extension, height classification was made according to the region (1: located in the crown, 2: in the coronal third of the root, 3: in the middle third of the root, 4: in the apical third of the root) (Figure 5).

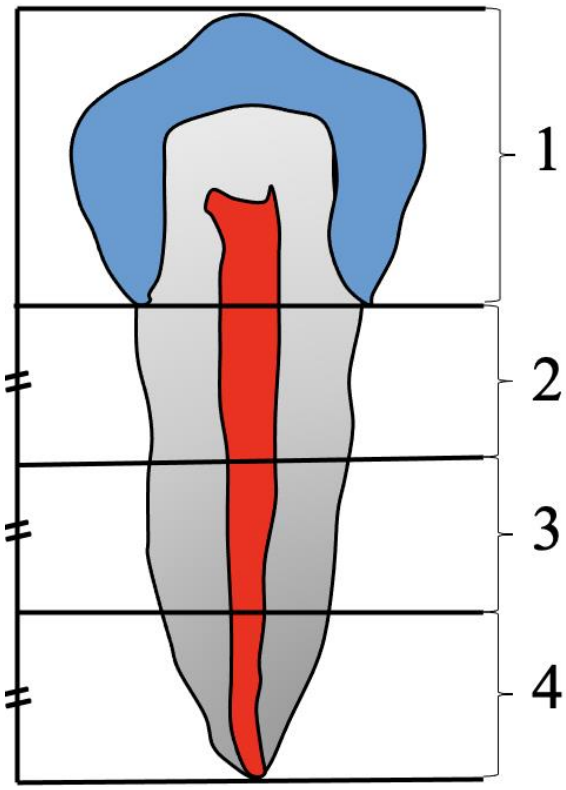

Figure 5. Height classification in sagittal and coronal slice which showed the longest corono-apical extension.

If the type of resorption was ECR, classification was performed based on Patel *et al.'s*[12] study. In this classification, there are four subgroups for the height classification; cemento-enamel junction level or coronal to the bone crest (1: supracrestal), extension into the coronal third of the root and apical to the bone crest (2: subcrestal), extension into the middle third of the root (3), and extension into the apical third of the root (4). The classification of circumferential spread is made according to the area covered by the resorption (A: ≤90°, B: >90° to ≤180°, C:>180° to ≤270°, D: >270°) in axial sections. The classification according to the proximity to the root canal in axial sections is made only if the lesion is limited to dentin or it contains probable pulp.[12]

Radiographic Technique

In every case, axial, coronal and sagittal slices with 0.2 mm interslice distance and 0.2 mm slice width were analyzed. All CBCT images were obtained using a Planmeca ProMax 3D Classic (Planmeca Promax 3D; Planmeca Oy; Helsinki, Finland) with the following parameters; 90 kVp, 4-10 mA, 200 µm voxel size. Linear measurements were

performed using the Planmeca Romexis 4.6.2.R software (Planmeca Romexis; Helsinki, Finland). Volumetric calculations were made by creating a 3D image of the resorption areas and teeth into the 3D semi-automatic segmentation program (ITK-SNAP 2.4), which was recorded as a DICOM data file obtained with CBCT. Linear measurements were made by an oral and maxillofacial radiologist (T.E.K.) with 10+ years experience and volumetric measurements were made by the other oral and maxillofacial radiologist (D.N.G.) with 5+ years experience.

Statistical Analysis

In this study, frequencies, percentages, and descriptive statistics (e.g. mean, standard deviation) were used to report demographic information. Jamovi (Version 1.0.4) program was used for statistical analysis. The normality of data distribution was checked using the Shapiro-Wilk test. The correlation between groups was calculated by Pearson's r., Kruskal-Wallis and Dwass-Steel-Critchlow-Fligner post-hoc tests were used for statistical analysis for differences between groups. Significance was set at p=0.05.

RESULTS

Distribution

A total of 43 teeth from 34 patients were evaluated in the study. The age range of these patients was 12-71 (range, 12-71 for ECR, 18-63 for IRR, 13-62 for ERR) years old, with an average of 41 (41.5 for ECR, 52.6 for IRR, 19.8 for ERR) years old. The records of 43 cases were identified, 26 of whom were male and 17 were female. Of the total 43 cases, 16 of 27 cases identified as having ECR were male and 11 were female; 9 of 12 cases identified as having IRR were male and 3 were female; and three of four cases identified as having ERR were female and one was male.

There were 27 cases of ECR in total with 14 identified in the maxilla, 10 of which were central incisors; 13 identified in mandibular, five of which were central incisors and five were first molars. There were 12 cases of IRR in total with eight identified in the maxilla, three of which were central incisors, two were laterals, and two were second molars. All four ERRs were in the maxilla, half of which were central, the remainder was lateral.

Linear/Volumetric Analysis and Gender

Table 1 presents the corono-apical/mesio-distal/bucco-lingual widest length, the thinnest buccal/mesial/distal/lingual/palatinal dentin thickness, the volume of ECR, ERR, IRR, the total volume of tooth and the total/resorption volume ratio. No significant difference was found between the values of these parameters (p>0.05).

Table 1. Values for the widest lengths, the amount of thinnest dentin, and the volume according to ECR, ERR, and IRR.

	Resorption type	Corono-apical length (mm)	Mesio-distal length (mm)	Bucco-lingual length (mm)	Thinnest buccal dentin (mm)	Thinnest mesial dentin (mm)	Thinnest distal dentin (mm)	Thinnest lingual/ palatinal dentin (mm)	Resorption volume (mm^3)	Total tooth volume (mm^3)	Total volume/ resorption volume ratio
Mean (±SD)	ECR (n=27)	4.62 (±1.93)	3.02 (±1.21)	3.59 (±1.63)	1.79 (±1.71)	0.977 (±1.20)	1.21 (±1.25)	0.768 (±1.24)	36.1 (±30.1)	618 (±333)	37.0 (±50.0)
	ERR (n=4)	6.36 (±1.95)	3.98 (±2.10)	3.20 (±0.836)	0.667 (±0.782)	0.652 (±0.758)	0.302 (±0.605)	0.667 (±1.33)	45.1 (±39.8)	537 (±135)	17.8 (±9.80)
	IRR (n=12)	5.08 (±3.19)	2.38 (±0.901)	3.31 (±1.34)	1.53 (±1.93)	0.597 (±0.399)	0.676 (±0.786)	1.23 (±0.889)	29.2 (±21.2)	624 (±269)	49.8 (±60.5)

ECR: external cervical resorption; ERR: external replacement resorption; IRR: internal root resorption; SD: standard deviation; mm: milimeter; mm^3: cubic milimeter.

Table 2 indicates the gender distribution of ECR, ERR, IRR, and total cases according to these parameters. There was no significant difference between the genders in these parameters for ECR, IRR, and total cases (p>0.05), except the total tooth volume for ECR and total cases (p<0.05). Total tooth volume was significantly higher in males than in females for ECR and total cases (p<0.05). Due to the small sample size of ERR in the study, the differences between the genders according to these parameters could not be evaluated.

Table 2. Values for the widest lengths, the amount of thinnest dentin, and the volume of ECR, ERR, IRR, and total cases according to gender.

	Gender	Resorption type	Corono-apical length (mm)	Mesio-distal length (mm)	Bucco-lingual length (mm)	Thinnest buccal dentin (mm)	Thinnest mesial dentin (mm)	Thinnest distal dentin (mm)	Thinnest lingual/ palatinal dentin (mm)	Resorption volume (mm^3)	Total tooth volume (mm^3)	Total volume/ resorption volume ratio
Mean (±SD)	Male (n=26)	ECR (n=16)	4.51 (±1.95)	3.35 (±1.20)	3.71 (±1.37)	1.93 (±1.85)	1.02 (±1.10)	1.57 (±1.40)	0.930 (±1.40)	40.6 (±34.9)	**771 (±315)***	29.9 (±18.5)
		ERR (n=1)	4.39	2.41	2.16	0.00	1.41	0.00	2.67	17.2	420	24.4
		IRR (n=9)	5.89 (±3.15)	2.38 (±0.964)	3.16 (±1.33)	1.72 (±2.18)	0.684 (±0.318)	0.834 (±0.840)	1.19 (±0.956)	33.1 (±22.1)	603 (±201)	34.0 (±39.3)
		All male cases (n=26)	4.98 (±2.43)	2.98 (±1.18)	3.46 (±1.35)	1.78 (±1.93)	0.92 (±0.89)	1.25 (±1.26)	1.09 (±1.26)	37.09 (±30.29)	**699.41 (±286.81)****	31.13 (±26.58)
	Female (n=17)	ECR (n=11)	4.78 (±1.99)	2.54 (±1.10)	3.42 (±2.01)	1.58 (±1.54)	0.908 (±1.38)	0.690 (±0.790)	0.532 (±0.964)	29.7 (±21.2)	**395 (±218)***	47.4 (±76.0)
		ERR (n=3)	7.01 (±1.77)	4.50 (±2.23)	3.54 (±0.579)	0.890 (±0.788)	0.400 (±0.693)	0.403 (±0.699)	0.00 (±0)	54.5 (±43.1)	576 (±135)	15.6 (±10.7)
		IRR (n=3)	2.68 (±2.10)	2.40 (±0.863)	3.77 (±1.50)	0.937 (±0.907)	0.333 (±0.577)	0.200 (±0.346)	1.34 (±0.813)	17.3 (±16.0)	689 (±478)	97.4 (±97.0)
		All female cases (n=17)	4.80 (±2.28)	2.86 (±1.44)	3.50 (±1.69)	1.34 (±1.33)	0.72 (±1.17)	0.55 (±0.71)	0.58 (±0.91)	31.87 (±26.12)	**478.66 (±274.59)****	50.59 (±73.82)

**Statistically significant difference between male and female according to total tooth volume in ECRs ($p<0.05$).*
*** Statistically significant difference between male and female according to total tooth volume in total cases ($p<0.05$).*
ECR: external cervical resorption; ERR: external replacement resorption; IRR: internal root resorption;
SD: standard deviation; mm: milimeter; mm^3: cubicmilimeter.

Percentages of Axial Classification, Height, and ECR Distribution According to Patel et al.'s Classification

Figure 6 shows the percentages of ECR, ERR, and IRR according to the eight regional axial classification.

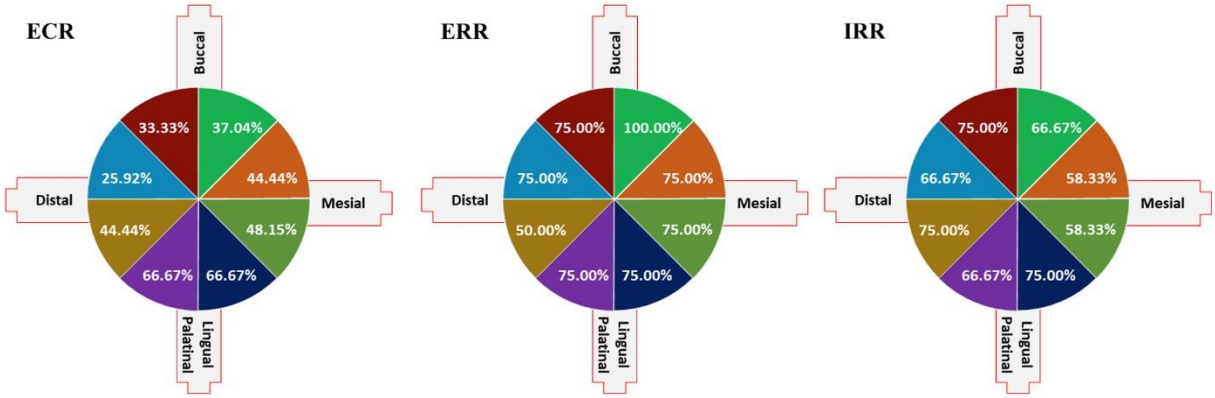

Figure 6. Percentages of ECR, ERR, and IRR according to the eight regional locations in the axial section. ECR: external cervical resorption; ERR: external replacement resorption; IRR: internal root resorption.

