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ORIGINAL ARTICLES

CASE REPORT

REVIEW

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34394 Mecidiyeköy, Şişli-İstanbul
Phone: +90 212 217 17 00
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TURKISH JOURNAL of
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Turkish Journal of Orthodontics (Turk J Orthod) is an international, scientific, open access periodical published in accordance with independent, unbiased, and double-blinded peer-review principles. The journal is the official publication of Turkish Orthodontic Society and it is published quarterly on March, June, September and December.

Turkish Journal of Orthodontics publishes clinical and experimental studies on on all aspects of orthodontics including craniofacial development and growth, reviews on current topics, case reports, editorial comments and letters to the editor that are prepared in accordance with the ethical guidelines. The journal's publication language is English and the Editorial Board encourages submissions from international authors.

Journal's target audience includes academicians, specialists, residents, and general practitioners working in the fields of orthodontics, dentistry, medicine and other related fields.

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Editor in Chief: Derya Germeç Çakan
Address: Bağdat Cad. No: 238, Göztepe,34728 İstanbul/Turkey
Phone: +90 216 468 08 00
Fax: +90 216 468 08 00
E-mail: info@turkjorthod.org

Publisher: AVES
Address: Büyükdere Cad. 105/9 34394 Mecidiyeköy, Şişli, İstanbul, Turkey
Phone: +90 212 217 17 00
Fax: +90 212 217 22 92
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REVIEW ARTICLE	5000	250	50	6	10 or total of 20 images
CASE REPORT	1000	200	15	No tables	10 or total of 20 images
LETTER TO THE EDITOR	500	No abstract	5	No tables	No media

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Tables should be included in the main document, presented after the reference list, and they should be numbered consecutively in the order they are referred to within the main text. A descriptive title must be placed above the tables. Abbreviations used in the tables should be defined below the tables by footnotes (even if they are defined within the main text). Tables should be created using the "insert table" command of the word processing software and they should be arranged clearly to provide easy reading. Data presented in the tables should not be a repetition of the data presented within the main text but should be supporting the main text.

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Book Section: Suh KN, Keystone JS. Malaria and babesiosis. Gorbach SL, Barlett JG, Blacklow NR, editors. Infectious Diseases. Philadelphia: Lippincott Williams; 2004.p.2290-308.

Books with a Single Author: Sweetman SC. Martindale the Complete Drug Reference. 34th ed. London: Pharmaceutical Press; 2005.

Editor(s) as Author: Huizing EH, de Groot JAM, editors. Functional reconstructive nasal surgery. Stuttgart-New York: Thieme; 2003.

Conference Proceedings: Bengisson S. Sothemin BG. Enforcement of data protection, privacy and security in medical informatics. In: Lun KC, Degoulet P, Piemme TE, Rienhoff O, editors. MEDINFO 92. Proceedings of the 7th World Congress on Medical Informatics; 1992 Sept 6-10; Geneva, Switzerland. Amsterdam: North-Holland; 1992. pp.1561-5.

Scientific or Technical Report: Cusick M, Chew EY, Hoogwerf B, Agrón E, Wu L, Lindley A, et al. Early Treatment Diabetic Retinopathy Study Research Group. Risk factors for renal replacement therapy in the Early Treatment Diabetic Retinopathy Study (ETDRS), Early Treatment Diabetic Retinopathy Study Kidney Int: 2004. Report No: 26.

Thesis: Yılmaz B. Ankara Üniversitesindeki Öğrencilerin Beslenme Durumları, Fiziksel Aktiviteleri ve Beden Kitle İndeksleri Kan Lipidleri Arasındaki Ilişkiler. H.Ü. Sağlık Bilimleri Enstitüsü, Doktora Tezi. 2007.

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Epub Ahead of Print Articles: Cai L, Yeh BM, Westphalen AC, Roberts JP, Wang ZJ. Adult living donor liver imaging. Diagn Interv Radiol. 2016 Feb 24. doi: 10.5152/dir.2016.15323. [Epub ahead of print].

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Address: Bağdat Cad. No: 238, Göztepe,34728 İstanbul/Turkey
Phone: +90 216 468 08 00
Fax: +90 216 468 08 00
E-mail: info@turkjorthod.org

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Address: Büyükdere Cad. 105/9 34394 Mecidiyeköy, Şişli, İstanbul, Turkey
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TURKISH JOURNAL of ORTHODONTICS

Contents

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Original Article

Nickel Release and the Viability of *Streptococcus mutans* Corresponding to Low Risk of Dental Caries in Artificial Saliva Containing Orthodontic Appliances: In Vitro Study

Serap Titiz[1], Zalike Keskin Erdoğan[2], Elif Esin Hames Tuna[3], Aynur Aras[4]

[1]Department of Orthodontics, Uşak University, Faculty of Dentistry, Uşak, Turkey
[2]Division of Biomaterials and Tissue Engineering, Eastman Dental Institute, University College London, London, United Kingdom
[3]Department of Bioengineering, Ege University, Faculty of Engineering, İzmir, Turkey
[4]Department of Orthodontics, Ege University, Faculty of Dentistry, İzmir, Turkey

Cite this article as: Titiz S, Keskin Erdoğan Z, Hames Tuna EE, Aras A. Nickel release and the viability of *Streptococcus mutans* corresponding to low risk of dental caries in artificial saliva containing orthodontic appliances: in vitro study. *Turk J Orthod.* 2022;35(3):157-165.

Main Points

- Corrosion is an inevitable natural process in fixed orthodontic appliances.
- The observed decrease in the growth of *Streptococcus mutans* was likely caused by corrosion or a related process.
- Even a low level of *S. mutans* represents a corrosion-promoting factor for stainless steel-based materials.
- The corrosion behavior and biocompatibility of the studied alloys might depend on their surface roughness.

ABSTRACT

Objective: The aims of this study were to determine the effect of different levels of *Streptococcus mutans* that correspond to a low risk of dental caries on nickel release and to determine the viability of *S. mutans*.

Methods: Simulated fixed orthodontic appliances composed of copper nickel titanium, nickel titanium, or stainless steel were immersed in Klimek artificial saliva for 10 days with or without *S. mutans* inoculation on day 7. Same levels of *S. mutans* cultures (4×10^4 cfu/mL) were inoculated into the artificial saliva without orthodontic appliances. Nickel release was detected by inductively coupled plasma mass spectrometry. The archwire surface was analyzed by atomic force microscopy and scanning electron microscopy.

Results: The density of *S. mutans* significantly increased in the artificial saliva without orthodontic appliances ($P < .05$). Appliances with nickel titanium alloys showed higher nickel release in the artificial saliva with or without *S. mutans* than those with copper nickel titanium or stainless steel archwires ($P < .05$). However, *S. mutans* increased nickel release only in orthodontic appliances with stainless steel archwires ($P < .05$). Although atomic force microscopy showed that the surface of as-received stainless steel archwires was smoother than that of nickel titanium or nickel titanium archwires, *S. mutans* increased the surface roughness of only the SS archwires. *S. mutans* adhered to all archwire types.

Conclusion: While corrosion or corrosion-related processes may have decreased the growth capacity of *S. mutans*, reciprocally, *S. mutans* influenced corrosion. Rough surfaces can also promote corrosion; therefore, the surface roughness of metal alloy orthodontic appliances should be evaluated to determine their corrosion behavior.

Keywords: Corrosion, dental caries, nickel release, orthodontic appliance, risk, Streptococcus mutans

INTRODUCTION

Metals or metal alloys are corroded due to oxidation or other chemical effects, and ions are released into the environment as a result. Metals become corroded in the oral environment within 7 days, after which corrosion decreases, and then stops.[1,2] This process is induced by the development of new corrosion factors. The cycle will

Corresponding author: Serap Titiz, e-mail: dtseraptitiz79@hotmail.com

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continue depending on the microbiological, enzymatic, ionic, and thermal properties in the oral environment and can cause the metal to corrode and degrade biologically. Therefore, corrosion is an inevitable natural process in fixed orthodontic appliances. Most orthodontic treatments are implemented using fixed devices such as brackets, tubes or bands, and wires made of metal alloys. Nickel (Ni) and chromium (Cr) are the primary ions released from these alloys. Ni and Cr are post-corrosion products that can have genotoxic, mutagenic, and cytotoxic effects that could cause contact allergies, asthma, hypersensitivity, birth defects, and reproductive damage.[3,4] Thus, the biocompatibility of the materials utilized in orthodontic treatments is of importance.

Streptococcus mutans is a gram-positive, facultative anaerobic bacterium found mostly in the human oral cavity and is involved in the formation of dental caries. Hence, *S. mutans* is graded according to the colony-forming units per milliliter (cfu/mL) in the mouth. The risk of caries is graded as high ($\geq 10^6$ cfu/mL), moderate (10^5-$<10^6$ cfu/mL), and low ($\leq 10^5$).[5] Orthodontic treatments should be implemented after the completion of all essential dental and periodontal therapies. Difficulties with brushing the teeth and an increase in areas of retention during fixed orthodontic treatment might increase the density of *S. mutans*, thereby increasing the risk of caries. However, it is unlikely for patients with good oral hygiene to have a high density of *S. mutans* during orthodontic treatment. Studies have reported that the corrosion of alloys such as cobalt (Co), Cr and nickel-chromium (Ni/Cr), and titanium (Ti) dental implants increases in the presence of *S. mutans*, which increases the risk of caries.[6-10] However, to the best of our knowledge, the in vitro corrosion behavior of alloys under a low risk of caries has not yet been investigated. The corrosion process during orthodontic treatment in a mouth with a relatively low risk of dental caries could inhibit the growth of *S. mutans*. Thus, in the present study, the primary objective was to determine the amount of Ni released by simulated orthodontic appliances with different types of archwires in vitro in the presence of *S. mutans* at levels that correspond to a low risk of caries and the secondary objective was to determine the growth ability of *S. mutans* in a corrosive environment.

METHODS

This was an in vitro study. Fixed orthodontic appliances representing half of the maxillary arch consisted of 5 structurally identical brackets, a molar band, and 6-cm-long copper-nickel-titanium (CuNiTi), nickel-titanium (NiTi), or stainless steel (SS) archwires tied with elastic ligatures (Astar Orthodontics Inc., Shanghai, China). Klimek artificial saliva comprising ascorbic acid (0.002 g), glucose (0.030 g), NaCl (0.580 g), $CaCl_2$ (0.170 g), NH_4Cl (0.160 g), KCl (1.270 g), NaSCN (0.160 g), KH_2PO_4 (0.330 g), urea (0.200 g), Na_2HPO_4 (0.340 g), and mucin (2.700 g) (Bacto-Mucin Bacteriological) in 1 L of distilled water (pH 6.75) was prepared.[11] In this study, there was 1 experimental group (EG) and 2 control groups (CG 1 and CG 2). The EG and CG 1 groups were subgrouped according to appliances with CuNiTi (group A), NiTi (group B), and SS (group C) archwires. All EG and CG 1 subgroups consisted of 3 replicates. All simulated fixed orthodontic appliances were immersed in 50 mL of Klimek artificial saliva. The artificial saliva in the EG (3 appliances each in group A [C], group B [C], and group C [C]) groups was inoculated with 100 µL of *S. mutans* (ATCC 25175; 4×10^4 cfu/mL) on day 7 of the experiment. The other half of the simulated fixed orthodontic appliances (3 appliances each in group A [C], group B [C], and group C [C]) remained submerged in the Klimek artificial saliva until day 10 without *S. mutans* inoculation in CG 1. The CG 2 group comprised 9 replicates; Klimek artificial saliva (without appliances) was inoculated with the same level of *S. mutans* under identical conditions. The samples were incubated at 37°C in a 5% CO_2 atmosphere for 72 h, following which *S. mutans* was evaluated (cfu/mL) using the spread plate technique. The initial and final pH values of Klimek artificial saliva were measured at room temperature using an HI-1131B pH meter (Hanna Instruments Inc., Carrollton, Tex, USA). The experimental setups and sample preparation for inductively coupled plasma mass spectrometry (ICP-MS) were made by S. Titiz, Z.K. Erdogan. Figure 1 shows a brief schema of the experiment.

Detection of Nickel Release by Inductively Coupled Plasma Mass Spectrometry (ICP-MS)

The amount of Ni released into Klimek artificial saliva was evaluated using an ELAN DRC-eICP-mass spectrometer (Perkin Elmer,

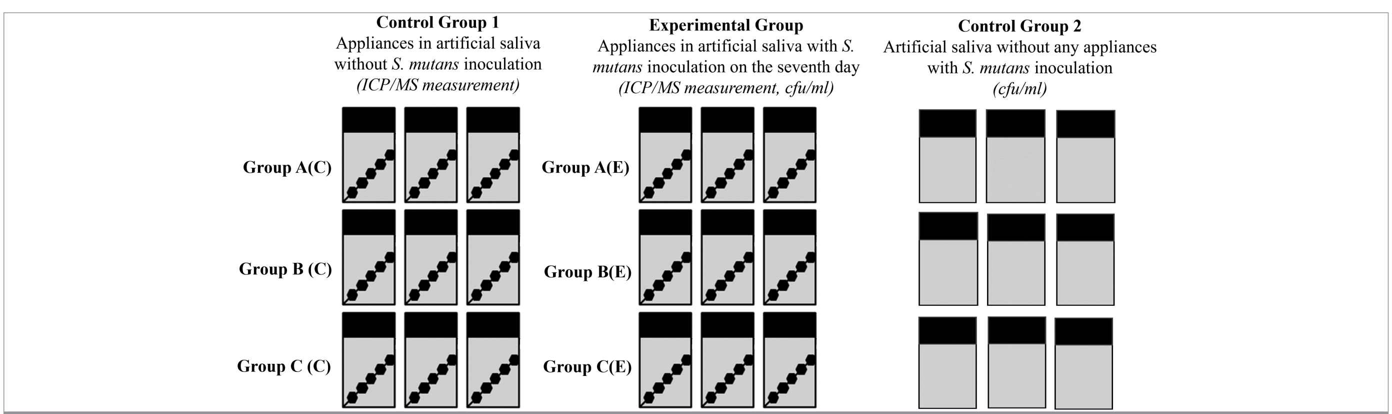

Figure 1. Schema of experimental setup. Subgroups of the experimental group: appliances with archwires containing CuNiTi (group A [E]), NiTi (group B ([E]), and SS (group C [E]). Subgroups of control group 1: appliances with archwires containing CuNiTi (group A [C]), NiTi (group B [C]), and SS (group C [C]). Control group 2: artificial saliva with *Streptococcus mutans* inoculation

Norwalk, CT, USA). Samples were placed in a 40-kHz ultrasonic water bath (ISOLAB Laborgeräte GmbH., Wertheim, Germany) for 30 min, centrifuged at 7000 rpm (Optima™ X Series centrifuge; Beckman Coulter, Brea, Calif, USA), and then passed through a 0.45-mm Millex® Syringe filter (Sigma-Aldrich Corp., St. Louis, Mo, USA). Samples of homogenized artificial saliva (500-600 µL) were weighed, immersed in 10 mL of 65% nitric acid (Sigma-Aldrich Corp.) to breakdown organic compounds, and placed in a microwave oven (1600 W, 100% power at 30° and 160 mmHg). The samples were then placed in an oven for measurement, with 50 mL of ultrapure water.