ECR was found more in the lingual location than in the other areas (66.67% for 4 and 5 regional settlements); ERR and IRR had similar distribution in all locations. The height percentages of ECR, ERR, and IRR in coronal and sagittal sections by region are shown in Figure 7.

	ECR	ERR	IRR
1	18.5%	0%	0%
2	40.7%	75%	50%
3	40.7%	75%	66,67%
4	0%	25%	25%

Figure 7. Percentages of ECR, ERR, and IRR according to the height classification. ECR: external cervical resorption; ERR: external replacement resorption; IRR: internal root resorption.

ECR cases resulted in A: 40.7%, B: 40.7%, C: 3.7%, and D: 14.8% according to circumferential spread, and also affected the pulp by 88.9% and the dentin by 11.1%.

Linear/Volumetric Analysis and Age

According to age distribution, the widest length (corono-apical/mesio-distal/bucco-lingual), the amount of thinnest (buccal/mesial/distal/lingual/ palatinal) dentin thickness and volumetric values (the volume of resorption, the total volume of tooth, and the total/resorption volume ratio) are shown in Figures 8, 9, 10, respectively. In ECRs, IRRs and total cases, the widest lengths decreased with increasing age (Figure 8).

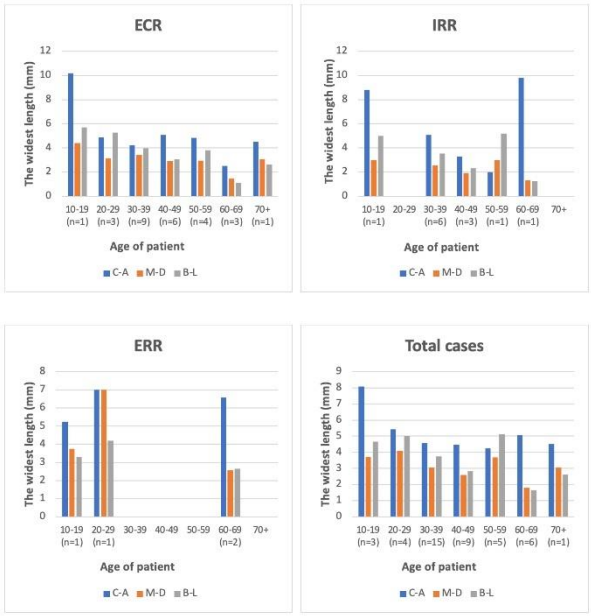

Figure 8. A column charts show the widest length (corono-apical, mesio-distal, bucco-lingual) of ECR, IRR, ERR, and total cases according to age of patients. ECR: external cervical resorption; ERR: external replacement resorption; IRR: internal root resorption; C-A: corono-apical; M-D: mesio-distal; B-L: bucco-lingual.

Of these, only the bucco-lingual length in ECR and total cases, and mesio-distal length in total cases were significant ($p<0.05$). In ECRs, IRRs and total cases, the amount of thinnest mesial dentin decreased, whereas the thickness in buccal direction increased (Figure 9).

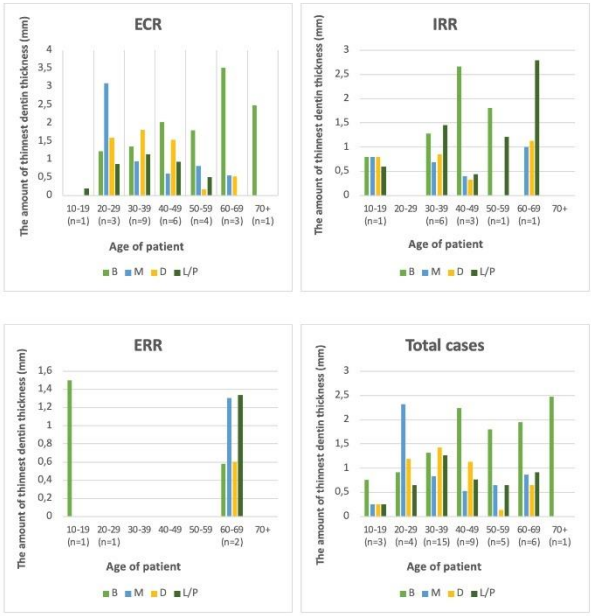

Figure 9. A column charts show the amount of thinnest dentin thickness (buccal, mesial, distal and lingual/palatinal) of ECR, IRR, ERR, and total cases according to age of patients. ECR: external cervical resorption; ERR: external replacement resorption; IRR: internal root resorption; B: buccal; M: mesial; D: distal; L/P: lingual/palatinal.

Of these, only the amount of buccal dentin in ECR and total cases was significant ($p<0.05$). Additionally, all volumetric values decreased in ECRs. Of these, only the total tooth volume was significant ($p<0.05$) (Figure 10).

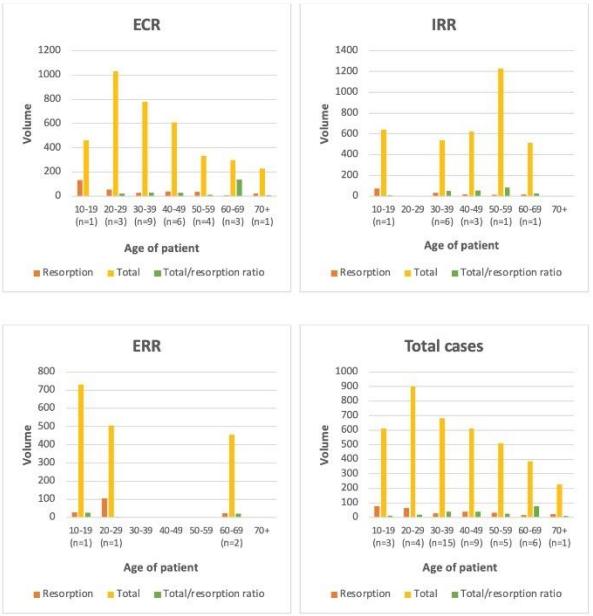

Figure 10. A column charts show the volumetric values (volume of resorption, total volume of tooth and the total/resorption volume ratio) of ECR, IRR, ERR, and total cases according to age of patients. ECR: external cervical resorption; ERR: external replacement resorption; IRR: internal root resorption.

In IRRs, the resorption volume decreased, the total volume and the total/resorption volume ratio increased ($p>0.05$). The total volume and the resorption volume significantly decreased in total cases ($p<0.05$). Nevertheless, the total/resorption volume ratio increased ($p>0.05$). Due to the small sample size of ERR in the study, the age distribution according to these parameters could not be evaluated.

DISCUSSION

Radiography is a main component in the successful diagnosis of root resorptions as in other endodontic diseases. Nevertheless, conventional methods such as PA and panoramic radiographs can make difficult the interpretation of images as they provide two-dimensional images of 3D structures. By providing 3D images, CBCT can overcome many of the limitations of other radiographic methods. According to the European Society of Endodontology (ESE) position statement, also the American Association of Endodontists (AAE) and American Academy of Oral & Maxillofacial Radiology (AAOMR) joint

position statement, CBCT imaging has been recommended for the localization and differentiation of root resorptions, and the determining appropriate management and prognosis.[16,17] In this study, the 3D volumetric and linear measurements of ECRs, ERRs, and IRRs were assessed using CBCT imaging to understand their nature and differentiation. In addition, the axial classification that would allow an objective interpretation of the diagnosis among clinicians was presented.

ECR occurs in three phases: an initiation phase, an active resorption phase, and a reparative phase, which initially expands coronally and later apically.[5,18] These directions depend on the movement of clastic cells, which have a relation to inflammatory mediators (e.g. cytokines), hormones (e.g. parathyroid hormone, calcitonin, calcitriol) and growth factors.[19,20] In the treatment of this resorbed lesion, methods such as the external repair of the resorptive defect with or without endodontic treatment, internal repair and root canal treatment, intentional replantation, periodic review and extraction in untreatable teeth can be applied.[21] The treatment plan of ECR is dependent on the dimension, localization, and proximity of the lesion to the root canal.[22] In terms of the resorption dimension, the findings in the present study showed that the widest lengths in ECR was similarly expanding in all three directions. This information is important for the clinicians to consider possible resorbed tissue in all directions while cleaning the resorbed tissue. Although gender seemed to have no effect on the widest lengths, increased age showed a decrease in ECR dimensions, especially bucco-lingual length. The age findings in the widest lengths may indicate that lesions have passed to the reparative phase.

One of the important parameters in the choice of treatment approach is the dentin thickness around the resorbed lesion. Goodell *et al.*[13] suggested the Rohde classification in ECRs, which detects the amount of dentin loss in the cervical area. By contrast, the present study compared the amount of thinnest dentin around the resorbed lesion between the axial directions (buccal, mesial, distal, lingual/palatinal). The findings in the present study showed that resorption did not make any difference in the direction of the dentin thickness in ECRs. Interestingly, with increasing age, the amount of the thinnest dentin in the buccal direction increased ($p<0.05$). Our findings indicated that the ECRs, which generally progress asymptomatically, may complicate clinical diagnosis by decreasing the pink spot image due to the increase in the thickness of dentin in buccal direction.

The pulp is not usually perforated because of the presence of a pericanalar resorption resistant sheet (PRRS) that protects against pulp penetration.[5] Nevertheless, in advanced resorption lesions, the root canal may be perforated.[18] ECR cases affected the pulp at rate of 88.9% in this study. The detection of PRRS, which have thicknesses of 70 to 490 μm, with CBCT may interfere with assessment of both the thickness and density of the area.[20] Also, most of the ECR lesions had less than 180° of circumferential spread. Although there seems to be no relationship between circumferential spread and pulpal perforation, further investigation is required.

Similar to other studies, ECR was not associated with patient's gender and had a wide age distribution.[11,23] ECR was most detected in maxillary central incisors (37%), followed by mandibular central incisors (18.5%) and mandibular first molars (18.5%). Patel *et al.*[22] determined the most commonly affected teeth as maxillary central incisors (30.4%), followed by mandibular first molars (15.7%), and mandibular central incisors (11.3%). The cause of percentage differences may be that the etiologic factors of ECR differ according to the population investigated.