Characterization of Surface Topography

The average roughness (Ra) of the as-received and post-immersion archwires and their surface morphologies were assessed in the EG and CG 1 groups by atomic force microscopy (AFM) and scanning electron microscopy (SEM) (Gemini SEM 300; Carl Zeiss AG., Oberkochen, Germany). Microorganisms were fixed by dehydrating the wires in a graded series of alcohol (50%, 70%, 85%, 90%, and 100%) and immersed in 10% (v/v) glutaraldehyde.

Statistical Analysis

Data are shown as number, mean, and standard deviation. Normal distribution was assessed using Shapiro—Wilk test, and variance homogeneity was evaluated using Levene test. The average Ni oscillation between independent groups satisfying the assumptions was compared using an independent samples *t*-test. The averages of 3 or more independent groups were compared using the one-way ANOVA if they met the assumed criteria and those of 3 independent groups that did not meet the assumption criteria were compared using Kruskal—Wallis test. Groups with differences were assessed with Bonferroni correction. Differences with a ***P***-value < .05 were considered significant.

RESULTS

Findings of ICP-MS

Table 1 and Figure 2a and b show a comparison of Ni-release in EG and CG1. More Ni was released by appliances with NiTi (group B) than with CuNiTi or SS archwires (group A or group C) in CG 1 and EG (P < .05). The amount of Ni released from appliances with SS and CuNiTi archwires was similar in CG 1 (P > .05), whereas more Ni was released from appliances with SS archwires in EG than from appliances with CuNiTi archwires (P < .05). Nickel release between the subgroups of CG 1 and EG was evaluated; it was found that the amount of Ni released between Groups C_C and C_E significantly differed (P < .05). Furthermore, *S. mutans* increased the rate of Ni-release from appliances with SS archwires (group C, P < .05) but did not significantly affect that from appliances with CuNiTi or NiTi archwires (group A or B; P > .05; Table 1, Figure 2b).

Characterization of Surface Topography

Table 2 and Figure 3 show the comparisons of the Ra values of archwires as-received and after immersion in the EG and CG 1 groups. The surface roughness of CuNiTi and NiTi archwires as-received and after immersion in artificial saliva medium with or without *S. mutans* was similar (P > .05), and their Ra values were

Table 1. Comparison of the amounts of nickel released between the experimental groups and control group 1

	Group A Mean ± SD	Group B Mean ± SD	Group C Mean ± SD	P	A/B P	B/C P	A/C P
CG1	42.52 ± 4.33	68.341 ± 2.657	37.97 ± 2.27	.0001*	.0001*	.000*	.65
EG	37.40 ± 4.28	72.307 ± 5.31	52.45 ±4.23	.000*	<.0001	.006*	.022*
P	.219	.312	.006*				

*Significant difference at P < .05. CG1, control group 1; EG, experimental group; SD, standard deviation. Appliances with CuNiTi archwires, group A (A); appliances with NiTi archwires, group B (B); appliances with SS archwires, group C (C).

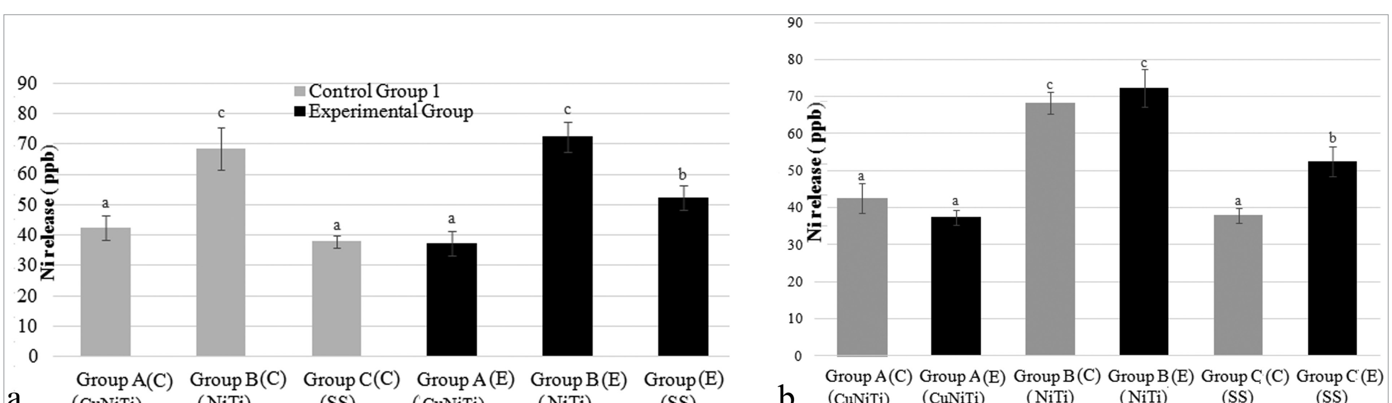

Figure 2. a, b. Nickel release in groups and subgroups. (a) Amount of Ni released in subgroups A_C, B_C, and C_C of control group 1, and A_E, B_E, and C_E of experimental group. Appliances with archwires containing CuNiTi (group A), NiTi (group B), and SS (group C). (b) Amount of Ni released by the control group 1 and experimental group subgroups. a and b indicate statistically significant differences (P < .05) between each measurement item compared

Table 2. Comparison of the Ra values between as-received archwires and those in the experimental groups and control group 1

	CuNiTi (A) Mean ± SD	NiTi (B) Mean ± SD	SS (C) Mean ±SD	*P*	A/B *P*	B/C *P*	A/C *P*
As-r	79.28 ± 1.00	78.18 ± 2.00	40.05 ± 1.00	.000*	1.000	.000*	.000*
CG1	80.66 ± 2.51	81.16 ± 1.00	41.66 ± 1.52	.000*	1.000	.000*	.000*
EG	81.00 ± 1.00	78.66 ± 2.77	60.04 ± 1.00	.027*	.534	.025*	.027*
P	.354	.082	.000*				
As-r/CG1			0.352				
As-r/EG			0.000*				
CG1/EG			0.000*				

*Significant difference at $P < .05$. As-r, as-received; CG1, control group 1; EG, experimental group; SD, standard deviation. Appliances with CuNiTi archwires, group A (A); appliances with NiTi archwires, group B (B); appliances with SS archwires, group C (C). Paired comparisons were not performed when *P* (ANOVA) was not significant.

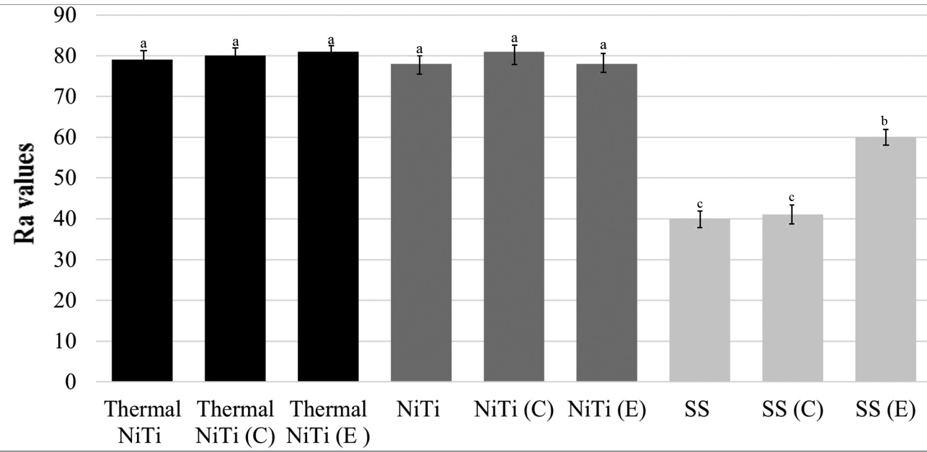

Figure 3. Comparison of the Ra values of archwires as-received and after immersion. Control group 1 (C) and experimental group (E). The first column shows the archwire type. a and b indicate statistically significant differences ($P < .05$) between each compared measurement item

higher than those of SS archwires ($P < .05$). The surface roughness of the CuNiTi and NiTi archwires did not change in the artificial saliva with and without *S. mutans* in the EG and CG 1 groups ($P > .05$). The surface roughness of the SS archwires increased in artificial saliva with *S. mutans* in CG 1 ($P < .05$), and the Ra values of SS archwires in the EG group were higher than those of as-recieved and SS archwires in the CG 1 group ($P < .05$). The AFM findings were consistent with the surface structures visualized by SEM (Figures 4–6).

Streptococcus Mutans Cell Viability

S. mutans proliferated more in artificial saliva in the absence of appliances in the CG 2 group compared with that in the EG group ($P < .05$), whereas the EG subgroups did not significantly differ ($P > .05$; Tables 3 and 4 and Figure 7). The SEM images revealed *S. mutans* adhesion to all types of archwires (Figure 6). The presence of *S. mutans* decreased the pH in the CG 2 group (pH 4.95-4.93), but it did not affect the pH of the EG subgroups (pH 6.75-6.73).

DISCUSSION

Non-optimal conditions in the oral cavity can accelerate corrosion; thus, understanding the corrosion behavior of metals is important to evaluate their biocompatibility. Metal (Ni, Fe, Cu, and Ti) ions released into the environment as a result of corrosion might cause local or systemic adverse reactions in some patients.[4] One of the most prevalent local reactions is sensitivity to Ni, which exerts systemic cytotoxic and mutagenic effects[3]; however, it is widely applied in dentistry. Thus, Ni-release from orthodontic appliances with NiTi, CuNiTi, or SS archwires was investigated in the presence of *S. mutans*. The corrosive behavior of metals or alloys is determined by estimating the number of ions passing into their liquid environment (immersion tests) or is determined electrochemically. However, electrochemically evaluating the corrosion behavior of metals can lead to significantly different results from those obtained in the oral environment.[12] Therefore, the corrosive behavior of metals was determined using immersion tests. In this study, simulated orthodontic appliances composed of 5 structurally identical SS brackets and bands, elastic ligatures, and 3 types of orthodontic wires. The difference in corrosive behavior in the EG and CG 1 subgroups can be attributed to the types of orthodontic wires. Ions passing into artificial saliva can be measured in immersion tests using various devices. Hwang et al.[1] and Kuhta et al.[13] determined the number of corrosion products by ICP/MS as in our study. However, Barret et al.[2] and Reddy[14] determined the number of ions by ICP-optical emission spectroscopy (OES).

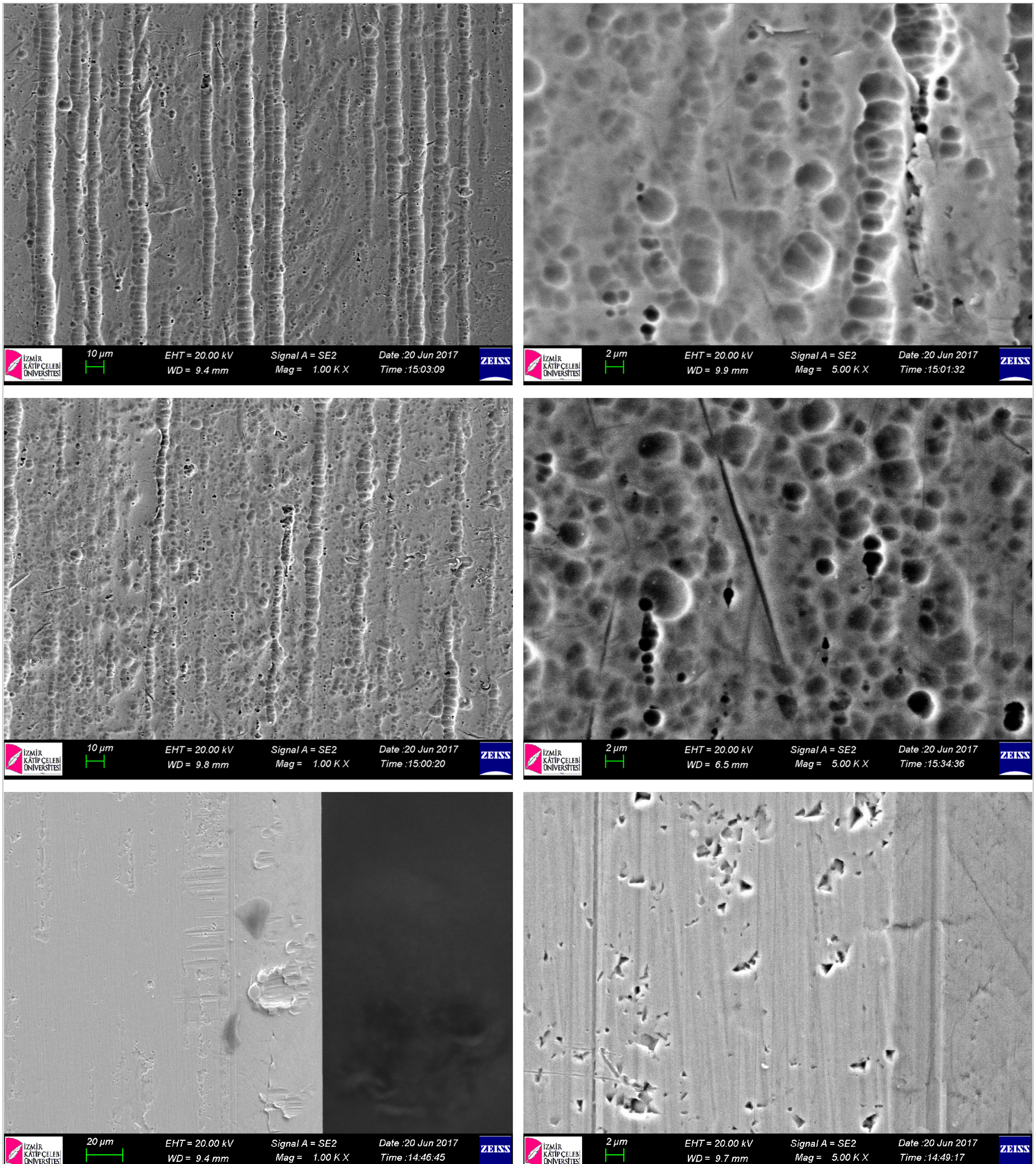

Figure 4. Scanning electron microscopy images of as-received archwires. Subgroups: CuNiTi (a, b), NiTi (c, d), and SS (e, f). Magnification: 1.00 KX (a, c, e) and 5.00 KX (b, d, f)

While ICP-OES is widely available and reasonably cost-effective, ICP-MS requires experienced staff and is expensive; furthermore, ICP-MS is more sensitive than ICP-OES. However, both devices are used in corrosion studies with the appropriate sample preparation protocol.[1,2,8,13,14]

In our study, more Ni was released by orthodontic appliances with NiTi than with SS or CuNiTi archwires in the absence of *S. mutans*; this finding is consistent with that of Barrett et al.[2] However, some study findings are controversial. Contrary to the findings of Barrett et al., Karnam and Reddy[14] found no

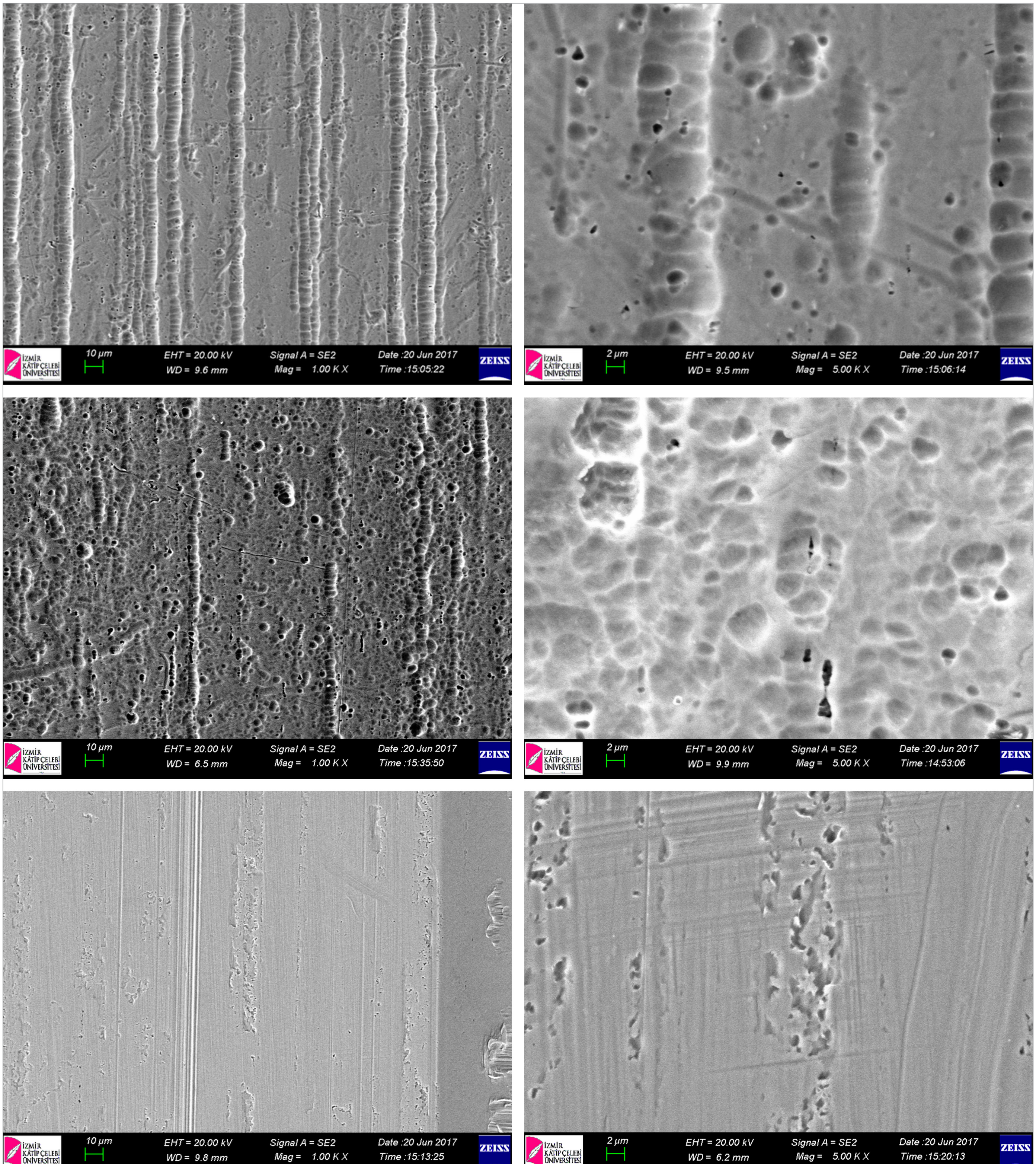

Figure 5. Scanning electron microscopy images of archwires in the control group 1 subgroups. Subgroups: CuNiTi (a, b), NiTi (c, d), and SS (e, f) archwires. Magnification: 1.00 KX (a, c, e) and 5.00 KX (b, d, f).

differences in the Ni-release rates of orthodontic appliances with SS, NiTi, CuNiTi or Elgiloy® archwires, and SS brackets. Moreover, Hwang et al.[1] reported that more Ni ion was released by SS than by CuNiTi or Sent alloy® and BioForce® archwires, and Kuhta et al.[13] found that SS archwires released the most Ni ions at pH 3.5 and 6.8 compared with thermal NiTi and NiTi archwires. The surface topography of an alloy is related to corrosion behavior.[15,16] In the present study, the surface roughness of the archwires was examined. Based on the findings of previous studies,[17,18] as well as our AFM and SEM findings, the surface of NiTi archwires is

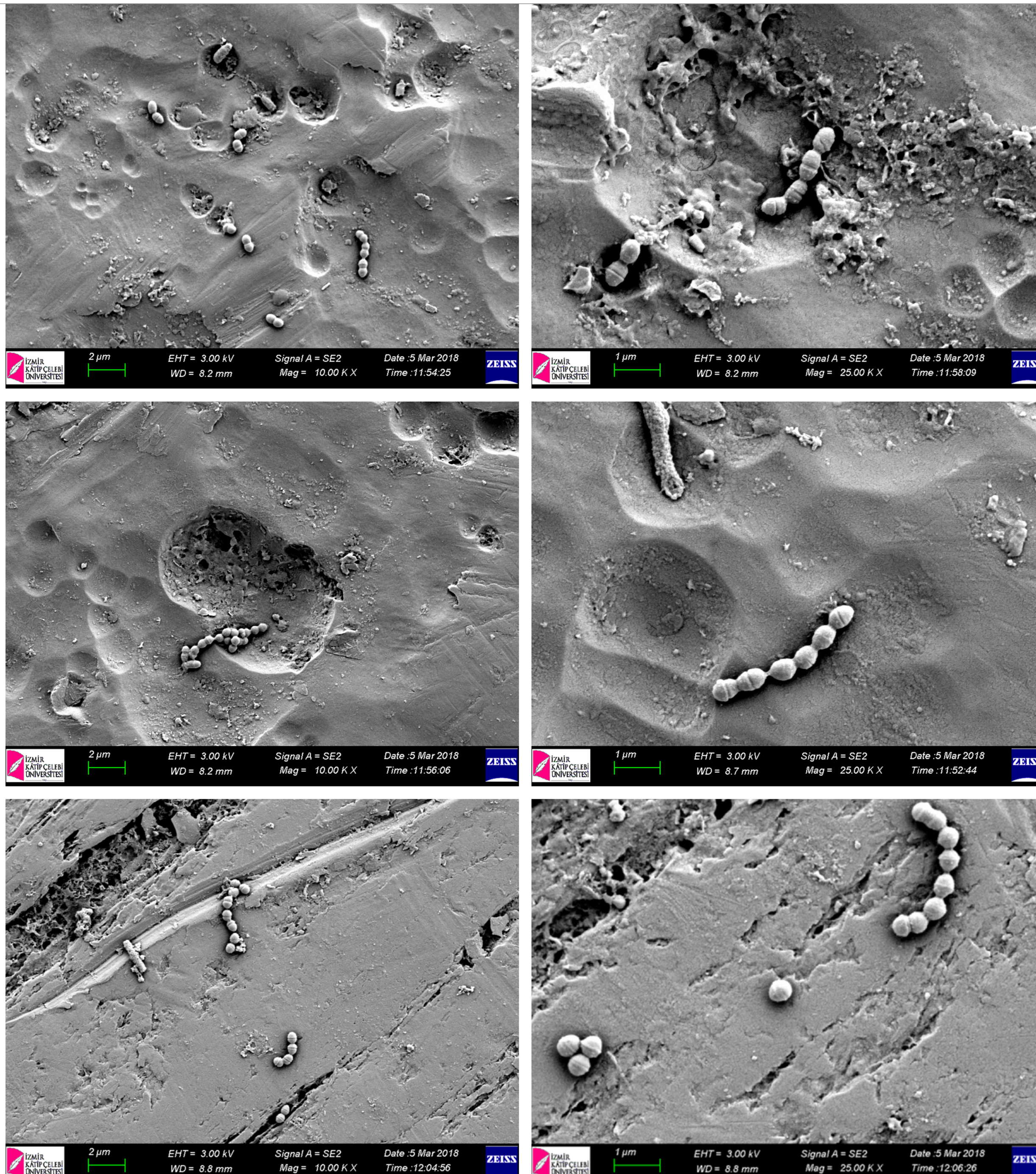

Figure 6. Scanning electron microscopy images of archwires with adherent *Streptococcus mutans*. *S. mutans* adhered to all types of archwires in the experimental group subgroups. Subgroups: CuNiTi (a, b), NiTi (c, d), and SS (e, f) archwires. Magnification: of 1.00 KX (a, c, e) and 5.00 KX (b ,d, f)

Table 3. Comparison of the counts of *Streptococcus mutans* in control group 2 and subgroups of the experimental group

	Initial	CG2	Group A_E	Group B_E	Group C_E	I/CG2 *P*	CG2/A *P*	CG2/B *P*	CG2/C *P*
cfu/mL	10^4	$10^6 \pm 5.1 \times 10^2$	$5 \times 10^4 \pm 5.19 \times 10^2$	$5.3 \times 10^4 \pm 1.1 \times 10^2$	$11 \times 10^4 \pm 8 \times 10^2$	.00*	.00*	.00*	.00*

*Significant difference at $P < .05$. CG 2, control group 2; E, experimental; I, initial density of inoculated *Streptococcus mutans* cells. Appliances with CuNiTi archwires, group A; appliances with NiTi archwires, group B; appliances with SS archwires, group C.

Table 4. Comparison of the counts of *S. mutans*

Groups	P
Initial/group A_E	1
Initial/group B_E	1
Initial/group C_E	0.78
Group A_E/group B_E 1	1
Group B_E/group C_E 1	1
Group AE/group C_E 1	1

Significant difference at P<0.05. I, initial density of inoculated *S. mutans*; E: Experimental. Appliances with CuNiTi archwires, Group A; appliances with NiTi archwires, Group B; appliances with SS archwires, Group C.

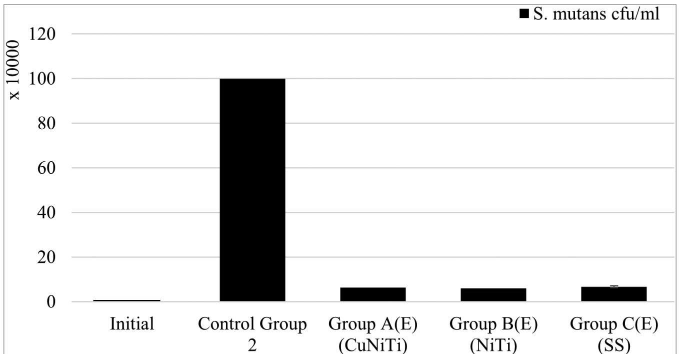

Figure 7. Density of *Streptococcus mutans* in control group 2 and the experimental group subgroups A_E, B_E, and C_E. I, original density of inoculated *S. mutans* cells

rougher than that of SS archwires. Increased surface roughness should be considered as a contributing factor to the corrosive behavior of orthodontic archwires by facilitating and increasing ion release.[19,20] Thus, it was considered that increased Ni-release from appliances with NiTi compared with that from appliances with SS archwires was associated with the rougher surface of NiTi than that of SS archwires.

The passive protective oxide layer on the surface of a metal or alloy provides resistance to corrosion and self-repair. Protective layers comprise Cr_2O_3 oxide on SS archwires and TiO_2 oxide on archwires that contain Ti. In alloys containing Ti, the layer of Ti-oxide is stronger than that of Cr-oxide, thus increasing corrosion resistance.[21] However, other factors may increase the corrosion rate of Ti-containing alloys. Alloys containing Ti have rougher surfaces than SS archwires, which can lead to the galvanic corrosion of these alloys.[22,23] Moreover, manufacturing defects in NiTi wires can be another factor that increase corrosion due to the rougher texture.[22] As many factors lead to corrosion, it was considered that various brands of alloys are produced using different methods or that differences in the surface topography of alloys and study designs may have led to contradictory results.