In contrast to external resorption, IRR occurs inside the pulp canal. For the initiation of IRR, the odontoblast layer and predentin, which is the outer protective of the canal wall, must be damaged. However, without bacterial stimulation, IRR will be self-limiting and does not progress.[2] It is important to treat the tooth with conservative methods before the IRR advances and consequently compromises the restorability of tooth. If the

resorbed lesion is limited to the root canal, root canal treatment is the first option.2 When the the perforation of root walls occurs, the management of the resorbed lesion could be more challenging with treatment methods such as sealing the resorbed area with bioactive cements, and/or surgical approaches.[24] According to the findings in IRR lesions of this study, the physician should be careful in whole direction during the preparation, irrigation or filling procedures, since there was a possibility similar to the widest lengths and the amount of thinnest dentin of IRR in all directions. Also, as the age increased, the widest lengths of the resorbed lesions may have been reduced in 3D images due to low-grade inflammation of the pulpal tissue.

In the present study, although IRR was more common in maxillary teeth, the distribution of teeth showed homogeneity. Trauma and then pulpal inflammation are the major contributing factors at the beginning of IRR.[2] The higher percentage of males (9/12, 75%) may be due to more traumatic injuries than in females. Also, IRR classifications using CBCT may be required for the physician to make a correct treatment plan, as with ECR.[12] This study may guide IRR classifications using CBCT.

ERR occurs as a result of acute damage to periodontal ligament cells due to severe traumatic injuries, such as intrusive luxation or avulsion with extended dry time.[25] These resorbed lesions cannot be arrested or the process reversed. For this reason, timing of decoronation should be planned according to the age and growth pattern of the patient.[26] The volumetric analysis of ERR, which was also considered for the first time in this study, may be an important criterion in the tooth decoronation decision. However, the small sample size in this study precluded definitive conclusions from being drawn on the prevalence of ERR. ERR was frequently seen in maxillary teeth (4/4, 100%) because it was generally traumatized and replanted for aesthetics and alveolar bone development.

The change of resorption volume compared with the total volume is the most important factor in the long-term prognosis of resorption. To our knowledge, only Matny *et al.*[14] investigated a volumetric quantitative assessment of ECRs. However, this is the first study to compare ECR, ERR, and IRR through volumetric assessment and to examine the age and gender distribution of these resorptions according to this parameter. In ECR lesions, the total volume for males was significantly higher than for females. This might be due to the fact that teeth with greater volume (e.g. premolar, molar) have a greater distribution in males. Interestingly, despite this difference in total tooth volume, no significant difference in resorption volumes of males and females in ECR lesions can lead us to conclude that male's teeth with ECR may be more resistant to fracture. With increasing age, the total tooth volume may have decreased as the ECR may have affected smaller volume teeth. With respect to this result, although the distribution passed to smaller volume teeth as age increases, the resorption volume did not decrease significantly, which may show that the total volume of the tooth in ECR is not a factor in the progression of resorption.

There was no difference between ECR, ERR, and IRR in terms of volumetric values of resorption. This means that even if the resorption classifications and localizations are different, ECR, ERR, and IRR may have close volumetric values due to having similar nature. When total cases were evaluated together, the high total tooth volume in males may be due to the fact that the teeth with greater volume such as molar teeth were more affected by resorption in male. With increasing age, the 3D volume of resorption decreased, suggesting that resorption treatments in adult patients may be more conservative. Also, the slowing of the inflammatory mechanism with age and the increasing secondary dentin thickness throughout life may indicate that resorption progress more slowly.[27]

The apical extent of resorption affects a physician’s decision in terms of treatment approach. ECR usually occurs in the cervical region of the tooth and expands in all directions away from portal of entry.[20] IRR initiates within the pulp space, whereas ERR is a pathologic loss of cementum, dentin, and periodontal ligament

with subsequent replacement of such structures by bone.[28] In the height classification, the height values of ECRs were evaluated by including the cervical region according to Patel *et al.*'s[12] classification. Thus, the total values complemented 100%. In ERRs and IRRs, the total values exceed 100% since the lesions do not have a specific starting point, such as the entry point of ECR, and are likely to be found simultaneously in the coronal, middle, and apical thirds.

Contrary to previous classifications, in the present study, we added eight settlement classification in axial section, which showed the widest resorption area of the tooth (Figure 4). This classification is of great importance when making treatment decisions and communicating more effective and accurate transmission of lesions among colleagues. Surgical approaches to resorption in the proximal location are more complicated than those found in buccal or lingual areas. For this reason, percentages of availability by regional settlement were determined, and ECR was found more in the lingual region than in other locations (Figure 6). This might be due to more plaque remaining in the lingual direction of the teeth during oral hygiene. The total percentage was not 100% in total cases because the resorptions were not just located in one region.

The primary limitations of this study were the lack of demografic data of the patients, not evaluating the etiology of resorptions or not selection of the treatment plan according to the parameters evaluated, and the absence of ECR's entry portal. Another limitation was that endodontically treated teeth, which do not have pulp and PRRS, were excluded.[29] Further research is needed for the volumetric/linear assessment of endodontically treated teeth.

CONCLUSIONS

Within the limitations of this study, even though the resorption types were different, there was no difference in terms of volumetric and linear analysis in 3D images. ECRs were mostly found in the lingual region, while IRRs and ERRs did not show regional differences in axial sections. There was no difference between genders in terms of volumetric and linear measurements in ECRs and IRRs, except total tooth volume was higher in males in ECRs. With increasing age in ECRs, the buccal dentin thickness increased, and bucco-lingual length and total tooth volume decreased. Using CBCT imaging, the volumetric/linear analysis and axial classification of resorptions, and demographic differences according to these parameters can help clinicians in deciding the treatment plan and in understanding the resorption nature. Further high-quality studies with larger samples are required to assess the nature and dimensions of root resorptions.

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CONFLICT OF INTEREST

The authors declare that they have no conflict of interest.

ETHICS APPROVAL

The study design was approved by the Ethics Committee of the Recep Tayyip Erdoğan University Faculty of Medicine.

Kök Rezorpsiyonlarının Konik Işınlı Bilgisayarlı Tomografi Kullanılarak Üç Boyutlu Hacimsel/Lineer Analizi ve Aksiyel Sınıflandırması: Retrospektif Çalışma

ÖZ

Amaç: *Bu çalışmanın amacı, konik ışınlı bilgisayarlı tomografi (KIBT) kullanılarak kök rezorpsiyonlarının hacimsel-lineer analizini araştırmak ve yeni bir aksiyel sınıflandırma sunmaktır.* ***Gereç ve Yöntemler:*** *Çalışmaya 34 hastanın toplamda 43 kök rezorpsiyonlu dişi (eksternal servikal rezorpsiyon (ESR) (n=27), eksternal replasman rezorpsiyon (ERR) (n=4), internal kök rezorpsiyonu (İKR) (n=12)) dahil edildi. Dişlerin KIBT görüntülerinde, hacimsel analiz için toplam diş hacmi ve rezorpsiyon hacimleri, lineer analiz için rezorpsiyonların en geniş uzunlukları ve bunların etrafındaki en ince dentin kalınlığı miktarları ölçüldü ve hacimsel/lineer ölçümler yaş ve cinsiyete göre karşılaştırıldı. Ek olarak, aksiyel kesitte sekizli bölgesel sınıflama uygulandı ve bu bölgeler karşılaştırıldı. Veriler Shapiro-Wilk, Pearson's r., Kruskal-Wallis ve*

Dwass-Steel-Critchlow-Fligner post-hoc testleri kullanılarak değerlendirildi. İstatistiksel analiz için anlamlılık p=0,05 olarak belirlendi. ***Bulgular:*** *ESR, ERR ve İKR'lerin hacimsel ve lineer ölçümleri arasında anlamlı bir fark bulunamadı. ESR bulunan erkek hastaların dişinin toplam hacmi kadınlara göre daha yüksek olması dışında (p<0,05), ESR ve İKR'lerin hacimsel ve lineer ölçümlerinde cinsiyetler arasında fark yoktu. ESR'lerde yaş arttıkça bukkal dentin kalınlığı arttı, bukko-lingual uzunluk ve dişin toplam hacmi azaldı (p<0,05). Aksiyel sınıflandırmada, ESR'ler çoğunlukla lingual bölgede bulunurken, ERR ve İKR'lerde bölgesel farklılık gözlenmedi.* ***Sonuçlar:*** *Kök rezorpsiyonları farklı lokalizasyon ve sınıflandırmalara sahip olsalar da benzer yapıya sahip olduklarından dolayı hacimsel ve lineer ölçümler açısından farklılık göstermediler. KIBT görüntüleme kullanılarak, rezorpsiyonların hacimsel/lineer analizi, aksiyel sınıflandırması ve bu parametrelere göre demografik farklılıkları klinisyenlerin rezorpsiyon doğasını anlamalarına ve uygun yönetimi belirlemelerine yardımcı olabilir.* ***Anahtar Kelimeler:*** *Sınıflama, konik ışınlı bilgisayarlı tomografi, endodonti, kök rezorpsiyonu.*

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Original research

DO THIRD MOLARS PLAY A ROLE IN SECOND MOLARS UNDERGOING ENDODONTIC TREATMENT?

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ABSTRACT

Background and aim: This study evaluated the rates of second molars undergoing endodontic treatment due to partially or fully erupted lower and upper third molars.

Materials and Methods: Radiographic data from 579 patients were analyzed to calculate the rates of second molars undergoing endodontic treatment due to third molars and other reasons. Descriptive statistics were expressed as numbers and percentages for categorical variables. The chi-square test was used to determine the relationships between categorical variables ($p<0.05$).

Results: The rate of second molars undergoing root canal treatment for reasons unrelated to third molars was statistically higher than that of second molars undergoing treatment because of third molars ($p<0.001$). The rate of lower second molars with endodontic treatment was significantly higher than that of upper second molars ($p<0.001$). There was no statistically significant difference between partially and fully erupted third molars causing root canal treatment of second molars ($p = 0.344$).

Conclusions: Root canal treatment of second molars can be related to fully or partially erupted third molars. All preventive measures should be taken to avoid the need for root canal treatment.

Key Words: Dental caries, endodontics, root canal therapy, third molar.

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INTRODUCTION

The third molars are the last teeth to erupt and are the most posterior in the oral cavity. Consequently, the probability of lack of space for their eruption is high.[1] If they are not impacted, they usually start to erupt between 17 and 21 years old.[2] Third molar eruption and subsequent continuous positional changes can be related to diet, race, genetic history, and the use of the mastication apparatus.[3]

Third molars may cause pericoronitis, periodontal diseases, caries, cyst or tumor formations, and systemic infections.[4] Partially erupted third molars show a higher incidence of symptoms than unerupted or fully erupted molars.[5] A partially erupted tooth does not participate in mastication and offers more favorable conditions for the accumulation of bacteria than a fully erupted tooth.[6] Moreover, pericoronitis associated with poor oral hygiene leads to food accumulation that cannot be cleaned by normal brushing and flossing, causing caries development.[7]

Winter classified mandibular third molar impaction according to the inclination of the long axis of the impacted third molar with respect to the long axis of an adjacent second molar.[8] The various types of impaction in maxillary third molars are similar to those of mandibular third molars with respect to their orientation to second molars. Hence, Winter's classification has been adapted to maxillary third molars.[9,10]

External root resorption or deep caries can be seen on the distal surface of a second molar[11] and are generally associated with the angulation of an adjacent third molar.[12] Partially or fully erupted mesioangular third molars are associated with the development of caries in the distal aspect of the corresponding second molar because of difficulties in cleaning.[13]

Distal caries in a second molar is more difficult to detect clinically in the presence of a third molar. Deep caries triggers a severe inflammatory reaction in the pulp and may cause pulp necrosis.[14] If these lesions remain undetected, they can progress and lead to the need for root canal treatment or extraction of the second molar.[15] Distal surface caries on a mandibular second molar can lead to problems in restoration owing to the frequent occurrence of subgingival caries accompanied by severe destruction of alveolar bone.[12] Second molars are generally considered more difficult to treat endodontically due to their anatomy and limited visibility and access.[16] For patients in whom mandibular second molars are at high risk of developing carious lesions due to their proximity to mandibular third molars, preventive extraction of the latter may be recommended to improve the prognosis of the former.[17]

Although many studies have investigated lower third molars causing distal caries in second molars,[11,12,15,18-20] no studies have examined second molars undergoing endodontic treatment because of both upper and lower third molars. The aim of this study was to evaluate second molars undergoing endodontic treatment associated with lower and upper third molars.