The corrosion current of NiTi archwires is higher than that of SS wires in electrochemical tests involving oral bacteria.[6,24,25] Kameda et al.[8] used ICP-OES to investigate the corrosive behavior of orthodontic appliances with SS and NiTi archwires in a high-risk caries environment inoculated with *S. mutans* and *Streptococcus sanguinis*. They reported that the surface of the SS appliances became rougher, and their ICP-OES results showed that Ni is released from SS, but not from Ni-Ti appliances, when cultured with oral bacteria. Similar to the findings of Kameda et al.[8] in this study, it was observed that *S. mutans* increased the surface roughness of SS archwires and caused Ni-release from orthodontic appliances with SS archwires. However, less Ni was released from orthodontic appliances with SS than from those with NiTi, probably due to the low abundance of *S. mutans*.

Biofilms produced on metal surfaces by *S. mutans* can lead to a localized acidic environment that promotes corrosion; therefore, the pH in an environment might not always reflect local pH changes.[8] In this study, a slight infection with *S. mutans* did not change the pH of artificial saliva with immersed appliances. Thus, the effects of *S. mutans* could be ascribed to localized changes in pH, and archwires made of SS might be more sensitive to the changes in localized pH than those made of NiTi. Our findings also suggest that while oral bacteria affect the corrosion of SS appliances, galvanic corrosion might occur primarily in Ni-Ti appliances.[22-23] Moreover, adding Cu to NiTi archwires increases the biocompatibility of NiTi archwires.[26] In the present study, it is found that CuNiTi wires released less Ni than NiTi wires in the artificial saliva with or without *S. mutans* although the Ra values of CuNiTi and NiTi archwires were similar.

An investigation of the effects of 16 pure metals on *S. mutans* growth in vitro showed that the corrosion process significantly depends on bacteriostasis[27] and that Co, CuNi, Ti, Fe, and vanadium inhibit the growth of the organism. Our findings of the effects of orthodontic alloys on the growth of *S. mutans* in artificial saliva in vitro were comparable with these results. Furthermore, it was found that *S. mutans* did not grow in the presence of corrosion.

Bacteria preferentially colonize rough surfaces over smooth surfaces.[28] The degree of surface roughness does not significantly affect bacterial adhesion after 6 hours of incubation with microorganisms.[29,30] Our SEM images were acquired after incubating the 3 types of archwire types with *S. mutans* for 3 days. Therefore, the rates of adhesion were similar even when the surface roughness of the archwires differed.

Many factors can affect corrosion, such as microbiological, enzymatic, ionic, and thermal properties in the oral environment. It is not possible to simulate the exact oral environment in vitro. However, it is important to determine the effect of the factors individually in an environment where many variables are present at the same time in order to understand the corrosion mechanism. For this reason, in vitro study is important. In this study, the density of *S. mutans* in an individual with good oral hygiene was considered. In order to understand the interaction between *S. mutans* and corrosion in a broader context, the effect of *S. mutans* on corrosion at different pH and different concentrations should be investigated.

CONCLUSION

The relationship between corrosion product formation and *S. mutans* is reciprocal, as corrosion inhibited the growth of *S. mutans* in Klimek artificial saliva. Even at a low density of *S. mutans*, Ni-release increased in appliances with SS archwires, indicating that *S. mutans* promotes corrosion. As rough surfaces can also promote corrosion, surface properties should be considered when evaluating the corrosion properties of any metal alloy.

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Informed Consent: Informed Consent is not applicable because this article does not contain any studies with human subjects.

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Author Contributions: Concept - S.T.; Design - S.T.; Supervision - E.E.H.H.; Data Collection and/or Processing - S.T., Z.K.S; Analysis and/or Interpretation - S.T., Z.K.S.; Literature Review - S.T.; Writing - S.T.; A.A.; Critical Review - A.A.

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Original Article

Changes in Angulation and Eruption Space of Developing Mandibular Third Molars Following Twin Block Treatment

Hanem Younes Elfeky[1], Engy Ali Abdelhaleem Salam[2], Fouad Aly El Sharaby[3]

[1]Department of Orthodontics, Faculty of Dentistry, Fayoum University, Faiyum, Egypt
[2]Department of Oral and Maxillofacial Radiology, Faculty of Dentistry, Fayoum University, Faiyum, Egypt
[3]Department Orthodontics, Faculty Dentistry, Cairo University, Giza, Egypt

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Main Points

- The development of third molars and their interaction with the rest of the dentition reveals a great challenge to general dentists as well as orthodontists.
- Despite the major controversy regarding the effect of functional treatment on the mandible, yet, there is a paucity of data concerning their effects on the developing mandibular third molars.
- Twin block bite jumping appliances have a non-significant influence on the angulation of the developing mandibular third molars.

ABSTRACT

Objective: The aim of this study was to assess the effects of twin block functional appliance three dimensionally on mandibular third molars angulation and eruption space.

Methods: This retrospective study included cone beam computer tomography (CBCTs) of 34 Class II females (11.84 ± 0.94 years) who were divided into 2 groups. The first group received a standard twin block appliance (intervention group), while the other was considered as a control. CBCT images were obtained for all patients before the start of the intervention (T0) and after the active phase (9.4 ± 1.33 months) in the intervention group and at the beginning (T0) and after the observation period (T1) in the control group (8.12 ± 2.72 months). Measurements for the retromolar space were performed on the axial views, while those for molar angulation were performed on sagittal views as well as CBCT panoramic reformatted images.

Results: Both twin block and control groups showed non-significant changes in the angular measurements (sagittal L8/MP° and panoramic L8/MP°) denoting lack of change in the angulation of the third molars in relation to the mandibular plane after treatment. On the other hand, retromolar spaces showed a statistically significant increase ($P \leq .05$) in both groups. The change was much significant for the twin block group, measuring 1.95 mm and 1.56 mm on the right and left sides, respectively, as compared to the control group which revealed less than 1 mm increase in the retromolar space on both the right and left sides.

Conclusions: In spite of their positive impact on the retromolar space, twin block bite jumping appliances have a non-significant influence on the angulation of the developing mandibular third molars.

Keywords: Cone beam CT, functional orthodontic appliance, third molar, three-dimensional imaging

INTRODUCTION

The development of third molars and their interaction with the rest of the dentition reveals a great challenge to general dentists as well as orthodontists. Their eruption position and pattern may influence or be influenced by orthodontic treatment. Hence, their direct involvement in treatment planning is mandatory.

Corresponding author: Fouad A. El Sharaby, e-mail: fsharaby@dentistry.cu.edu.eg

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Lower third molars are considered the second most commonly impacted teeth following upper third molars.[1] A minimum of one impacted mandibular third molar has been reported in about 73% of young adults. The prevalence of impaction varies in different populations between 18% and 32%.[2] Formation of third molars begins at about 8-10 years of age, with a degree of variation ranging from 5 to 14 years, which is relatively consistent with the time advocated for mandibular functional treatment to correct sagittal discrepancies, especially in females.

It is generally believed that lack of space between the distal surface of the erupted second molar and the ascending ramus constitutes the major factor for the high frequency of mandibular third molar impaction.[3] The smaller the space available, the greater the likelihood of impaction.[4]

Class II malocclusion is a frequently seen problem in daily orthodontic practice.[1] It could have a negative impact of variable degrees on patient esthetics, function, as well as psychology. Recognition of mandibular deficiency as the major contributing factor for Class II structural etiology[5] has prompted the increased implementation of bite jumping functional appliances. The major goal of functional appliance therapy is to enhance or to redirect the growth of the mandible in a favorable direction.

A multitude of functional appliances has been presented in the orthodontic literature for the correction of Class II malocclusion.[6,7] The technique of fabrication, method of bite construction, as well as patient compliance are the key factors that govern the differences in the outcomes of various functional appliances. The twin block functional appliance (TB), originally developed by Clark,[8] has gained increasing acceptance. The appliance consists of maxillary and mandibular acrylic plates with interlocking bite blocks that posture the mandible forward on closure.

Despite the major controversy regarding the effect of functional treatment on the mandible, yet, there is an undeniable evidence of mandibular length increase after treatment with several functional appliances.[9] Meanwhile, clinical results remain to be the main impetus for their indispensable use. The literature is replete with articles reporting various effects of functional treatment on mandibular dentition,[10,11] yet, there is a paucity of data concerning their effects on the developing mandibular third molars eruption space and angulation.[12] Accordingly, the aim of this study was to assess the effects of TB functional appliance three dimensionally (3D) on developing mandibular third molar eruption space and angulation.

METHODS

Trial Design

The radiographs for this retrospective study were collected from the records of patients treated at the outpatient clinic of the Department of Orthodontics, Cairo University. The CBCTs were taken for those patients in the course of treatment with TB appliance for another study to evaluate skeletal, dentoalveolar, and temporomandibular joint changes.[10] This single-blind study was approved by the Research Ethics Committee (No. 130811), Faculty of Dentistry, Cairo University, Egypt, and participation consent forms were signed by the patients' parents or their legally authorized representatives.

Sample Size, Eligibility Criteria, and Settings

Sample size calculation was done with an alpha value of 0.05 and a power of 80% based on the study conducted by Bayram et al.[13] Power analysis showed a minimum sample of 15 patients in each group. Patients who met the eligibility criteria were included in the sample (Table 1).

A total of 17 patients were included in each group with a total sample size of 34 patients. A standard TB appliance manufactured according to Clark[8] was confirmed. The exact active treatment time together with the patients' compliance with the appliance wear was acknowledged from the patients' follow-up records. CBCT images of 17 untreated, clinically matching control patients were obtained from a control databank in the same institute. Lateral cephalometric radiographs constructed from CBCT images were used to assess the baseline characteristics of the patients (Table 2).

CBCT Imaging and 3D Analysis

CBCT images of the involved patients were confirmed to be acquired using the same machine (Sirona Dental Systems, Bensheim, Germany). Parameters of the CBCT scanner were set according to the recommendations of De Vos et al.[14] and provided a minimal set of CBCT device-related parameters to minimize the radiation dose to the minimum following the as low as reasonably achievable guidelines. CBCT images were obtained for all patients before the start of treatment (T0) and after the active phase of the appliance (T1) in the treatment group and at the beginning (T0) and after the observation period (T1) in the control group. The functional phase lasted for 9.4 $\pm$ 1.33 months and the observational period for the control group was 8.12 $\pm$ 2.72 months.[10] The CBCT images were then converted to Digital Imaging and Communications in Medicine (DICOM)

Table 1. Eligibility criteria of patients included in the study

Inclusion Criteria	Exclusion Criteria
Females mean age: 11.84 $\pm$ 0.94 years Convex profile with retruded mandible Full unit Class II molar and canine relationship Stage 3 Cervical Vertebrae Maturation Index (CVMI) as verified from lateral cephalometric radiographs Erupted mandibular second molars Arch length discrepancy $\leq$ 5 mm Third molar crown formation completed Active treatment between 8 and 10 months	History of previous orthodontic treatment History of TMJ disorders Systemic disease or chronic medication Congenitally missing or extracted teeth

Table 2. Baseline characteristics of the sample compared with independent *t*-test

	Twin Block		Control		
	Mean	SD	Mean	SD	*P*
Age (years)	11.89	1.85	11.27	2.19	.335
SNA (°)	81.27	3.58	81.75	3.52	.703
SNB (°)	73.00	3.24	73.97	2.30	.326
ANB (°)	8.28	1.19	7.51	1.81	.171
Go-Gn (mm)	74.18	4.17	74.52	3.13	.791
SN/MeGo (°)	43.69	3.38	38.9	4.5	.051

SD, standard deviation; SNA, Sella. Nasion. Point A; SNB, Sella. Nasion. Point B; ANB, Point A. Nasion. Point B; Go-Gn, Gonion-Gnathion; SN/MeGo, Sella. Nasion/ Menton.Gonion.

format and processed into volumetric images using Invivo Anatomage image processing software version 5.2 (Anatomage, San Jose, Calif, USA). Multiplanar sagittal, coronal, and axial projections were generated. A customized craniofacial analysis was developed specifically for this research. Measurements for both treatment and control groups at (T0) and (T1) were performed on the axial views, CBCT panoramic reformatted image, as well as the sagittal views (Table 3). The assessors were blinded during the analysis, and the measurements were performed by the same observer twice at 2 weeks intervals and by another observer.

The linear measurements for the retromolar space (RMS) were performed on the axial view following Marchiori et al.[4] method. The measurement was taken after scrolling between the axial cuts till positioned parallel to the occlusal plane at the level of interproximal contact points of permanent molars and premolars. At this level, 2 tangent lines were drawn from the center point of mandibular canal across the second molars to be intersecting at a point midway between central incisors. The distance between the distal surface of right and left second molar and

Table 3. Definitions of the included landmarks and measurements

Measurement	Definition
L8 (long axes of the third molar buds)	The line extending from the point of intersection between the converging tangents to the mesial and the distal outlines of the molars and the mid-point on the occlusal surface
MP (mandibular plane)	The line extending from the Menton, the most inferior point at the mandibular symphysis, to the Gonion, the most posterior inferior point at the outline of the angle of the mandible
Panoramic RL8/ MP°	The angle formed between long axis of the right third molar and the right mandibular plane line as viewed from CBCT panoramic reformatted image
Panoramic LL8/MP°	The angle formed between long axis of the left third molar and the left mandibular plane line as viewed from CBCT panoramic reformatted image
Sagittal RL8/MP°	The angle formed between long axis of the right third molar and the right mandibular plane line as viewed from the sagittal view
Sagittal LL8/MP°	The angle formed between long axis of the left third molar and the left mandibular plane line as viewed from the sagittal view
RRMS (right retromolar space)	The linear distance between the most convex point on the distal surface of the right second molar and anterior border of the right ramus as viewed from the specified axial view
LRMS (left retromolar space)	The linear distance between the most convex point on distal surface of the left second molar and anterior border of the left ramus as viewed from the specified axial view

RL8, right lower third molar; LL8, left lower third molar

Figure 1. The axial section with linear measurements of the right and left retromolar spaces

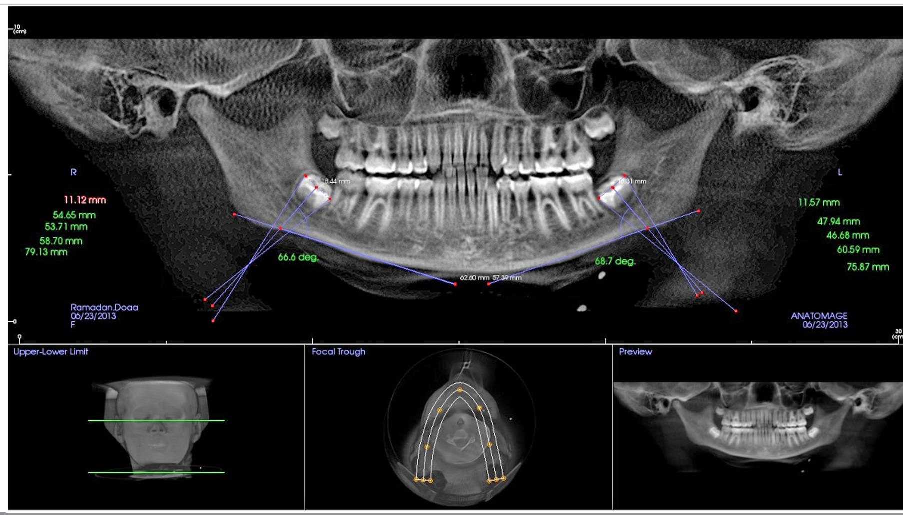

Figure 2. The panoramic reformatted image with angular measurements of the right and left sides

anterior border of the right and left ramus was measured (RRMS and LRMS axial), respectively (Figure 1).

The angular measurements were performed on CBCT panoramic reformatted image (Figure 2) as well as the sagittal view (Figure 3) after adjustment of the axial orientation line to be along the occlusal plane, while the coronal orientation line midway along the long axis of the mandibular third molar, and the sagittal orientation line from mandibular third molar to a point midway between central incisors (Figure 4).

Statistical Analysis

Statistical analysis was performed using Statistical Package for the Social Sciences version 22.0 (IBM SPSS Corp., Armonk, NY, USA) for windows. Numerical data were explored for normality by checking the data distribution, calculating the mean and median values, and using Kolmogorov–Smirnov and Shapiro–Wilk tests. Data showed parametric distribution, so it was represented by mean and standard deviation values. Inter- and intra-group comparisons were done using independent and paired *t*-tests, respectively. For inter- and intra-observer reliability, concordance correlation coefficients including 95% confidence limits were used.

RESULTS

Intra- and interobserver reliability tests showed an excellent concordance correlation (0.99). Both control and TB groups showed non-significant changes ($P > .05$) in the angular measurements (sagittal L8/MP° and panoramic L8/MP°) denoting lack of change in the angulation of the developing third molars in relation to the mandibular plane after treatment (Table 4). On the other hand, both RRMS and LRMS showed a statistically significant increase ($P \leq .05$) in both groups. The change was greater for the TB group, measuring 1.95 mm and 1.56 mm on the right and left sides, respectively, as compared to the control group which revealed a less than 1 mm increase in the RRMS and LRMS (0.86 mm and 0.34 mm, respectively) (Table 4).

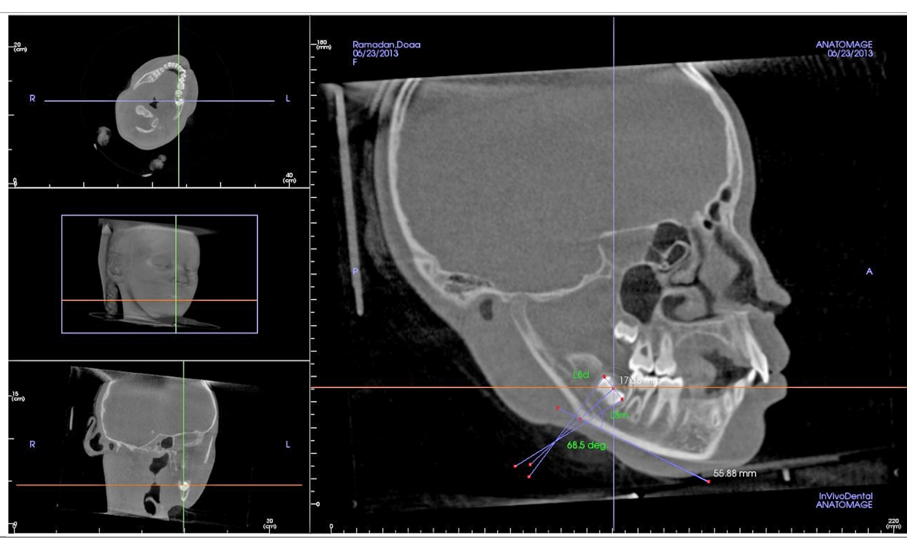

Figure 3. The sagittal section with angular measurements of the left sides

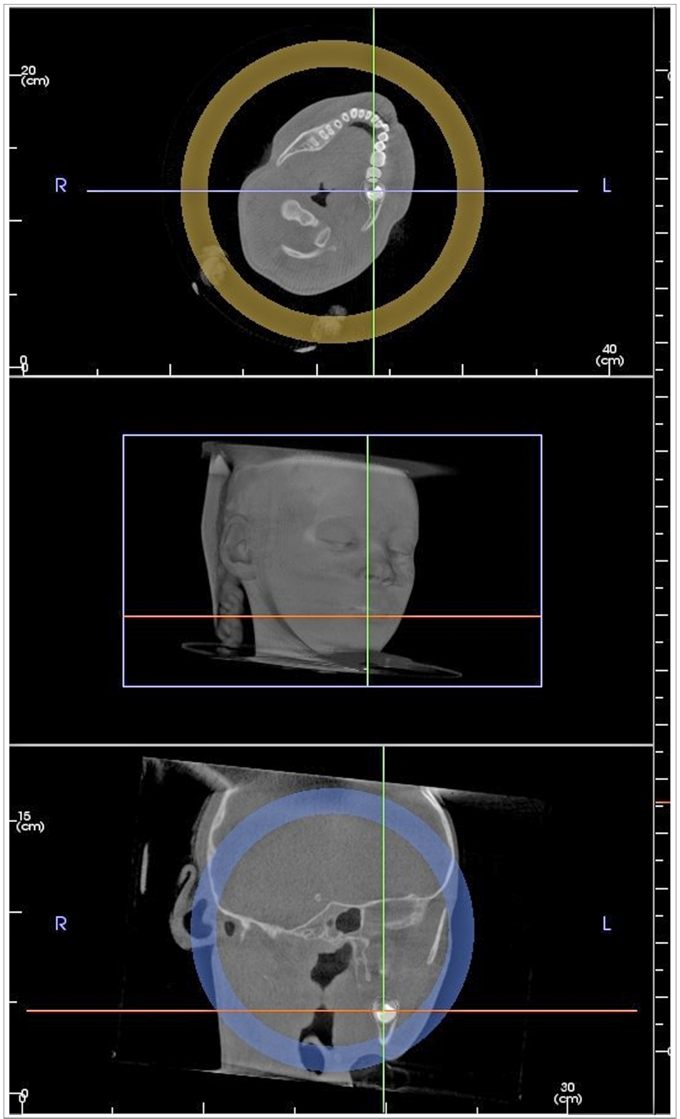

Figure 4. The axial and coronal sections illustrating the adjustment of the axial orientation line, sagittal orientation line and coronal orientation line

Additionally, non-significant changes (*P* > .05) were reported between the TB and the control groups concerning molar angulation in the panoramic and sagittal views' measurements before and after the study period (Table 5).

DISCUSSION

Functional orthopedic appliances have been used in growing individuals with skeletal Class II aiming at establishing muscular balance, eliminating oral dysfunction, and/or allowing for the lengthening of the mandible. Despite the controversial conclusions of published systematic reviews, improvement in mandibular growth together with proclination of the lower incisors following the use of TB functional appliances has been reported.[6,14]

There is a paucity of data concerning the optimum timing for functional jaw orthopedics; however, there is a consensus that this treatment modality better be commenced around the period of puberty[16,17] which in turn is coincident with the time of development of mandibular third molars.[18]

The current study was conducted to evaluate the effects of TB functional appliance treatment on developing mandibular third molar eruption space and angulation. Similar studies have been conducted to assess changes in the position of third molars associated with extraction versus non-extraction orthodontic treatments,[19-22] and limited studies were concerned with the effect of functional treatment on third molar position and angulation.[12] Panoramic radiograph was the common tool used for the evaluation in those studies despite its inherent weakness of 2-dimensional (2D) representation of 3D objects.[23]

In their systematic review, Araujo et al.[23] reported the usefulness of 3D imaging in providing additional information on the relationship between lower third molar and neighboring structures. Likewise, Marchiori et al.[4] confirmed the high accuracy of CBCT imaging in analyzing the third molar development, crown size, and jaw dimensions. They demonstrated a method for measuring the RMS on the axial views from CBCT images. Their method for measuring the RMS together with the method of Mendoza-García et al.[24] for measuring the third molar angulation with the mandibular plane as viewed on panoramic radiographs was implemented in the current study.

Table 4. Mean and standard deviation of angular and linear measurements before and after twin block treatment and observation period using independent t-test

Linear and angular measurements	Twin Block group					Control group				
	Before		After			Before		After		
	Mean	SD	Mean	SD	*P*	Mean	SD	Mean	SD	*P*
Sagittal RL8/ MP°	61.82	14.58	63.04	15.06	0.116	72.3	10.63	74.23	9.76	0.224
Sagittal LL8/ MP°	72.67	7.53	77.67	9.22	0.072	70.97	8.88	71.83	9.28	0.126
Panoramic RL8/ MP°	64.87	5.7	67.36	5.57	0.163	71.9	6.27	73.83	7.97	0.218
Panoramic LL8/ MP°	76.8	9.55	81.08	9.8	0.147	70.45	5.63	72.1	7.23	0.194
Axial RRMS (mm)	11.61	2	13.56	2.35	0.001*	8.43	3.2	9.23	3.5	0.018*
Axial LRMS (mm)	10.84	3.04	12.42	2.64	0.001*	6.71	3.49	7.05	3.41	0.021*

*Significance at P ≤ .05.
SD, standard deviation; LRMS, left retromolar space; RRMS, right retromolar space.

Table 5. Intra and inter group comparison of mean and standard deviation of panoramic and sagittal views' measurements for the Twin Block and the control group

		Imaging Method		
	Group	Panorama (Mean ± SD)	Sagittal (Mean ± SD)	*P*
Before	TB	70.38 ± 9.62	68.15 ± 11.24	.338
	Control	71.07 ± 5.44	71.54 ± 8.81	.765
P		.863	.499	
After	TB	73.69 ± 10.31	71.23 ± 12.68	.228
	Control	72.84 ± 6.94	72.86 ± 8.74	.989
Difference		0.850	1.630	
P		.780	.666	

Significance value (*P*-value)
SD, standard deviation; TB, twin block

The measurement was taken after scrolling between the axial cuts till positioned parallel to the occlusal plane at the level of interproximal contact points of permanent molars and premolars. This would not have been possible to accomplish with 2D imaging using panoramic radiography. Additionally, the main advantage of 3D imaging is that it offers cuts in the axial, coronal, and sagittal planes that allow for the better localization of intended objects.

It has been reported that the mandibular third molar starts its development in the ramus of the mandible with its occlusal surface having an angle with the mandibular plane. In order to erupt with a normal occlusal relationship, the third molar should experience an uprighting movement, the degree of which depends on its original angulation to the mandibular plane.[25]

The baseline characteristics for the study groups presented in Table 2 showed no statistically significant difference concerning any of the considered measurements. This in turn reflected homogenous sample with no remarkable differences.

Results from the current study revealed non-significant changes in the angulation of the third molars in relation to the mandibular plane following the study period in both groups. This was consistent with the results of Cornell and Park[26] who reported that 4 out of 6 included studies in their systematic review showed no significant difference in mandibular third molars angulation between the extraction and non-extraction treatments. These results could be explained by the observation reported by Silling[27] who emphasized that important changes in the axial inclination of the mandibular third molar take place between the ages 16 and 18 years when the bud has reached a point in close proximity to the distal aspect of the second molar, the condition that was not established in the current study. On the other hand, Aslan et al.[12] reported a significant uprighting of the third molar by 4.28° following treatment with Forsus fatigue resistant device with no significant difference compared to the control.

Despite many factors that could interfere with the eruption of mandibular third molars, the available space at the posterior borders of the dentition is considered the most decisive. The difference detected in the RMS between the 2 groups at the baseline could be attributed to a tooth size/arch length discrepancy. In the current study, the RMS showed an increase between 0.34 mm and 0.80 mm for the control group as compared to 1.58 mm and 1.95 mm for the TB group during the study period. This increase in RMS could be associated with the increase in the corpus length following the use of TB appliance as reported by Elfeky et al.[10] who attributed the overall mandibular skeletal changes to the increase in mandibular length by 3.19 mm. Cozza et al.[15] demonstrated comparable results in their systematic review to investigate mandibular changes produced by functional appliances in Class II malocclusion. Their results revealed an increase of mandibular length by 0.23 mm/month following the use of TB appliance. Likewise, Ehsani et al.[11] and D'Antò et al.[28] acknowledged a mandibular increment increase by 2.9 mm/year and 2.9 mm, respectively, following the use of the same appliance. Another possible and more advocated explanation for the increase in the RMS could be the mesial drift of the entire dental arch with forward migration of the mandibular first molars and proclination of the mandibular incisors.[6,10,11] A similar finding was presented by Toth et al.[30] who reported forward movement of the lower incisor by 0.7 mm during TB treatment and Aslan et al.[12] who reported an 8.79° increase in incisors inclination following the use of Forsus fatigue resistant device. Additionally, Aslan et al.[12] reported a significant greater increase in the RMS at the end of the treatment (from 0.37 mm to 0.65 mm; 0.28 mm) compared to the control group (from 0.44 mm to 0.54 mm, 0.10 mm).

The position and eruption of mandibular third molars in relation to different orthodontic treatment mechanics continue to be a controversial issue. Different orthodontic treatment mechanics establish different space conditions in the dental arches that could affect the eruption of mandibular third molars hence the decision of their prophylactic extraction.