MATERIALS AND METHODS

The study protocol was approved by the Ethics Committee of Bezmialem Vakif University (decision no.545, date: 12.01.2020). Power analysis with G*Power ver. 3.1.2 (University of Duesseldorf, Duesseldorf, Germany) was conducted to determine the sample size. An alpha level of 0.05, a power of 0.80 and an effect size 0.01 for every variable were assumed when Independent t-Test was used to establish the significance of correlations. The estimated sample size was 383 patients. In this retrospective study, clinical and radiographic records of patients referring to the Faculty of Dentistry of Bezmialem Vakif University between January 2019 and February 2020 were collected. The study included 758 patients who were referred to the Department of Endodontics by the Department of Oral Radiology for second molar root canal treatment. The inclusion criteria were healthy patients without serious systemic diseases, and with the presence of a partially or fully erupted third molar and an adjacent second molar undergoing endodontic treatment. The exclusion criteria were as follows: second molars with vertical root fracture, traumatic injury and ankylosis; patients who were currently receiving orthodontic treatment; patients younger than 20 years and older than 51 years; patients

without an adjacent third molar and an initial panoramic radiography. Of the patients, 179 did not meet these criteria. The panoramic and periapical radiographs (Romexis Viewer, Planmeca, Helsinki, Finland) of 579 patients with endodontically treated upper or lower second molars were analyzed (Figure 1).

Figure 1. Examples of patients' panoramic radiographs. (*A*) A lower third molar with mesioangular angulation and (*B*) an upper third molar with vertical angulation.

The power was recalculated to 0.95 using post-hoc analysis according to 579 second molar. It was observed that the sample size of the study was compatible with a power of 0.95.

The eruption status of the third molars causing root canal treatment of second molars was determined on panoramic radiography. The rates of second molars undergoing root canal treatment because of third molars and for other reasons (such as prosthetic or iatrogenic causes, failed vital pulp treatments, and pulp and periapical pathologies) were calculated. The variables recorded were sex, age, location of the second molars undergoing endodontic treatment, and location, eruption status, and angulation of the third molars responsible for distal caries in the second molars.

Descriptive statistics were expressed as numbers and percentages for categorical variables. The chi-square test was used to determine the relationships between categorical variables. A z-ratio test was used to investigate the relationships between second and third molars. The level of statistical significance was set to $p<0.05$. IBM SPSS Statistics ver. 24 (IBM, Armonk, NY, USA) and Minitab ver. 17 (Minitab, State College, PA, USA) for Windows were used for the statistical analyses.

RESULTS

A total of 579 second molars of 279 (48.2%) male and 300 (51.8%) female patients were assessed in this study. Of the 579 patients, 258 (44.6%) were aged 21–30, 160 (27.6%) were aged 31–40, and 161 (27.8%) were aged 41–50. The number of second molars undergoing endodontic treatment because of third molars was higher in males, whereas the number of second molars undergoing treatment for other reasons was higher in females. However, the difference was not statistically significant ($p=0.284$). No statistically significant differences were observed between second molars with endodontic treatment and the patients' ages ($p = 0.869$; Table 1).

Table 1. Reasons for Root Canal Treatment According to Patients' Demographic Data ($n = 579$)

Reason	**Sex**		***P***
	Male	**Female**	
Third molar	71	65	0.284
Other	208	235	
	Age		
	21–30	**31–40**	**41–50**
Third molar	59	40	37	0.869
Other	199	120	124	

The angulation types of third molars causing root canal treatment of second molar teeth are shown in Figure 2.

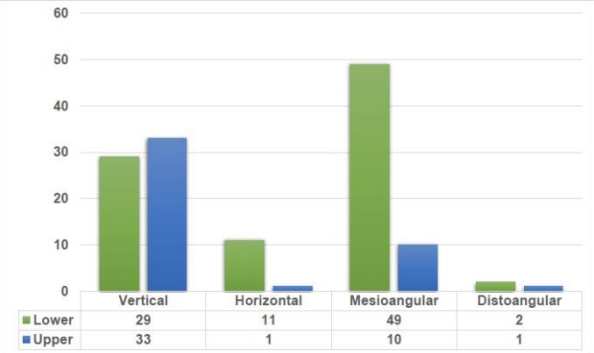

Figure 2. Angulation types of third molars causing root canal treatment of second molars.

No statistically significant differences were observed between third molar angulation and gender (p = 0.585) or age (p = 0.147). No statistically significant difference was found between partially and fully erupted third molars causing root canal treatment of second molars (p = 0.344). The eruption status of the third molars is shown in Figure 3. In patients undergoing second molar root canal treatment for reasons unrelated to third molars, 68% of the third molars were fully erupted (Figure 3).

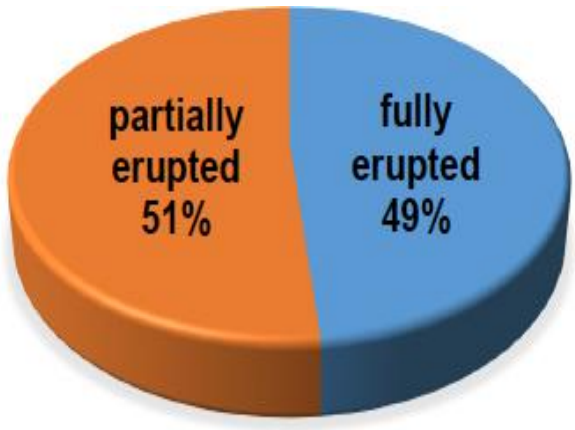

Figure 3. Eruption status of third molars causing root canal treatment of second molars.

Of the 579 second molars, 136 (23.5%) underwent root canal treatment because of third molars. The rate of second molars undergoing root canal treatment for reasons not related to third molars was statistically higher than that of second molars undergoing treatment because of third molars (p<0.001). The rate of lower second molars with endodontic treatment was significantly higher than that of upper second molars (p<0.001). The locations and reasons for endodontic treatment of second molars are shown in Table 2.

Table 2. Reasons for Endodontic Treatment and Locations of Second Molars (n = 579)

		***n* (%)**	***P***
Reason	Third molar	136 (23.5%)	<0.001
	Other	443 (76.5%)	
Location	Lower	336 (58%)	<0.001
	Upper	243 (42%)	

DISCUSSION

Of the 579 second molars included in this study, 136 (23.5%) underwent root canal treatment because of third molars and 443 (76.5%) for other reasons, such as prosthetic or iatrogenic causes, failed vital pulp treatments, or caries other than distal caries. Dental caries are the most common second molar lesions seen on panoramic radiographs and most commonly affect second molars adjacent to impacted third molars at the cervical line.[18] However, considerably more cases of external cervical resorption have been diagnosed with cone beam computed tomography than with panoramic radiography.[21] In this study, external root resorption in second molars could not be assessed, as they were examined only on panoramic radiography and not on cone beam computed tomography. Therefore, all lesions were accepted as distal caries.

Third molars can cause second molars a number of problems.[22] They may also cause pericoronitis, periodontal diseases, cyst or tumor formations, and systemic infections besides distal caries.[4] These problems can be related to the inability to effectively clean the distal area.[23] In cases of bacterial invasion of the pulp or of deep

caries with spontaneous pain, endodontic treatment is inevitable. Other reasons for root canal treatment include trauma, failed root canal treatment, and restorative or prosthetic procedures.[24]

McArdle and Renton (2006) assumed that distal caries in a mandibular second molar is tooth-specific and does not develop in the absence of a third molar.[13] It has been reported that the incidence of distal caries in mandibular second molars is closely associated with mesial angulation and the distance between the distal cementoenamel junction of the mandibular second molar and the mesial cementoenamel junction of the mandibular third molar.[12] The most common type is mandibular mesioangular angulation (48.3%), followed by horizontal angulation (29.3%).[9] Knutsson *et al.*[5] (1996) reported that mesioangular and horizontally positioned third molars are more likely to be associated with caries development in adjacent second molars. The incidence of distal caries in second molars associated with mesioangular third molars varies between countries. A rate of 12.6% has been reported in the Turkish population[19], 26% in the American population[5], 38.53% in the Pakistani population[25], 21.5% in the Jordanian population[18], and 27.4% in the South Korean population.[26] According to the results of these studies[5,18,19,25,26], mesioangular third molars showed a high incidence of distal caries of the adjacent second molar. In this study, 49 of 91 (53.8%) mandibular third molars that causing second molars to be treated endodontically were in mesioangular position. The reason for the higher rate in our study may be the fact that we did not examine the incidence of distal caries but second molars that required endodontic treatment because of mesioangular third molars. It was assumed that distal caries may have been noticed and treated restoratively before reaching the pulp. Therefore, this result may be difficult to compare with other studies.

Previous studies have reported that vertical angulation of third molars is the most common angulation in the maxilla.[9,27,28] In this study, we did not investigate the frequency of each angulation type according to location. However, among the upper third molars, 10 teeth with a mesioangular angle and 33 with a vertical angle were found to cause root canal treatment of second molars. Third molars in the vertical position may indirectly cause caries on the distal side of second molars. Because flossing between the second and third molars can be difficult, interproximal caries may occur regardless of the third molar's angulation. Alhobail *et al.*[27] (2019) found no significant association between the distoangular position and the incidence of distal surface caries in second molars. Similarly, in this study, third molars in the distoangular position were not a high-risk factor for root canal treatment of second molars due to distal caries.

Altan *et al.*[29] (2018) have reported a significantly higher incidence of distal caries in the presence of a third molar in males than in females. In contrast, AlHobail *et al.*[27] (2019) found that gender did not significantly affect the risk of distal surface caries in second molars because of third molars. Likewise, in this study, we observed no statistically significant difference between male and female patients in this respect.

In some studies, most patients were aged between 25 and 34.[27,30] It has been suggested that the longer a third molar is exposed in the mouth, the higher the chance of caries developing on the distal surface of a second molar.[12,31] Odirinu *et al.*[22] (2012) found a strong association between an older age and the development of distal cervical caries in a second molar adjacent to an impacted mandibular third molar. In contrast, according to Altıparmak *et al.*[32], (2017) age does not correlate with the prevalence of distal caries lesions in second molars. The reason that we determined the age range for included patients as 21–50 years was that we frequently perform root canal treatments not only on young patients but also on middle-aged patients. In line with Altıparmak *et al.*[32] (2017), we found no statistically significant relationship between age and second molars with endodontic treatment because of third molars (p=0.869). This may be related to the fact that we only examined second molar teeth undergoing root canal treatment. Moreover, our results only reflect the rates of second molars undergoing endodontic treatment because of third molars. This study was a single-

center study conducted in Istanbul. The rates could be different in other regions of Turkey, or between urban and rural areas.