Limitations in the current study should be considered when interpreting the results. First, the data were collected from the records of patients treated at the outpatient clinic of the Department of Orthodontics, Cairo University,[10] and hence, randomization of the sample was not feasible. Only female patients were recruited which despite helping in the validation of the comparison through precluding possible gender effect on growth and development, yet, it could limit the generalizability of the results. Moreover, a longer assessment duration could have better elucidated the actual impact of the appliance on the developing molars.

CONCLUSION

The use of TB bite jumping appliances for the treatment of growing Class II patients does not seem to affect the angulation of the developing mandibular third molars despite its positive impact on the RMS available for their eruption.

Ethics Committee Approval: Ethics committee approval was received from the Research Ethics Committee of the Faculty of Dentistry, Cairo University, Egypt (No. 130811).

Informed Consent: Written informed consent was obtained from all patients' parents or legally authorized representatives.

Peer-review: Externally peer-reviewed.

Author Contributions: Concept – F.A.E.S.; Design – H.Y.E.; Data Collection and/or Processing – H.Y.E.; Analysis and/or Interpretation – E.A.A.S.; Writing – F.A.E.S.; Critical Review – F.A.E.S.

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Original Article

Comparative Evaluation of Soft Tissue Profile Changes with Herbst and Twin Block Appliances in Class II Malocclusion Patients: A Perception Study

Annapurna Kannan[1], Sridevi Padmanabhan[1]

[1]Department of Orthodontics and Dentofacial Orthopaedics, Sri Ramachandra Faculty of Dental Sciences, Sri Ramachandra Institute of Higher Education and Research, Chennai, India

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Main Points

- Within the appliances, profile changes were perceptible with the Twin Block for the orthodontists and with Herbst and Twin Block for the general dentists. Laypersons did not perceive any profile improvement on treatment with both functional appliances.
- Between Herbst and Twin Block appliances, no difference was present in the profile perception with all 3 groups of examiners.
- The ANB angle contributed to the difference in profile perception between the appliances.

ABSTRACT

Objective: To comparatively evaluate the perception of patients' soft tissue profiles treated with Herbst and Twin Block appliances and correlate the perception with cephalometric parameters.

Methods: The record of 30 patients (15 Herbst and 15 Twin Block) treated for a period of 6 months (±1.1 months) was included in the study. A total of 60 resulting profile silhouettes (from pre- and post-functional profile photographs) were evaluated by 30 examiners and were divided into 3 groups: orthodontists, general dentists, and laypersons. The profiles were arranged in a randomized order, and the examiners rated the profiles using a visual analog scale. Paired *t*-test and independent *t*-test were performed to find a significant difference within and between the appliances, respectively. A treatment outcome correlation was done using Pearson's correlation test between the visual analog scale scores and cephalometric parameters.

Results: Within the appliances, the orthodontist perceived a difference with only the Twin Block appliance ($P = .02$). The general dentists perceived a significant difference with both Herbst ($P = .02$) and Twin Block ($P = .001$) appliances, whereas the laypersons did not perceive any profile improvement on treatment with functional appliances. However, between the appliances, no statistically significant profile difference was seen with all 3 groups of examiners. The ANB angle had a significant negative correlation ($P = .007$) to the visual analog scale scores given by the orthodontists for the Herbst appliance.

Conclusion: No perceptible difference was found in the profile enhancement between Herbst and Twin Block appliances with all 3 groups of examiners. The ANB angle contributed to the difference in profile perception between the appliances for the orthodontists.

Keywords: Herbst, Twin Block perception, visual analogue scale

INTRODUCTION

Facial aesthetics plays a pivotal role in the perception of beauty. Malocclusion and self-perceived poor facial aesthetics have shown to have strong correlations with negative self-esteem and reduced quality of life.[1,2] Skeletal Class II malocclusion with retrognathic mandible, characteristically seen with a soft tissue convex profile, is said to have an adverse emotional impact on growing children and acts as a deterrent to their social interactions.[3,4] Hence by correcting the profile, there are added psychological benefits to the patient along with a marked improvement in a patients' facial aesthetics.

Corresponding author: Annapurna Kannan, e-mail: annapurnakannan@gmail.com

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Growth modifications are attempted to alter a developing skeletal Class II relationship in young children, predominantly during the growth phase by redirecting and accelerating the patients' remaining facial growth to a favorable size or position of the jaws using functional appliances—fixed and removable.[5-8]

Twin Block is a commonly used removable functional appliance in growing patients with Class II malocclusion. Studies that have evaluated the soft tissue profile changes with Twin Block have shown that the appliance provides an effective anterior lip seal with retracted upper lip, advancement in the soft tissue pogonion with an increase in the lower facial height and decrease in the H angle.[9-11]

With a continuous mechanism of action, the fixed functional appliance—Herbst—has been used in patients whose growth is near completion. Studies that have evaluated the effects of Herbst appliance treatment on the soft tissue profile have found a reduction in facial convexity and upper lip protrusion.[12-14]

The skeletal changes are seen on both the maxilla and the mandible with the Herbst appliance[15] and restricted predominantly to the mandible with Twin Block appliance.[16] This is seen in the resultant improvement of the facial profile. Güler and Malkoç[17] have concluded that both Twin Block and Herbst appliances provide a volumetric improvement in the mandible and thus show enhancement of the soft tissue profiles of the patients. However, the soft tissue changes are generally variable in magnitude and whether the changes are appreciable clinically is questionable.

do Rego et al.[3] in their profile perception study on Herbst appliance have concluded that it brings about positive changes to the facial profile which can be perceived visually, immediately, and 2 years after treatment. However, Baysal and Uysal[18] have shown the Twin Block appliance to have a greater change in the soft tissue profile when compared to that of the Herbst appliance, quantitatively. While the efficacy of Herbst and Twin Block appliances has been extensively studied, the clinical perception of the treatment changes brought about by Herbst appliance when compared to that of Twin Block has not yet been analyzed.

Thus, a study is required to assess the perceptional changes in soft tissue profile induced by treatment with Herbst and Twin Block appliances, by comparing the facial profile silhouettes before and after treatment. Also, a correlation of the perceived difference in the profile of the patient to that of the cephalometric values obtained is required.

The aim of this study was to assess the perceptional changes in soft tissue profile induced by treatment with Herbst and Twin Block appliances by comparing facial profile silhouettes before and after treatment, as evaluated by orthodontists, general dentists, and laypersons and correlate with cephalometric parameters.

We tested the null hypothesis of no significant difference in perception of soft tissue profile changes with Herbst and Twin Block appliances.

METHODS

The study was conducted at the Department of Orthodontics, Sri Ramachandra Faculty of Dental Sciences, Chennai after approval from the University's Institutional Ethics Committee (CSP/17/JUN/59/205).

This retrospective study was based on archival records of patients treated with Twin Block and Herbst appliances between 2013 and 2020. Informed consent was obtained from all patients included in the study.

Inclusion Criteria

1. Class II skeletal pattern with ANB angle greater than 5° and Wits appraisal of 2 mm or more were included.
2. Full-step or three-quarter step Class II Division 1 dental relationship
3. Overjet of 7 mm or greater
4. No previous orthodontic treatment
5. Post-functional: Class I molar and canine relationships with 1-2 mm overjet
6. Age: 11-14 years
7. Convex profile in pre-treatment photographs

Exclusion Criteria

1. Anterior open bite
2. Patients with extreme vertical growth pattern (Go-Gn to SN greater than 36°)
3. Non-compliant patients
4. Developmental abnormalities

Sample size calculations [d = 0.5, α error = 0.05, and power of study = 85%] were based on the study by do Rego et al.[3] to detect a clinically relevant difference between the 2 appliances and indicated that a sample size of 15 patients would be required per group.

The samples were matched based upon the degree of skeletal discrepancy, age group, and treatment duration. Fifteen patients in Cervical vertebrae maturation index (CVMI) stage 3 were treated with Herbst appliance [10 boys (mean age: 13.5 years $\pm$ 1 month), 5 girls (mean age: 12.8 years $\pm$ 2 months)], and 15 patients in CVMI stage 2 were treated with Twin Block appliance [11 boys (mean age: 13.1 years $\pm$ 2 months), 4 girls (mean age: 12 years $\pm$ 1 month)], both treated for a mean treatment period of 6 months $\pm$ 1.1 months, were included in the study.

With regards to the facial pattern, in the Herbst appliance group, 11 patients had a low angle Class II (Go-Gn to SN less than 32°) and 4 patients had a high angle Class II (Go-Gn to SN greater than 32°) based on Steiner's cephalometric analysis.[19] While with the Twin Block, 14 patients had a low angle Class II and 1 patient had a high angle Class II.

In the Twin Block group, the patients were treated using a standard Twin Block appliance (Figure 1). With the Herbst appliance, the patients were treated using banded Herbst with a telescopic mechanism connecting between the maxillary and

Figure 1. Standard Twin Block

mandibular arch (Figure 2). The construction bite was taken for all patients such that on advancement of the mandible, the patient achieved a straight profile. Phase II using the fixed appliance therapy phase was begun for patients of both the groups following the completion of phase I treatment using functional appliances.

Pre-treatment and post-functional profile photographs of patients taken in the natural head position with standardized camera settings were selected. From the profile pictures, profile silhouettes (Figure 3) were generated with Adobe Photoshop Version 7 (Adobe Inc., San Jose, Calif, USA).

Randomization

Using a computer-generated program (www.randomization.com), a simple randomization allocation sequence of the 60 pre- and post-functional profile silhouettes were generated and the silhouettes were uploaded into a non-editable computerized presentation.

A total of 30 examiners [sample size calculated based on the study by von Bremen et al.[20] which involved 10 orthodontists and 10 laypersons] belonging to 3 categories: 10 orthodontists (5 men and 5 women; number of years in orthodontic practice: 12 years ± 2 months), 10 general dentists with no orthodontic training (5 men and 5 women; number of years in general dentistry practice: 11 years ± 5 months), and 10 laypersons (5 men and 5 women) with no familiarity of dentistry were shown in the presentation.

Thirty seconds was given to analyze each profile. The examiners were instructed to rate the profile using a visual analog scale (VAS) that consisted of a 10-cm line. A score of 0 denoted that the profiles looked least pleasing, whereas 10 denoted that the profile was most pleasing. The first impression was taken as the final opinion. No additional information such as the age and gender of the patients was provided to the examiners.

Pre- and post-functional lateral cephalograms of the patients were traced by 1 examiner using Dolphin imaging software version 11 (Dolphin Imaging & Management Solutions, Chatsworth, Calif, USA). All cephalograms were taken using a single cephalostat with standardized magnification. The VAS scores of the treatment outcome were correlated to that of the cephalometric parameters: anteroposterior changes (SNB, ANB, and N-Pog), mandibular plane angle (GoGn-SN), inter-incisal angle, and soft tissue convexity (G′-Sn-Pog′).

Error of Method

The VAS scores of 3 examiners per group and the cephalometric data of 5 patients per group were recorded again after 3 weeks of the initial assessment. The test–retest intraexaminer reliability coefficient indicated a score of 0.8 (good reliability) for the VAS scores of all 3 groups of examiners and 0.9 (excellent reliability) for the cephalometric data collected.

Statistical Analysis

The data were analyzed with IBM Statistical Package for the Social Sciences Statistics for Windows, version 26.0 (IBM Corp., Armonk, NY, USA). The Kolmogorov–Smirnov's test was used to check the normality of the data and showed a normal distribution of data. To find the significant difference within the groups, a paired *t*-test was performed between the pre- and post-treatment values for the Herbst and Twin Block appliances among each group of examiners. An independent *t*-test was performed

Figure 2. Banded Herbst

Figure 3. a, b. Sample of profile silhouettes of patients treated with Twin Block (*left to right*: 1-3) and Herbst (*left to right*: 4-6): (a) pre-treatment; (b) post-functional

to test the significance between Herbst and Twin Block appliances. To assess the relationship between the cephalometric parameters and the VAS, a Pearson's correlation test was used. In all the above statistical tools, the probability value level of .05 was set as significant.

RESULTS

Intragroup Comparison of Visual Analog Scale Scores

With the Herbst appliance, all 3 groups of examiners gave a higher rating for the post-functional profile silhouettes. However, a statistically significant difference to pre-treatment profile silhouettes was perceived only by the general dentists ($P = .02$).

With the Twin Block appliance, all 3 groups of examiners gave a higher rating for the post-functional profile silhouettes. On comparing the pre- and post-functional profile silhouettes, a statistically significant difference was perceived by the general dentists as well the orthodontists, with the orthodontists giving a higher rating.

For both the pre- and post-functional profile silhouettes, the laypersons gave the highest VAS scores with both the appliances (Table 1).

Intergroup Comparison of Visual Analog Scale

On comparing the perception of treatment outcome between Twin Block and Herbst appliances, no significant difference was

Table 1. Visual analog scale scores for comparison of changes in profile silhouettes before and after treatment with Herbst and Twin Block appliances

	Herbst			Twin Block		
	Pre-Treatment	Post-Treatment	*P*	Pre-Treatment	Post-Treatment	*P*
Orthodontists	4.13	4.88	.09	4.55	5.4	.02*
General dentists	3.26	4.70	.02*	3.53	4.85	.001**
Laypersons	5.28	5.78	.20	5.49	5.80	.30

$^{*}P < .05$, $^{**}P < .01$.
Statistical test: Intragroup comparison: Paired *t*-test.

Table 2. Perception comparison of treatment outcome between Twin Block and Herbst appliances

	Herbst	Twin Block	*P*
Orthodontists	0.42	0.78	0.50
General dentists	0.49	0.53	0.91
Laypersons	0.49	0.30	0.55

Statistical test: Intergroup comparison: Independent *t*-test.

Table 3. Intergroup comparison of pre- and post-treatment difference in cephalometric parameters

Cephalometric Parameters	Herbst	Twin Block	*P*
ANB	−1.72 ± 1.46	−2.61 ± 1.79	.148
SNB	2.87 ± 1.55	2.35 ± 1.60	.374
GoGn-SN	2.14 ± 1.62	2.72 ± 2.04	.395
Interincisal angle	−6.97 ± 11.10	−2.27 ± 8.05	.195
N-Pog (mm)	−2.66 ± 2.04	−2.81 ± 2.24	.853
G'-Sn-Pog'	−3.27 ± 2.71	−4.87 ± 2.80	.123

Statistical Test: Intergroup comparison: Independent *t*-test.

perceived between the appliances by all 3 groups of examiners (Table 2).

Intergroup Comparison of Cephalometric Parameters

On comparing the pre- and post-functional changes in cephalometric parameters, no significant difference was perceived between Herbst and Twin Block appliances for any of the parameters (Table 3).

Correlation between VAS Scores and Cephalometric Parameters

The ANB angle showed a statistically significant negative correlation with the VAS scores given by the orthodontists for the Herbst appliance ($P = .007$). The higher the ANB, the lesser the VAS scores were (Table 4).

DISCUSSION

The ideal soft tissue responses anticipated from functional therapy are a significant improvement in the facial profile contributed by the anterior movement of soft tissue pogonion, retraction of the upper lip, and an increase in the lower anterior facial height.[10] Although the efficacy and treatment response to functional appliances have been studied extensively, there is a lacuna in the literature regarding the perception of the treatment outcome achieved between the appliances.[21]

While analyzing the profile photographs of patients treated using the Herbst appliance, von Bremen et al.[20] found that laypersons had rated the facial profiles more critically when compared to orthodontists. According to de Paula et al.[22] with mandibular protraction appliance, lay evaluators found a greater difference in the profile silhouettes than orthodontists. Between Herbst and Forsus, while the post-treatment profile with Herbst appliance was preferred, no significant difference was seen in the rating between the groups suggesting minimal aesthetic improvement when compared to baseline values.[23] This is the first study to assess the clinical perception of the treatment outcome between the 2 most commonly used functional appliances—Herbst and Twin Block.

Facial silhouettes were chosen in this study due to their unbiased nature of presenting a patients' profile, and 3 varied groups of examiners were selected to detect the perspective differences. Visual analog scale scores were used due to their simplicity, convenience, and speed; the greater the amount of information available, the more cautious the examiners will be with their scores.

All 3 groups of examiners preferred the profiles achieved after treatment with both Herbst and Twin Block appliances over the pre-treatment profiles. However, this perceived improvement was not statistically significant between the Herbst and the Twin Block appliances (Table 1 and 2). There was little difference in the cephalometric parameters between the treatment outcome of

Table 4. Correlation between visual analogue scale scores of herbst and twin block appliances and cephalometric parameters

	Herbst			Twin Block		
	Orthodontist	General Dentist	Laypersons	Orthodontist	General Dentist	Laypersons
ANB	0.67 $P = .007^{**}$	0.46 $P = .087$	0.161 $P = .566$	−0.103 $P = .714$	0.196 $P = .485$	0.021 $P = .940$
SNB	0.11 $P = .686$	−0.033 $P = .908$	−0.179 $P = .524$	0.214 $P = .443$	0.230 $P = .410$	−0.068 $P = .810$
Go-Gn-SN	0.29 $P = .290$	0.169 $P = .548$	−0.002 $P = .995$	−0.071 $P = .801$	−0.153 $P = .585$	−0.349 $P = .203$
Interincisal angle	0.33 $P = .229$	0.400 $P = .139$	0.391 $P = .150$	0.427 $P = .113$	0.167 $P = .552$	0.302 $P = .274$
N-Pog	0.17 $P = .537$	0.011 $P = .969$	−0.058 $P = .837$	0.233 $P = .404$	0.282 $P = .308$	0.009 $P = .976$
G'-Sn-Pog'	0.26 $P = .352$	0.310 $P = .260$	−0.162 $P = .565$	0.302 $P = .274$	−0.017 $P = .951$	0.102 $P = .718$

$^{**}P < .01$.
Statistical Test: Pearson's correlation test.

both the appliances, and the difference was not statistically significant, consistent with previous findings.[18]

However, within the appliances, general dentists were able to perceive a statistically significant profile difference with both the Herbst and the Twin Block appliances. Whereas, the orthodontists were able to perceive a statistically significant difference only in the Twin Block and not with the Herbst contrary to the study done by do Rego et al.[3] Although none of the cephalometric parameters correlated with the VAS scores, the only exception was the negative correlation between the ANB angle and the VAS scores obtained for the Herbst by the orthodontist. It appears that the orthodontist is more discerning than the general dentists in their evaluation of the soft tissue profile as borne out by the ANB angle (Table 1 and 4).

While the highest ratings using the VAS scores were given by the laypersons, the perceived difference in the magnitude of changes pre- and post-treatment was small and not significant for both Herbst and Twin Block appliances (Table 1). This suggests that the laypersons are more accepting of convexity in the facial profiles prior to treatment than orthodontists and general dentists.

The limitations of our study were as follows. The quantification of the natural growth of the mandible could not be done due to the absence of an untreated control group. However, as patients of similar age groups were recruited for both Twin Block and Herbst appliance groups, the confounding factor of natural growth would be eliminated since it would be similar in both groups.

Perception of facial beauty varies with ethnic origin. Multi-centered studies with standardized methodology are required to comparatively analyze the results obtained from the current study to other environments and settings. Future studies are required to assess the perception of changes produced using functional appliances according to patients, as little evidence exists regarding the patient-centric perception of treatment modalities. Also, eye-tracking systems can be used to provide quantitative measurement on which area of the profile catches the visual attention of each group of examiner.

Some clinical implications that can be drawn from our study are: Between Herbst and Twin Block, one was not superior over the other in the profile changes. However, within the appliances, profile changes with treatment were perceived both by the orthodontists and the general dentists with the Twin Block and only by the general dentists with the Herbst appliance.

Laypersons seem to be more accepting of convexity in facial profile and rated both the pre- and post-treatment silhouettes high and similar. This suggests that they were not as discerning of facial profiles when compared to orthodontists and general dentists.

CONCLUSION

- Within the appliances, general dentists found a significant difference in the profile enhancement with the Herbst appliance, and both general dentists and orthodontists found a significant difference with the Twin Block appliance. However, no significant difference was found between the 2 appliances with regards to profile enhancement with all 3 groups of examiners.
- Except for the ANB angle, which contributed to the perception difference between the 2 appliances, other cephalometric parameters had no correlation to the perception.
- Laypersons gave the highest scores for both pre- and post-functional profile silhouettes. The changes perceived between the 2 were small and statistically not significant.

Ethics Committee Approval: Ethics committee approval was received for this study from the University's Institutional Ethics Committee (CSP/17/JUN/59/205).

Informed Consent: Informed consent was obtained from all patients included in the study.

Peer-review: Externally peer-reviewed.

Author Contributions: Concept - A.K., S.P.; Design - A.K., S.P.; Supervision - S.P.; Materials - A.K.; Data Collection and/or Processing - A.K.; Analysis and/or Interpretation - A.K., S.P.; Literature Review - A.K.; Writing - A.K., S.P.; Critical Review - S.P.

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Original Article

Evaluation of Orthodontic Patients' Anxiety Levels During the COVID-19 Pandemic: A 1-Year Follow-Up

Mehmet Ali Yavan[1], Merve Nur Eğlenen[2]

[1]Department of Orthodontics, Adıyaman University, Faculty of Dentistry, Adıyaman, Turkey
[2]Department of Orthodontics, Yeditepe University, Faculty of Dentistry, İstanbul, Turkey

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Main Points

- The state anxiety levels of orthodontic patients decreased during the follow-up, while there was no significant change in their trait anxiety levels.
- The decrease in state anxiety scores was more pronounced in women and in individuals aged under 18 years.
- In the follow-up, gender-based difference in anxiety scores disappeared.

ABSTRACT

Objective: The aim of this study was to evaluate the anxiety levels of orthodontic patients during the 1-year period in the ongoing pandemic.

Methods: The study included patients between the ages of 12 and 30 years and who were continuing their fixed orthodontic treatment at Adıyaman University, Faculty of Dentistry, Department of Orthodontics and filled out the State-Trait Anxiety Inventory. A total of 266 patients filled out the questionnaire at their first clinical visit between June 8 and July 8, 2020 (T0) and 176 of 190 patients (response rate: 92.63%) that were still under treatment filled out the questionnaire for a second time between June 15 and July 16, 2021 (T1).

Results: In the total population, there was a significant decrease in the State-Trait Anxiety Inventory-S score ($P < .05$), while there was no significant change in the State-Trait Anxiety Inventory-T score ($P > .05$). Anxiety scores were significantly higher in women and individuals aged over 18 years at T0 ($P < .05$), whereas only the anxiety scores of individuals aged over 18 years were significantly higher in T1 than in individuals aged below 18 years ($P < .05$). The State-Trait Anxiety Inventory-S score showed a significant decrease at T1 compared to T0 for female patients (36.02 ± 11.32 vs. 38.82 ± 9.84) and patients aged under 18 years (34.26 ± 9.54 vs. 36.85 ± 9.26) ($P < .05$).

Conclusion: The state anxiety levels of orthodontic patients decreased during the 1-year period of the pandemic, while there was no significant change in their trait anxiety levels.

Keywords: Anxiety, COVID-19, orthodontics

INTRODUCTION

Coronavirus disease 2019 (COVID-19) has dramatically affected almost all medical fields including dentistry.[1] Of note, many countries suspended nonurgent dental procedures during this period.[2] Moreover, orthodontic patients were probably the most affected dental patient group during the COVID-19 quarantine since they need routine checkup. Yavan[3] reported that in the first year of the pandemic, new patient applications for orthodontic treatment also decreased by 48.3% compared to the previous year.

Numerous studies have reported significant increases in anxiety and depression levels in individuals as a result of increased health concerns and unemployment as well as decreased social contact caused by isolation and lockdown in the early stages of COVID-19.[4-7] Studies conducted on orthodontic patients in the first wave of the

Corresponding author: Merve Nur Eğlenen, e-mail: nureglenen@yahoo.com

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pandemic reported that the patients were highly worried about attending their appointments,[8] they were concerned about the delay and prolongation of their treatment,[9,10] and they were even worried that there could be an increase in the incidence of failure of orthodontic appliances and deterioration in their periodontal health.[11] Xiong et al.[12] reported that more than one-third of orthodontic patients experienced mental distress in the early phase of the pandemic and that the severity of this distress was affected by factors such as the type of appliance, time since the last dental visit, and the method of communication with the orthodontist.

Data from previous pandemics show that the effects of pandemics on mental health are not only acute, but that psychological distress may persist after the pandemic is over.[13] Additionally, it has also been suggested that the psychological impact of COVID-19 quarantine may be wide ranging, effective, and long lasting. A longitudinal study by Veldhuis et al.[14] evaluated the effects of COVID-19 pandemic on mental health in 2020 and reported that although the prevalence of depressive symptoms and suicidal thoughts and behaviors increased over the time between April 28 and September, the prevalence of acute stress symptoms decreased. In another longitudinal study, Pieh et al.[15] evaluated individuals' mental health during the COVID-19 lockdown and the subsequent 6 months after the lockdown and reported that there was a significant decrease in stress levels and a significant increase in well-being levels, while the proportion of participants with mental health problems did not decrease.

The aim of this study was to compare the clinical anxiety levels of individuals with ongoing fixed orthodontic treatment during the 1-year follow-up period from June 2020 to June 2021. Our null hypothesis was that there would not be a significant difference in anxiety levels in patients.

METHODS

Ethical Approval

An ethical approval was obtained both from Republic of Turkey Ministry of Health (No: 2021-05-06T15_11_38) and Adıyaman University Non-Interventional Clinical Research Ethics Committee (No: 2021/06-13). An informed consent was obtained from each participant and/or parent/guardian. Questionnaires were kept anonymous and the study protocol was conducted in accordance with the Declaration of Helsinki.

Study Design

The study included patients who applied to Adıyaman University Dentistry School Orthodontics Clinic for fixed orthodontic treatment. The patients were asked to fill out the State-Trait Anxiety Inventory (STAI) at 2 time points: (i) between June 8 and July 8, 2020, when the first national lockdown ended in Turkey (T0) and (ii) between June 15 and July 16, 2021 (T1). During the study, individuals were able to enter the clinic by automatically verifying the security code given to them by a tracing mobile application, which is part of official precautionary measures.[16] Both questionnaires were filled out immediately after the treatment and by using disposable pens.

Study Sample

The study reviewed the medical records of 266 patients (out of 281, response rate: 94.66%) who had resumed their fixed orthodontic treatment at Adıyaman University and filled out the STAI questionnaire at their first clinical visit between June 8 and July 8, 2020, when the national lockdown was lifted in Turkey.[9] One year later (between June 15 and July 16, 2021), 190 patients that were still under treatment. Of these 190 patients, 176 (response rate: 92.63%) of them consented to participate in the study and filled out the questionnaire for a second time. Patients between the ages of 12 and 30 years at T0 and who were continuing their fixed orthodontic treatment during this 1-year period were included in the study. The exclusion criteria were as follows: patients that refused to fill out the questionnaire, whose treatment was completed during this 1-year period, patients using psychiatric drugs, and those that missed more than two appointments.

State-Trait Anxiety Inventory

State-Trait Anxiety Inventory is an anxiety measure developed by Spilberger et al.[17] This inventory has 2 subscales with 20 items each: (i) the State Anxiety Inventory (STAI-S) and (ii) the Trait Anxiety Inventory (STAI-T). State Anxiety Inventory determines how a person feels at a particular time and under a particular condition and STAI-T determines how a person feels regardless of the time and situation. Each item has a 4-point Likert-type response format ranging from (1) "Not at all" to (4) "Very much so" depending on the severity of the situation. The STAI-S score ranges between 20 and 80 and is calculated by subtracting the sum of opposite statements from that of direct statements and adding a predetermined number to the resulting score. By contrast, the STAI-T score ranges between 20 and 80 and is calculated by subtracting the sum of direct statements from that of opposite statements and adding a predetermined number to the resulting score. The Turkish adaptation study was conducted by Öner and Le Compte,[18] and the internal consistency coefficient (Cronbach's alpha) of STAI-S and STAI-T were 0.83 and 0.87, test-retest reliability values were 0.71 and 0.86, and item reliability values were 0.34 and 0.72, respectively.