The length of time required for a mesioangular or horizontal third molar to either fully or partially erupt is a critical factor in the development of distal caries in an adjacent second molar.[33] Allen *et al.*[15] (2009) found that distal second molar caries were present in 11%, 55%, and 53% of unerupted, partially erupted, and fully erupted adjacent mesioangular third molars, respectively. Alhobail *et al.*[27] (2019) reported a higher incidence of caries in second molars in the presence of fully erupted than impacted third molars. In our study, 51% of third molars associated with second molars undergoing root canal treatment were partially erupted, and 49% were fully erupted. In the case of second molars undergoing root canal treatment for other reasons, 68% of adjacent third molars were fully erupted. Although we found no statistically significant difference, these results suggest that partially erupted third molars lead to more caries and destruction of adjacent second molars. A partially erupted third molar could also lead to the need for extraction of a second molar. Therefore, we postulate that the damage caused by partially erupted third molars could be even greater.

In this study, we found a significantly higher rate of lower than upper second molars undergoing endodontic treatment ($p < 0.001$). Of the 136 second molars undergoing root canal treatment because of third molars, 45 (33.1%) were in the maxilla and 91 (66.9%) were in the mandible.

This study had some limitations. First, we only investigated second molars undergoing endodontic treatment because of lower and upper third molars and did not consider second molars undergoing restorative treatment because of third molars. If the latter had been included in the study, the rates may have been different. Second, we only included patients with second molars undergoing root canal treatment that had adjacent third molars. Inclusion of patients undergoing second molar root canal treatment following third molar extraction may have altered the results. Finally, the fact that this was a single-center study and the fact that certain potentially influencing factors (such as oral hygiene and lifestyle habits) were not considered could also accepted as limitations.

The strength of this study was that it was the first study to investigate upper third molars causing distal caries in second molars or second molars treated endodontically because of upper and lower third molars. Therefore, we believe that our findings make a significant contribution to the literature.

CONCLUSIONS

This retrospective study found an association between second molars undergoing root canal treatment and fully or partially erupted third molars. Control of third molars with regular radiographs is recommended. Further studies are needed to establish whether prophylactic removal of a third molar should be considered. Optimal oral hygiene practices are recommended for patients who do not wish to have their third molars extracted.

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The authors deny any conflicts of interest related to this study.

ÖZ

Amaç: *Bu çalışmada kısmen veya tamamen sürmüş alt ve üst üçüncü molar dişlere bağlı olarak endodontik tedavi gören ikinci molar dişlerin oranları değerlendirilmiştir.* ***Gereç ve Yöntemler:*** *Üçüncü molar dişler ve diğer nedenlerle endodontik tedavi yapılan ikinci molarları saptamak için 579 hastadan alınan radyografik veriler analiz edilmiştir. Tanımlayıcı istatistikler, kategorik değişkenler için sayı ve yüzde olarak ifade edilmiştir. Istatistiksel analiz için Ki-Kare testi kullanılmıştır (p<0,05).* ***Bulgular:*** *Üçüncü molar dişlerden bağımsız olarak kök kanal tedavisi gören ikinci molar dişlerin oranı, üçüncü molar dişler nedeniyle tedavi gören ikinci molarların oranından istatistiksel olarak daha yüksek bulunmuştur. (p<0,001) Endodontik tedavi gören alt ikinci molar dişlerin oranının, üst ikinci molar dişlere oranla daha fazla olduğu tespit edilmiştir (p<0,001). İkinci molar dişlerin kök kanal tedavisi görmesine neden olan kısmen veya tamamen sürmüş üçüncü molar dişler arasında istatistiksel olarak anlamlı bir farklılık bulunamamıştır (p=0,344).* ***Sonuç:*** *İkinci molar dişlerin kök kanal*

tedavisi tamamen veya kısmen sürmüş üçüncü molar dişler ile ilişkili olabilir. Kök kanal tedavisi ihtiyacını önlemek için tüm önleyici tedbirler alınmalıdır. ***Anahtar Kelimeler:*** *Diş çürüğü, Endodonti, kök kanal tedavisi, üçüncü molar diş.*

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Original research

VOLUMETRIC ANALYSIS OF THE ARTICULAR EMINENCE PNEUMATIZATION USING CONE-BEAM COMPUTED TOMOGRAPHY

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ABSTRACT

Objectives: To assess tomographic features of articular eminence pneumatization (AEP) using cone beam computed tomography (CBCT).

Materials and Methods: To evaluate 659 CBCTs (500 women and 159 men) of the Oral and Maxillofacial Radiology service of Universidad Peruana Cayetano Heredia Dental Clinic, between 2014 – 2015. The age group was between 7 to 79 years-old. The classification of Al Faleh and Ibrahim was also used to assess the degree of pneumatization, and the statistical analysis was performed using the chi-square test.

Results: The frequency of AEP was 76.2% (502 cases). The highest frequency was found for grade 0 and 2, the highest frequency was found in the 6th decade of life and great predominance was found for the female sex. However, no statically significant differences were found with respect to the gender.

Conclusions: AEP prevalence was 76.2% and CBCT became the gold-standard that allows an adequate evaluation of this anatomical variant.

Keywords: Cone-beam computed tomography, temporal bone, temporomandibular joint, zygoma.

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INTRODUCTION

In recent years Cone Beam Computed Tomography (CBCT) has been used with great frequency in the evaluation of bony structures of the skull. The image detail, the short examination time, the low cost and the lower exposure to radiation compared to conventional computed tomography (CT) has made it become the gold standard for the proper evaluation of the skull.[1]

The pneumatization process can be defined as a development of air within the bone cavities and can occur in numerous locations in the skull including the temporal bone.[2] The mastoid antrum is the first cell of the mastoid air system to develop around the 4th and 5th month of intrauterine life. The pneumatization process begins around the 7 months of intrauterine life. During the post-natal development, the epithelium of the mastoid portion expands and begins its development 1 to 2 years after birth.[3,4] Some authors, among them Groell and Fleischman[5], reported that articular eminence pneumatization (AEP) occurs through a sub-epithelial bone resorption process. The complete pneumatization of mastoid cells can be divided into 3 stages: infantile stage, from birth to 2 years of age; the transitional stage, from 2 to 5 years; and the adult stage, after 5 years.[2] The AEP can be in relation to the middle ear, the Eustachian tube and the mastoid structure, depending on the degree there may be repercussions in the cholesteatoma processes, chronic otitis and even in pathological or surgical procedures such as mastoidectomy.[6] Another entity associated with the AEP is the middle-ear barotrauma, this entity is defined as the damage of the middle ear tissues where the Eustachian tube does not allow the entry of air into this structure producing a pressure difference between the middle ear and the surrounding environment. Uzun *et al.*[7] reported an inverse relationship between the size of pneumatization and risk of symptomatic middle ear barotrauma in sport scuba divers. This indicates that people with AEP are protected against a barotrauma since the mastoid cells act as shock absorbers before sudden changes in pressure.

Panoramic radiography and other conventional projections of the skull do not provide adequate visualization of the posterior aspect of the zygomatic arch due to the superposition of structures. These disadvantages have been overcome now, cone-beam CT (CBCT) has a great field of applications in dentistry, including preoperative implant planning, third molar imaging, temporomandibular joint (TMJ) evaluation, orthodontic treatment planning, and craniofacial anomaly estimation. In comparison to computed tomography (CT) they are cheaper and incur a lower radiation dose. Recently, a higher prevalence of temporal bone pneumatization around TMJ has been reported using CT.[8]

Within the radiographic features, AEP appears as radiolucent images of defined limits and of similar shape and size to the mastoid pneumatization (MP) air cells. These cells can appear unilaterally or bilaterally and present a unilocular or multilocular radiographic pattern. Also, they do not produce expansion or symptomatology, important characteristics to be able to rule out some pathologies such as an eosinophilic granuloma, hemangiomas or solitary bone cysts at this level.[9] Several studies have classified the AEP, among them Han *et al.*[10] and Yamakami *et al.*[11] However, few were made using CBCT. Recently, Shamshad *et al.*[12] reported a prevalence of 52% in India. In 2014, Nascimento *et al.*[13] found a frequency of 3.3% in Brazil and Demirel *et al.*[14] reported 67.6% in Turkey. In 2013, Delibasi *et al.*[15] described 2.54% and Ladeira *et al.*[1] found 21.3% in Brazil. The pneumatization pattern can affect any surgical procedures involving the skull base region. Pneumatization of the articular eminence is a challenging entity for TMJ surgery and spread of infections in this region. Practitioners who are dealing with TMJ surgery and pathology should need detailed information about this anatomical variation since it may cause serious complications. The aim of this study was to classify articular eminence pneumatization in adults using CBCT data sets in a peruvian population.

MATERIALS AND METHODS

We designed a descriptive, transversal and retrospective study. This study used CBCT images of patients who were referred to the Oral and Maxillofacial Radiology Service at Universidad Peruana Cayetano Heredia, between February 2014 and December 2015. The study protocol (17.12.2014), was approved by the Institutional Ethics Committee of the Universidad Peruana Cayetano Heredia (CIE- UPCH). Selection criteria for patients (6 to 79 years of age) included images with field of view in which the right and left MP were adequately seen. Cases displaying cystic or tumoral pathologies in the temporal bone or maxillofacial fracture history were excluded from the study. The variables that were taken into account were age, gender, laterality (unilateral,bilateral), sides (right or left) and degree of pneumatization. Guidelines were drawn perpendicular to the axis of the condyle on axial views, and cross-sectional reconstructions were made perpendicular to these lines with 1-mm slice thicknesses and 1-mm slice intervals. Axial and sagittal sections were also used. For the degree of pneumatization, the Al Faleh and Ibrahim[16] classification was used, which is conformed by 4 grades (0 to 3): grade 0 = pneumatization limited to the MP, grade 1=pneumatization between the MP to the deepest part of the glenoid fossa, grade 2 = pneumatization between the deepest part of the glenoid fossa and the tip of the articular eminence and grade 3 = pneumatization extending beyond the crest of the articular eminence (Figure 1).

Figure 1. Example of AEP (sagittal view) showing the degree of pneumatization based on Al Faleh and Ibrahim[16] classification. (A) Grade 0. (B) Grade 1. (C) Grade 2. (D) Grade 3.

The principal investigator was trained and calibrated by an oral and maxillofacial radiologist with more than 10 years of experience. This calibration was performed on 15 CBCT scans (Siemens, Germany). All the scans were acquired on a Galileos unit (Siemens, Germany) operating from 10mA to 42Ma and 85Kv according to each patient, all the images were exported on a Lenovo H61 compatible computer and were evaluated through the Galaxis 1.7.2 software. The inter-observer Kappa was 0.82 and 0.9 for the intra-observer agreement. 20 CBCTs were evaluated per day on an inter-day basis in a dimmed room at a distance of 60 cm from the diagnostic viewing screen, with low ambient light and maximum of 2 hours per day. The digital images were analyzed on a 21-inch screen, with a resolution of 1600x900 pixels and 32-bit color depth.

Statistical methods

The collected data was statistically analyzed using SPSS ver.23 for Windows (IBM SPSS, Chicago, Illinois, USA). Frequency distribution tables were used for the variables sex, laterality, side and degree of pneumatization. For the bivariate analysis, the Chi-Square Test and the Yates-corrected Chi-square Test were used for the case of sex because it was a non-homogeneous sample. The study had a confidence level of 95% and $p < 0.05$.

RESULTS

The study population consisted of 659 CBCTs. There were 159 male patients and 500 female patients. The prevalence of AEP for the female gender was 58.3% (384 CBCTs) and for the male gender 17.9% with 118 CBCTs. Overall, 445 cases (33.8%) had grade 0 pneumatization, 371 cases (28.1%) had grade 1, 432 cases (32.8%) had grade 2, and 70 cases (5.3%) had grade 3. Regarding the AEP grade by gender, the highest prevalence was grade 0 followed by grade 2 for both genders. There was no significant relationship between the grade of pneumatization and sex ($p=0.82$) (Table 1).

Table 1. Distribution of AEP groups and sex groups

	Pneumatization grade							
Sex	**Grade 0**		**Grade 1**		**Grade 2**		**Grade 3**	
	n	**%**	**n**	**%**	**n**	**%**	**n**	**%**
Male	114	8.6	85	6.4	103	7.8	16	1.2
Female	331	25.1	286	21.7	329	25.0	54	4.1
TOTAL	445	33.8	371	28.1	432	32.8	70	5.3

Yates-corrected Chi-square Test (p=0.51).

For the AEP grade and the age group, the highest prevalence was on the 50-59 years-old group for grade 0. For grade 2, the 40-49 years-old group had the highest prevalence (figure 2).

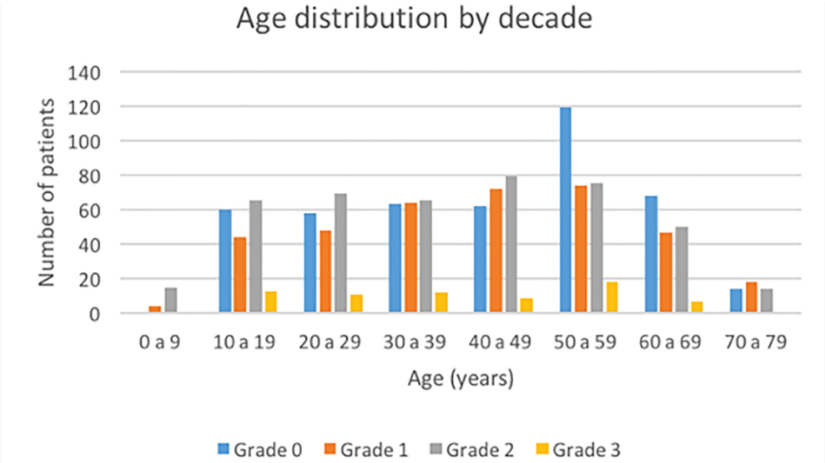

Figure 2. Frequency distribution of the AEP in relation to the age.

With respect to the side and frequency of the AEP grade, the most prevalent grade for the right side was grade 0. For the left side, grade 2 was the one with the highest prevalence. A statistically significant difference was found between the AEP grade and the side (Table 3).

Table 3. Distribution of AEP groups and side

	Pneumatization grade							
Side	**Grade 0**		**Grade 1**		**Grade 2**		**Grade 3**	
	n	**%**	**n**	**%**	**n**	**%**	**n**	**%**
Right	252	19.1	182	13.8	192	14.6	33	2.5
Left	193	14.6	189	14.3	240	18.2	37	2.8
TOTAL	445	33.8	371	28.1	432	32.8	70	5.3

Chi-Square Test (p<0.01).

In relation to laterality, grade 2 was the most prevalent grade found in bilateral cases. For unilateral cases, the highest prevalence was in grade 0 (Table 2).

Table 2. Distribution of laterality between the pneumatization groups

Laterality	Pneumatization grade							
	Grade 0		Grade 1		Grade 2		Grade 3	
	n	%	n	%	n	%	n	%
Absent	157	100.0	0	0.0	0	0.0	0	0.0
Unilateral	128	49.6	84	32.6	40	15.5	6	2.3
Bilateral	3	0.4	287	38.5	392	52.5	64	8.6

Chi-Square Test (p<0.01).

DISCUSSION

The present study is one of the few studies available in South America and the first in our country using CBCT. This technique allows to evaluate and detect the AEP more precisely.[13] The frequency of the AEP in the present study was 76.2% (502 cases) of 659 revised CBCTs. This result is similar to the one published by Demirel *et al.*[14] with a frequency of 67.6% (169 cases) of 250 revised CBCTs and to the study reported by Khojastepour *et al.*[17] with a prevalence of 76.7% (251 cases) of 327 CBCT patients. On the other hand, a lower frequency of 6.47% (39 cases) was reported in the turkey population.[9] Furthermore, Ladeira *et al.*[1] and Delibasi *et al.*[15] found 21.3% (140 cases) and 2.54% (21 cases) respectively in Brazil. Recently, Şallı *et al.*[18] reported a prevalence of 14.7% (147 cases) of 1000 cases in a tukish population.

Regarding studies using CT, Groell and Fleischmann (9) found a frequency of 12% (12 cases) in Austria, and Bronoosh *et al.*[19] found 9.55% (43 cases) in Iran. Also, Al Faleh and Ibrahim[16] found 34% (102 cases) using conventional tomograms in Egypt. Only one study has reported a higher prevalence using CT (69% of 100 cases) in India.[12] Moreover, using panoramic radiography Shokri *et al.*[20] and Khojastepour *et al.*[8] found a frequency of 6.2% (98 cases) and 2.1% (64 cases) respectively in Iran using panoramic radiography. In India, Kishore *et al.*[21] and Patil *et al.*[22] found similar frequencies of 2.5% (63 cases) and 1.82% (141 cases) respectively. Orhan *et al.*[2] reported a similar frequency of 1.88% (19 cases) to the ones reported by Hofmman *et al.*[23] with a frequency of 2.38% (20 cases) and of 1.85% (20 cases) respectively in Germany (Table 4). We have noticed that this anatomical variant increases its frequency when evaluated through CBCT. The improvement of the image and the advance on the techniques can contribute to an adequate evaluation. Therefore, the frequency of AEP can be increased.

Our study showed a greater predilection of AEP on females. Nevertheless, there was no statistically significant difference. Similar results were reported by other authors.[6,16,23–25]On the other hand, Ladeira *et al.*[1] found a slight predilection for the male gender with respect to the total of patients with AEP evaluated with CBCT. Some authors attribute a higher prevalence on the female sex because pneumatization begins with maturation, for this reason girls are chronologically and biologically older than children. Another theory may be due to the random recruitment performed at the time of the study.

Our findings detected more cases with AEP in the sixth decade of life with an age range of 7 to 79 years-old. In the present study, there was a statistically significant difference. Ladeira *et al.*[1] found a similar result. This may be due to the main indication for taking CBCT, since most of the patients in the clinic are referred by the implantology area. Another theory according to Orhan *et al.*[2] is that accessory air cells begin their pneumatization after puberty and end their development several years later, even in the adult stage.

Regarding the AEP localization, most studies found that there is a greater predilection for the left side, as reported in the present study where we found a statistically significant difference. However, other studies such as that of Patil *et al.*[22],

Bronoosh *et al*.[19] and Carter *et al*.[24] found a greater predilection for the right side (Table 4).

Table 4. Percentages of articular eminence pneumatization from previous studies by sex, age, side and laterality

Author	Year	Coutry	Sex				Age range	Most frequent age group	N° of cases by side				Imaging Technique
			Female	%	Male	%	(Years)	(Years)	Right	Left	Unilateral	Bilateral	
Şallı et al.[18]	2020	Turkey	253	51.8	235	48.2	16-77	--	149	88	237	381	CBCT
Khojastepour et al.[17]	2018	Iran	112	44.6	139	55.4	9 - 65	---	41	35	76	175	CBCT
Shamshad et al.[12]	2017	India	48	48	52	52	18 - 65	---	14	17	31	38	CT
Kishore et al.[21]	2015	India	----	----	----	----	19 - 78	29 - 38	36	46	44	19	PAN
Demirel et al.[14]	2014	Turkey	179	55.5	159	44.5	----	----	----	----	----	----	----
Bronoosh et al.[19]	2014	Iran	----	----	----	----	----	----	32	30	24	19	CT
Khojastepour et al.[8]	2014	Iran	41	64	23	36	19 - 69	19 - 29	----	----	----	----	PAN
Shokri et al.[19]	2013	Iran	65	66.4	33	33.6	8 - 60	11 - 20	30	34	64	34	PAN
Ladeira et al.[1]	2013	Brasil	75	37	129	63	11 - 85	50 -59	94	110	76	64	CBCT
Patil et al.[22]	2012	India	----	----	----	----	19 - 75	19 - 28	96	79	107	34	PAN
Miloglu et al.[9]	2010	Turkey	25	54	14	46	----	----	12	21	23	16	PAN
Al Faleh et al.[16]	2005	Egypt	54	52.9	48	47.1	----	----	86	89	----	----	Conventional CT
Orhan et al.[2]	2005	Turkey	12	63.1	7	36.9	11 - 29	20 - 29	----	----	----	----	PAN
Hofmman et al.[22]	2001	Germany	11	55	9	45	7 - 87	20 - 29	----	----	----	----	PAN
Carter et al.[23]	1999	USA	20	50	20	50	17 - 83	60 - 69	25	23	32	8	PAN

CBCT: Cone-beam CT, PAN:Panoramic radiography, CT: Computed tomography

Moreover, with respect to laterality a higher prevalence was found for unilateral presentations on CT, panoramic radiography and CBCT. However, Nascimento *et al*.[13] found a higher prevalence of bilateral presentations. Our study found a similar result, this can be due to the same time of development of both temporal bones. In the present study, a statistically significant difference was found with respect to AEP with regard to laterality (Table 4).

Finally, based on Al Faleh and Ibrahim[16] mastoid cells classification, the highest prevalence was for grades 0 and grade 2. With respect to the gender, females with grade 0 had the highest prevalence. However, no statistically significant differences were found. Statistically significant differences were found regarding the age group, the sixth and fifth decade of life were the most prevalent. Finally, the left side and a bilateral presentation were the most prevalent, with grade 2 in a predominant occurrence. A statistically significant difference was also found.

It is very important to know the degree of pneumatization that mastoid cells can present. This can allow us to relate, prevent or rule out pathologies associated with the temporal bone at this level. An adequate diagnosis and also the possibility of being participants in a multidisciplinary management with other areas of medicine may benefit the patient.

CONCLUSIONS

In conclusion, AEP pneumatization was found in 76.2% of the patients, the highest prevalence of AEP was found in grades 0 and 2, and our results were consistent with previous studies using cone-beam CT. Knowing the degree of AEP pneumatization is important because we can prevent or rule out pathologies associated with the temporal bone at this level. Further studies using

cone-beam CT including greater numbers of patients may be useful to define the frequency of this entity and its relationship with other variables.

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Reviews

CLINICOPATHOLOGICAL PARAMETERS RELATED TO MALIGNANT TRANSFORMATION OF ORAL LEUKOPLAKIA: A META-ANALYSIS

ABSTRACT

Objective: To assess the clinical-pathological factors related to the malignant transformation of oral leukoplakia.

Materials and Methods: A search for articles on malignant transformation factors related to oral leukoplakia was conducted in the following electronic databases: PubMed (MEDLINE, Cochrane Library), Web of Science (WoS) and Google Scholar. Thirty-seven articles with a low-moderate risk of bias according to the Newcastle-Ottawa methodological quality scale were included in this meta-analysis. The data were analyzed using the statistical programs RevMan 5.4 (The Cochrane Collaboration, Oxford, UK) and MedCalc Statistical Software version 16.4.3 (MedCalc Software Ltd. Ostend, Belgium) programs. The estimated prevalence was calculated according to DerSimonian and Laird random method. For dichotomous outcomes, the estimates of effects of an intervention were expressed as odds ratios (OR) using the Mantel-Haenszel (M-H) method with 95% confidence intervals.

Results: The estimated global prevalence of malignant transformation of oral leukoplakia was 9.15%. The factors with the highest malignant transformation risk of oral leukoplakia were: non-homogeneous clinical types (OR: 5.41; p<0.001); leukoplakias with moderate-severe dysplasia (OR: 3.43; p<0.001); lesions located on the tongue and/or the floor of the mouth (OR: 3.19; p<0.001); leukoplakias in non-smokers (OR: 2.08; p<0.001) and lesions in women (OR: 1.73; p<0.001). In contrast, older age or regular alcohol intake were factors without significant influence (p>0.05).

Conclusions: Non-homogenous oral leukoplakias and with moderate-severe dysplasia are those with the highest probability of malignant transformation.

Keywords: Cell transformation, neoplastic, epidemiology, leukoplakia oral, risk factors.

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INTRODUCTION

In 2005, the World Health Organization (WHO) in collaboration with the UK Center for Oral Cancer and Precancer carried out a redefinition of oral leukoplakia (OL) as a "white plaque of questionable risk whose diagnosis is reached having excluded other known diseases or disorders that do not involve an increased cancer risk".[1]

OL is the most common potentially malignant disorder of the oral mucosa with an overall prevalence of around 2.6%.[2] Clinically, two main clinical forms are differentiated: a) homogeneous, with uniform white lesions and b) non-homogeneous, within which three types are distinguished: speckled, nodular and verrucous.[3] Its true potential for malignancy is not yet well established and is under constant analysis. Most oral leukoplakias are related to tobacco and/or alcohol consumption. However, idiopathic leukoplakias not associated with these factors have a higher rate of malignant transformation. According to different studies, the OL malignant transformation rate ranges between 0.13% and 34%.[4] The purpose of this study was to assess the clinicopathological factors related to the malignant transformation of oral leukoplakia.

MATERIALS Y METHODS

According to the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) guidelines, a search for studies on risk factors for malignant transformation of oral leukoplakia was performed in the following databases: PubMed (MEDLINE, Cochrane Library), Web of Science (WoS) and Google Scholar. Search strategies included a combination of Medical Subjects Headings (MeSH) and free-text terms. The search terms were as follows: "leukoplakia, oral" [MeSH Terms] AND ("cell transformation, neoplastic" [MeSH Terms] OR "malignant" [All Fields] OR "transformation" [All Fields] OR "degeneration" [All Fields] OR "progression" [All Fields]); "Oral", "leukoplakia" AND "malignant"; allintitle: "malignant", "oral leukoplakia". After this initial search, 2994 articles were found (1029 in PubMed, 1867 in WoS and 98 in Google Scholar), 1792 of them duplicates, leaving 1202 articles for review. Article titles and abstracts were examined independently by two authors (ARA and CFP) that selected jointly the articles to include in the present study. The exclusion criteria were: a) articles without full-text availability (n=563); b) articles with a score of fewer than 6 stars out of a maximum of 9 on the Newcastle-Ottawa methodological quality assessment scale[5] (n=134), and c) studies with non clinical or non-usable data (n=468). Finally, 37 studies were included in the meta-analysis (Figure 1).

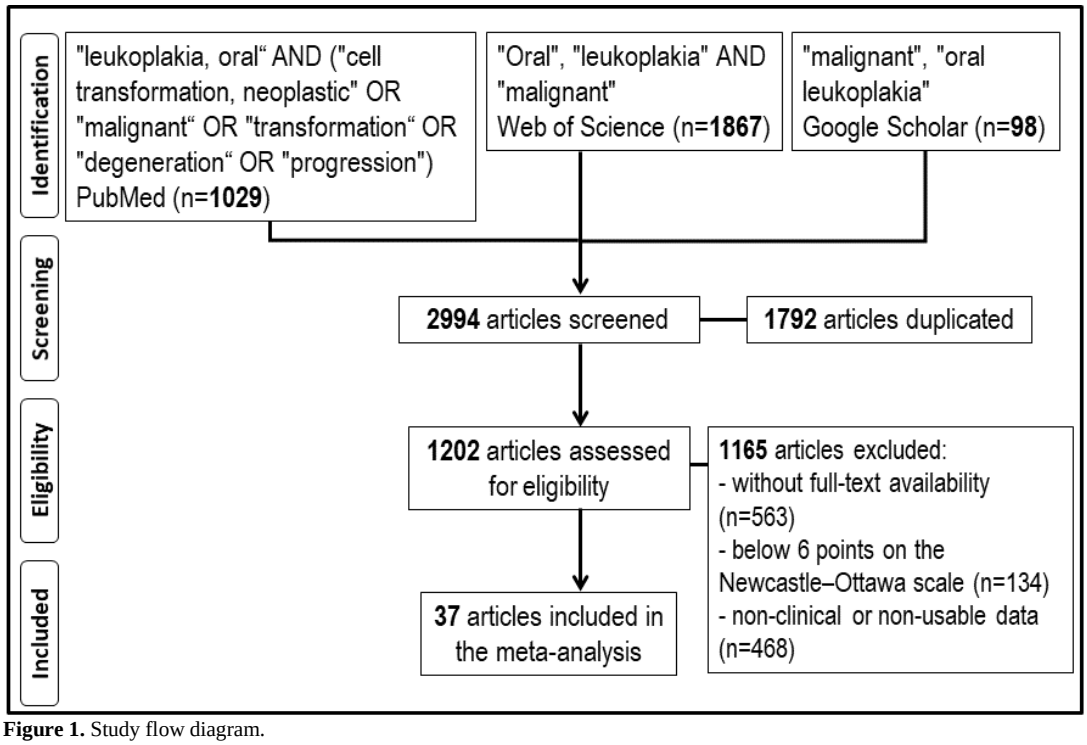

Figure 1. Study flow diagram.

Statistical Analysis

Data were statistically analyzed with the RevMan 5.4 (The Cochrane Collaboration, Oxford, UK) and MedCalc Statistical Software version 16.4.3 (MedCalc Software Ltd. Ostend, Belgium) programs. The estimated prevalence was calculated according to DerSimonian and Laird random method. For dichotomous outcomes, the odds ratio (OR) with the Mantel-Haenszel Chi-square formula (M-H) and 95% confidence intervals (95% CI) was used. Heterogeneity was determined according to the P values, Cochran's Q, and Higgins statistic (I^2). A random-effects model was applied if the heterogeneity was high (I^2>50%). The minimum level of significance was set at $p<0.05$.

RESULTS

Table 1 presents the thirty-seven studies[6-42] that analyzed the prevalence of malignant transformation of oral leukoplakia in populations from 15 different countries. The estimated global prevalence of malignant oral leukoplakia was 9.15% (95% CI: 6.71 to 11.93%) with a range from the maximum prevalence of 34.00% (95% CI: 21.20 to 48.76%)[24] to the minimum of 0.12% (95% CI: 0.04 to 0.27%).[10]

Table 1. Studies on the prevalence (and 95% CI) of malignant transformation of oral leukoplakia

Study	Year	Country	Sample size	Prevalence	(95% CI)
Einhorn[6]	1967	Sweden	782	1.53%	(0.79 to 2.66%)
Pindborg[7]	1968	Denmark	214	5.14%	(2.59 to 9.01%)
Gangadharan[8]	1971	India	1411	4.46%	(3.44 to 5.67%)
Roed-Petersen[9]	1971	Denmark	331	2.71%	(1.25 to 5.09%)
Silverman[10]	1976	India	4762	0.12%	(0.04 to 0.27%)
Banoczy[11]	1977	Hungary	670	5.97%	(4.29 to 8.04%)
Kramer[12]	1978	UK	29	24.13%	(10.29 to 43.54%)
Pogrel[13]	1979	UK	19	15.78%	(3.38 to 39.57%)
Gupta[14]	1980	India	735	1.63%	(0.84 to 2.83%)
Roch-Berry[15]	1981	UK	117	17.09%	(10.76 to 25.15%)
Silverman[16]	1984	USA	257	17.51%	(13.06 to 22.71%)
Lind[17]	1987	Norway	157	8.91%	(4.96 to 14.50%)
Hogewind[18]	1989	Netherlands	46	6.52%	(1.36 to 17.89%)
Shi[19]	1992	China	235	13.61%	(9.50 to 18.67%)
Schepman[20]	1998	Netherlands	166	12.04%	(7.51 to 17.99%)
Ge[21]	1999	China	211	6.63%	(3.67 to 10.88%)
Saito[22]	1999	Japan	111	7.20%	(3.16 to 13.70%)
Guan[23]	2001	China	110	11.81%	(6.44 to 19.36%)
Napier[24]	2003	UK	50	34.00%	(21.20 to 48.76%)
Mishra[25]	2005	India	2920	0.68%	(0.41 to 1.05%)
Lee[26]	2006	Taiwan	1046	12.90%	(10.93 to 15.09%)
Hsue[27]	2007	Taiwan	913	3.61%	(2.50 to 5.03%)
Arduino[28]	2009	Italy	207	7.24%	(4.11 to 11.67%)
Lan[29]	2009	China	409	12.71%	(9.64 to 16.33%)
Zhu[30]	2009	China	150	9.33%	(5.19 to 15.16%)
Liu[31]	2010	China	218	17.89%	(13.04 to 23.63%)
Wang[32]	2011	China	576	11.45%	(8.97 to 14.34%)
Warnakulasuriya[33]	2011	UK	335	6.86%	(4.40 to 10.12%)
Brzak[34]	2012	Croatia	54	1.85%	(0.04 to 9.89%)
Gao[35]	2012	China	1832	4.64%	(3.72 to 5.70%)
Ho[36]	2012	UK	91	25.27%	(16.74 to 35.47%)
Liu[37]	2012	China	320	17.81%	(13.77 to 22.45%)
Lian[38]	2013	Taiwan	1238	7.10%	(5.74 to 8.68%)

Brouns[39]	2014	Netherlands	144	11.11%	(6.48 to 17.41%)
Kil[40]	2016	South Korea	27	25.92%	(11.11 to 46.28%)
Wang[41]	2018	Taiwan	1046	12.90%	(10.93 to 15.09%)
Gandara-Vila[42]	2018	Spain	85	8.23%	(3.37 to 16.23%)
	Total (*random effects*)		**22024**	**9.15%**	**(6.71 to 11.93%)**

Test for heterogeneity
Q=1480.19; df: 36 (P<0.0001); I^2=97.57%; 95% CI: (97.15 to 97.92)

UK: United Kingdom; **USA:** United States of America; **%:** percentage; **(95% CI):** 95% confidence interval.

The main risk factors related to the malignant transformation of oral leukoplakia are shown in Table 2.

Table 2. Main risk factors related to malignant transformation of oral leukoplakia (OL)

Risk factor	n	Outcome	OR	(95% CI)	I^2	p-value
Age	6	>60 years-old	1.56	(0.95 to 2.57)	46%	0.08
Gender	22	Female	1.73	(1.47 to 2.05)	21%	<0.001*
OL clinical type	13	Non-homogeneous	5.41	(3.24 to 9.02)	61%	<0.001*
Degree of dysplasia	6	Moderate-Severe	3.43	(2.30 to 5.11)	0%	<0.001*
OL Location	9	Tongue- FM	3.19	(2.26 to 4.50)	41%	<0.001*
Smoking	6	Non-smoker	2.08	(1.51 to 2.80)	0%	<0.001*
Drinking	6	Non-drinker	1.02	(0.76 to 1.38)	0%	0.87

n: number of studies; **OR:** Odds Ratio; **(95% CI):** 95% confidence interval; **I^2:** Higgins statistic for heterogeneity (percentage); **FM:** floor of the mouth; *****statistically significant.

Six studies[11,28,31,33,37,42] examined the possible influence of age on the oral leukoplakia (OL) malignant transformation risk. Although the malignant transformation of the oral leukoplakia was more frequent in those older than 60 years, age was a factor without influence on the OL malignancy. After statistical analysis, no significant relationship was observed (OR=1.56; 95% CI: 0.95 to 2.57; p=0.08).

Twenty-two studies[7,9-11,13,15-20,24,26,28-33,35,37,40] considered gender as a possible OL malignant transformation risk factor. Women were 1.73 times more likely to present malignant leukoplakias compared to men, finding a highly significant statistical association (OR=1.73; 95% CI: 1.47 to 2.05; p<0.001).

Thirteen studies[11,14,17-19,24-26,28-30,36,37] assessed the clinical type of oral leukoplakia (OL). Non-homogeneous OL had a 5.41-fold increase in the risk of malignant transformation compared to homogeneous ones, with highly significant statistical differences (OR=5.41; 98% CI: 3.24 to 9.02; p <0.001).

Six studies[20,28,33,36,37,43] analyzed the degree of epithelial dysplasia of oral leukoplakias (OLs). Moderate-severe dysplasia OLs were 3.43 times more likely to malignant transformation than mild dysplasia OLs. After statistical analysis, a highly significant relationship was found (OR=3.43; 95% CI: 2.30 to 5.11; p<0.001).

Nine studies[11,20,25,26,28,31,37,39,42] determined the oral leukoplakias malignant transformation risk based on the location of the lesions. Oral leukoplakias located on the tongue and/or floor of the mouth increased 3.19 times the risk of malignant transformation with a highly significant statistical association (OR=3.19; 95% CI: 2.26 to 4.50; p<0.001).

Six studies[26,28,31,37,39,42] evaluated the role of harmful habits, both tobacco consumption and alcohol intake, on the malignant transformation risk of oral leukoplakia (OL). Non-smoking patients with oral leukoplakias had 2.08 times more risk, observing highly significant statistical differences (OR=2.08; 95% CI: 1.54 to 2.80; p<0.001). The alcohol intake had no significant effect on the OL malignant transformation probability (OR=1.02; 95% CI: 0.76 to 1.38; p=0.87).

DISCUSSION

Data from thirty-seven studies on the clinicopathological factors related to malignant

transformation of oral leukoplakia have been considered in the present meta-analysis.

In this paper, the estimated global prevalence of malignant transformation of oral leukoplakia was 9.15% (95% CI: 6.71 to 11.93%). Warnakulasuriya *et al*.[4] conducted a systematic review of 24 studies in which they analyzed the rate of malignant transformation of oral leukoplakias, finding 405 malignant cases (3.5%) out of a total of 11423 leukoplakias, a prevalence rate lower than that observed in our study.

In the present study, an older age did not imply a greater risk of malignant transformation of oral leukoplakias, without a statistically significant relationship (p=0.08). Of the six studies that examined age, five of them[11,28,31,33,37] observed more malignant lesions in patients older than 60 years and only one,[42] in those younger than this age. The findings of the different studies on the role of age were highly variable. Some researchers argue that age is not a risk factor,[31] while others state that the patient's age is an important risk factor that affects malignant transformation and that it may be correlated with individual genetic susceptibility.[37] There is no clear evidence that older age increases the probability of malignant progression in oral leukoplakia. Older people, probably due to immune dysfunction and long-term exposure to other associated risk factors, may be more susceptible to malignancy.[4]

In the present study, women were 1.73 times more likely to present malignant oral leukoplakias with a highly significant statistical association (p<0.001). Of the 22 studies that considered gender, nineteen[7,9-11,16-20,24,26,29-33,35,37,40] agreed to observe more malignant lesions in women; meanwhile, three of them[13,15,28] observed it more in men. Most of these studies indicate that females' oral leukoplakias have a higher risk of malignant transformation. Although oral leukoplakia is relatively uncommon in women compared to men, the malignant transformation of leukoplakia is significantly higher in women. The reason why females are more predisposed to the malignant transformation of its lesions remains a paradox.[4] Moreover, an increased risk of malignant transformation of oral leukoplakia has been observed in non-smoking women. It is not clear either why the absence of smoking habit is associated with an increased risk of malignant transformation only in women.[20]

In this study, non-homogeneous oral leukoplakias increased 5.41-fold their risk of malignancy, observing highly significant statistical differences (p<0.001). Twelve studies[11,14,17,19,24-26,28-30,36,37] pointed out a higher probability of malignancy in non-homogeneous oral leukoplakias. Similarly, a higher degree of dysplasia (moderate-severe) raised 3.43-fold the probability of malignancy, with a highly significant relationship (p<0.001). Of the 6 studies that examined the degree of dysplasia, five of them[20,28,33,36,37] showed a higher risk of malignancy in the most dysplastic leukoplakias and only one[43] did not observe this fact, without statistically significant results. Almost all studies claim that non-homogeneous oral leukoplakias show a higher malignant transformation risk compared to homogeneous leukoplakias that appear to follow a more benign course. In non-homogeneous lesions, it is important an adequate choice of the biopsy site since it will condition its correct diagnosis, as well as a more aggressive treatment for this type of leukoplakias. Lee *et al*.[26] in their study of 1046 oral leukoplakia found that non-homogeneous lesions were 5.69 times more likely to present epithelial dysplasia and 28.13 times more likely to malignant transformation. 72.6% of the non-homogeneous leukoplakias and 33.3% of the homogeneous ones were dysplastic lesions. Malignant transformation of non-homogeneous oral leukoplakias approached 20% in contrast to less than 1% in homogeneous leukoplakias. Classifying the grade of dysplasia as: no dysplasia, mild, moderate, and severe, lends itself to some subjectivity in interpretation by pathologists and could distort the results. Therefore, in an attempt to unify criteria, a classification into two categories has been proposed: a) no/questionable/mild - low-grade dysplasia and b) moderate/severe - high-grade dysplasia). High-grade dysplasias are closely associated with an increased malignant transformation risk and in shorter periods. This justifies periodic follow-up during the first 2-3

years for patients with high-grade dysplastic oral leukoplakias to be able to detect early events of malignant transformation.[37]

In this study, oral leukoplakias located on the tongue and/or floor of the mouth were 3.19 times more likely to suffer malignant transformation with a highly significant statistical association ($p<0.001$). The nine studies[11,20,25,26,28,31,37,39,42] that focused on the location of oral leukoplakia, showed that the lingual location and/or on the floor of the mouth were the ones with the highest risk of malignant transformation. In a systematic review, the most frequent locations of malignant oral leukoplakias were the tongue (24.22% of cases) and the floor of the mouth (14.85%).[4] Lee *et al*.[26] found that leukoplakias located on the tongue and/or the floor of the mouth increased 1.84 times the probability of epithelial dysplasia and 2.72 times the risk of malignancy compared to leukoplakias with other locations. Severe dysplastic lesions tended to be located on the ventrolateral lingual surface and the floor of the mouth, showing greater potential for malignant transformation and a greater frequency of loss of heterozygosity in chromosomes 3p, 9p and 17p. A possible explanation for this higher risk in these locations would be that these areas are substantially more exposed to local carcinogens due to the greater permeability of the oral mucosa.[42]

In the present investigation, surprisingly non-smokers had an increase of 2.08 times the malignant transformation risk of their leukoplakias with highly significant statistical differences ($p<0.001$). Regular alcohol consumption did not have a significant impact on the malignancy of oral leukoplakia, without reaching statistical significance ($p=0.87$). All studies[26,28,31,37,39,42] indicated an increased malignant risk in leukoplakias from non-smoking subjects. In the case of alcohol intake, three of them[26,37,42] found a higher malignant transformation risk in lesions from non-drinkers, compared to another three[28,31,39] who did show it in lesions from drinkers. However, none of the results of these studies was statistically significant. The tobacco and/or alcohol consumption play an important role in the development of oral leukoplakia, although their role in its malignant transformation remains controversial and it has not been clarified yet.[37] Smoking and drinking are well-established risk factors for dysplastic oral leukoplakia and oral cancer, but not for the malignant transformation risk from leukoplakia. Various studies show that smoking-related oral leukoplakias appear to have less malignant potential than those not associated with smoking. The reasons for these seemingly paradoxical findings remain unclear. Several possible explanations could be raised: 1) in the absence of tobacco and/or alcohol as stimulating agents, there are other more potent carcinogenic factors; 2) since carcinogenesis is a multistep process, the factors that condition the development of oral leukoplakias would be different from the factors responsible for the malignant transformation of these lesions; 3) the lower malignant transformation risk of leukoplakias among smokers/drinkers could be justified in that the oral carcinogenesis process is more prolonged in non-smokers/abstainers and, therefore, the evolution time of oral leukoplakias is longer predisposing them to malignancy.[26]

This study has some limitations. The periods of follow-up of the lesions are highly variable in the different studies. In some of them, they are too short and there is probably an underestimation of cases of malignancy. Considering the harmful habits, on some occasions, the quantity and age of the habit, as well as the alcohol content of the beverages, could not be adequately evaluated. The influence of superinfection of oral leukoplakias by human papillomavirus (HPV) and/or *Candida* species could not be analyzed either.

Finally, the high heterogeneity observed in some comparisons of this meta-analysis demands a cautious interpretation.

CONCLUSIONS

In this study, the estimated global prevalence of malignant transformation of oral leukoplakia was 9.15%. The factors with the highest malignant transformation risk of oral leukoplakia were: non-homogeneous clinical types (OR:5.41; $p<0.001$); leukoplakias with moderate-severe dysplasia (OR:3.43; $p<0.001$); lesions located on the tongue

and/or the floor of the mouth (OR:3.19; p<0.001); leukoplakias in non-smokers (OR:2.08; p<0.001) and lesions in women (OR:1.73; p<0.001). In contrast, older age or regular alcohol intake were factors without significant influence (p> 0.05).

CONFLICTS OF INTEREST STATEMENT

No conflicts of interest.

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