Statistical Analysis

Sample size was calculated using G*POWER. Using an effect size of 0.19,[15] a critical t value of 1.65, an alpha level of 0.05, and 80% power, the minimum required sample size for each group was 172. Statistical analyses were performed using Statistical Package for Social Sciences for Windows version 22 (IBM SPSS Corp., Armonk, NY, USA). Normality of distribution was determined using Shapiro-Wilk test. Binary comparisons were conducted using Independent-samples t-test and more than 2 variables were compared using 1-way analysis of variance test. Comparison of categorical variables between the 2 time periods was performed using Chi-square test. A P value of $<.05$ was considered significant.

RESULTS

Table 1 presents demographic characteristics of patients at both time points. Of the 266 patients that filled out the questionnaire

Table 1. Demographic characteristics

		T0	T1	
		n (%)	n (%)	P^{μ}
Gender	Female	195 (73.3)	126 (71.60)	.692
	Male	71 (26.7)	50 (28.40)	
Age (years)	12-18	160 (60.15)	109 (61.93)	.707
	18-30	106 (39.85)	67 (38.07)	
Educational status	Secondary school	46 (17.29)	26 (14.66)	.781
	High school	188 (70.68)	128 (72.72)	
	University	32 (12.03)	22 (12.5)	

T0, 2020; T1, 2021.
$^{\mu}$Chi-square test.

at T0, a total of 90 patients were excluded from the study, of whom 70 patients completed their treatment before T1, 6 patients missed more than 2 appointments, and 14 patients refused to fill out the questionnaire. Accordingly, the remaining 176 patients were included in the study. No significant difference was found between the two time points with regard to the demographic characteristics of the participants ($P > .05$).

Table 2 presents the comparison of STAI-S and STAI-T scores according to gender, age, and education. At T0, female subjects' STAI-S (38.82 ± 9.84) and STAI-T (43.16 ± 9.10) scores were significantly higher than those of male subjects (35.11 ± 9.93 and 39.15 ± 8.58, respectively) ($P < .05$), whereas no significant difference was found between male and female subjects' scores at T1 ($P > .05$). At both time points, the STAI-S (T0: 39.32 ± 10.88, T1: 38.10 ± 12.58) and STAI-T (T0: 43.80 ± 8.32, T1: 42.90 ± 10.17) scores of patients aged over 18 years were significantly higher than those of patients aged under 18 years (STAI-S; T0: 36.85 ± 9.26, T1: 34.26 ± 9.54 and STAI-T; T0: 40.97 ± 9.48, T1: 39.62 ± 9.27) ($P < .05$). Nevertheless, no significant difference was found between the educational levels of the patients and their anxiety scores at both time points ($P > .05$).

Table 3 shows the comparison of patients' STAI scores according to their demographic characteristics at both time points. The STAI-S score showed a significant decrease at T1 compared to T0 for total population (35.72 ± 10.92 vs. 37.83 ± 9.98), female patients (36.02 ± 11.32 vs. 38.82 ± 9.84), and patients aged under 18 years (34.26 ± 9.54 vs. 36.85 ± 9.26) ($P < .05$), whereas no significant difference was found for other subcategories ($P > .05$). By

Table 2. Comparison of anxiety scores according to demographic characteristics

	STAI-S				STAI-T			
	T0		T1		T0		T1	
Variables	Mean ± SD	P	Mean ± SD	P	Mean ± SD	P	Mean ± SD	P
Female	38.82 ± 9.84	.007$^{\alpha*}$	36.02 ± 11.32	.562$^{\alpha}$	43.16 ± 9.10	.001$^{\alpha*}$	41.26 ± 9.93	.387$^{\alpha}$
Male	35.11 ± 9.93		34.96 ± 9.89		39.15 ± 8.58		39.86 ± 9.19	
Age, 12-18	36.85 ± 9.26	.048$^{\alpha*}$	34.26 ± 9.54	.023$^{\alpha*}$	40.97 ± 9.48	.013$^{\alpha*}$	39.62 ± 9.27	.030$^{\alpha,*}$
Age, 18-30	39.32 ± 10.88		38.10 ± 12.58		43.80 ± 8.32		42.90 ± 10.17	
Secondary school	35.13 ± 9.01	.102$^{\beta}$	31.69 ± 6.23	.071$^{\beta}$	40.34± 9.04	.176$^{\beta}$	39.00 ± 8.77	.571$^{\beta}$
High school	38.20 ± 10.13		36.81 ± 11.45		42.15 ± 9.29		41.17 ± 9.59	
University	39.53 ± 10.05		34.13 ± 11.15		44.25 ± 7.92		41.27 ± 11.61	

STAI-S, State-Trait Anxiety Inventory-State anxiety; STAI-T, State-Trait Anxiety Inventory-Trait anxiety; T0, 2020; T1, 2021; SD, standard deviation.
$^{\alpha}$Independent-samples t-test, $^{\beta}$ANOVA test, *$P < .05$.

Table 3. Changes in anxiety scores between two time points

	STAI-S						STAI-T					
	T0	T1		95% CI			T0	T1		95% CI		
	Mean ± SD	Mean ± SD	*d*	L	U	P^{α}	Mean ± SD	Mean ± SD	*d*	L	U	P^{α}
Total	37.83 ± 9.98	35.72 ± 10.92	0.33	0.13	4.09	0.037*	42.09 ± 9.12	40.86 ± 9.72	0.20	-0.56	3.01	.178
Female	38.82 ± 9.84	36.02 ± 11.32	0.48	0.45	5.15	.020*	43.16 ± 9.10	41.26 ± 9.93	0.32	-0.22	4.02	.079
Male	35.11 ± 9.93	34.96 ± 9.89	0.21	-3.47	3.78	.934	39.15 ± 8.58	39.86 ± 9.19	0.12	-3.93	2.52	.667
Age, 12-18	36.85 ± 9.26	34.26 ± 9.54	0.41	0.30	4.88	.026*	40.97 ± 9.48	39.62 ± 9.27	0.19	-0.95	3.64	.250
Age, 18-30	39.32 ± 10.88	38.10 ± 12.58	0.19	-2.34	4.77	.501	43.80 ± 8.32	42.90 ± 10.17	0.21	-1.88	3.70	.523
Secondary school	35.13 ± 9.01	31.69 ± 6.23	0.43	-0.53	7.41	.089	40.34± 9.04	39.00 ± 8.77	0.20	-3.03	5.72	.541
High school	38.20 ± 10.13	36.81 ± 11.45	0.22	-1.01	3.80	.256	42.15 ± 9.29	41.17 ± 9.59	0.15	-1.14	3.10	.364
University	39.53 ± 10.05	34.13 ± 11.15	0.86	-0.44	11.23	.070	44.25 ± 7.92	41.27 ± 11.61	1.49	-2.35	8.30	.267

STAI-S, State-Trait Anxiety Inventory-State anxiety; STAI-T, State-Trait Anxiety Inventory-Trait anxiety; T0, 2020; T1, 2021; SD, standard deviation, *d*, Cohen's effect size; L, lower; U, upper.
$^{\alpha}$Independent samples t-test. *$P < .05$.

contrast, no significant difference was found between the STAI-T scores at T0 and T1 (*P* > .05).

DISCUSSION

The present study evaluated the immediate clinical and long-term anxiety effects of COVID-19 on orthodontic patients over the 1-year follow-up period and the results indicated that although a significant reduction was observed in state anxiety, no significant change was found in trait anxiety. Accordingly, our null hypothesis was partially accepted.

Examining the pandemic conditions in the 2 time periods in 2020 and 2021, when the study was conducted, is of great importance for interpreting the long-term changes in patients. In early June 2020, when the first questionnaire was filled out by the patients, the nationwide measures, which had lasted for about 3 months and included lockdown, were relieved and gradual normalization measures were announced and then routine dental practices were resumed. On June 8, 2021, when the second questionnaire was filled out by patients, the decreasing trend in the number of confirmed COVID-19 cases and COVID-19-related deaths continued.[19,20] In one of our previous studies,[9] we shared the results of the questionnaire in detail for individuals aged 14 and over in a period when the pandemic remained uncertain in many respects. Subsequently, in 2021, a rapid vaccination program was initiated in many countries, leading to a glimmer of hope.[21]

The risk of COVID-19 transmission is relatively higher in closed areas such as in dental clinics and in situations where masks cannot be used such as dental procedures.[16,22] In the present study, we used STAI to investigate the feelings of orthodontic patients during the clinical visit, which is frequently visited, and to evaluate the long-term change in their feelings during the current unpredictable pandemic period.

In our study, STAI scores decreased significantly at T1 compared to T0. This finding could be explained by the decrease in the potential SARS-CoV-2 threat in the clinic among orthodontic patients in addition to the continuation of the precautions taken in the clinic, rapid vaccination of healthcare personnel beginning from early 2021, and rapid increase in the rate of mass vaccination in Turkey during the study period. On the other hand, mean STAI-S score was remarkably higher than the pre-pandemic STAI-S score reported by Yıldırım and Karacay (26.60 $\pm$ 4.47).[23] This finding indicates that patients have not yet returned to their immediate pre-pandemic psychological comfort. Additionally, continuing their orthodontic treatment during the pandemic period along with the high risk of infection and the risk of returning to strict measures that may hinder the treatment may also play a role in the immediate anxiety of the patients.

Numerous studies have indicated that natural, environmental, or traumatic disasters are associated with a wide range of mental and behavioral disorders and that mental health problems may persist for a long time.[24] In the present study, no significant improvement was observed in the STAI-T scores in the total population. However, longitudinal studies conducted on COVID-19 have reported conflicting results. Pieh et al.[15] reported that the mental health problems that emerged in the first month of lockdown in Austria remained mostly unchanged 6 months later, when there were no serious restrictions. In contrast, Daly and Robinson[25] showed a relatively rapid psychological adaptation to the COVID-19 pandemic in the United States. In our study, unlike in other studies, the primary factor that could affect long-term anxiety was the initiation and continuation of mass vaccination. However, it has been reported that the consequences of pandemics on mental health are related not only to the disease itself but also to economic losses or the problems caused by lockdown restrictions.[13] This relationship could be explained by rapid spread of the delta variant in the community and the high daily number of new reported COVID-19 cases as well as the fear of being infected and of inability to return to pre-pandemic daily life or the job loss and financial losses caused by the pandemic.[19]

In our study, STAI scores were significantly higher in women than in men at T0 and this difference disappeared at T1. This finding could be associated with the significant decrease in the STAI-S scores of women along with the absence of a significant change in men during the 1-year follow-up period. In a similar way to our study, studies that evaluated orthodontic patients in the first months of the pandemic emphasized that women had higher anxiety levels compared to men.[10,12] This finding could be explained by the nature of women's responses to stressors and risk factors or their lower quality of life during orthodontic treatment.[26,27] On the other hand, the response of women to the reduction of risk factors may have played a role in the significant decrease in their STAI-S scores during this period.

Our findings also showed that adult individuals (>18 years) had significantly higher STAI-S scores at both T0 and T1 than individuals under the age of 18. Moreover, although there was a significant decrease in the STAI-S scores of individuals aged under 18 years, there was no significant change in individuals aged over 18 years. In contrast, some of the studies conducted on individuals who received orthodontic treatment at the beginning of the pandemic reported no significant relationship between age and anxiety levels,[12] while some others reported a negative correlation between age and anxiety.[10,28] In a longitudinal study, Kwong et al.[29] showed that the sudden increase in anxiety in children in the early stages of lockdown was caused by mitigation measures such as lockdown and social distancing rather than the COVID-19 infection.[29] This finding could be explained by the fact that the nationwide lockdown measures had not been lifted in Turkey at T0 and they had been lifted at T1. It is also known that adult orthodontic patients have different psychological characteristics compared to children and adolescents.[30] On the other hand, the long-term anxiety scores in our study showed that the difference between age groups persisted at T1. This difference could be attributed to the economic hardships and uncertainties experienced by adults working full time and to the children's and adolescents' having less responsibility.

At both time points, no significant relationship was found between educational status and anxiety scores and also no significant change was observed in the anxiety scores at T0 and T1 with regard to educational status. This finding implicates that the educational status of individuals does not affect their anxiety scores during the COVID-19 pandemic, which is consistent with the findings of Hawryluck et al.[31] who evaluated the patients during the SARS-CoV-2 pandemic.

Our study was limited in several ways. First, there was no untreated control group in the same age group. The inclusion of such a group would be beneficial to determine the role of oral braces in the changes in long-term anxiety; however, to our knowledge, there has been no study measuring the anxiety of a population not receiving fixed orthodontic treatment in a similar population since the beginning of the pandemic. The second limitation, the included participants were not screened for background anxiety disorders.[32-35] The third limitation, as in other cross-sectional studies, was the evaluation of a particular population at specific time periods. The course of the COVID-19 pandemic varies considerably among countries, regions, and even cities and thus countries have developed different strategies to prevent the spread of the pandemic.[36] Access to vaccines, which are the beacons of hope for ending the pandemic, and the vaccination rates in countries and even in different regions of the same country can vary considerably.[37] Therefore, the changes observed in the anxiety levels of our orthodontic patients over the 1-year follow-up period may not be generalized to orthodontic patients in other countries or even in other regions and cities of Turkey. Accordingly, further studies are needed to investigate the long-term changes in larger sample sizes at different time intervals using different mental health scales.

CONCLUSION

It was observed that the state anxiety levels of orthodontic patients decreased during the 1-year period of the pandemic, while there was no significant change in their trait anxiety levels. It was also revealed that both state and trait anxiety scores of adults were higher than those of adolescents.

Ethics Committee Approval: Ethical committee approval was received from the Non-Interventional Clinical Research Ethics Committee of Adıyaman University (Approval No: 2021/06-13).

Informed Consent: Informed consent was obtained from each participant and/or parent/guardian.

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Original Article

Anterior Tooth Size Discrepancy in Class III Surgical Patients

Ezgi Sunal Aktürk[1], Özge Müftüoğlu[2], Tülin Ufuk Toygar Memikoğlu[3]

[1]Department of Orthodontics, Bezmialem Vakif University, Faculty of Dentistry, İstanbul, Turkey
[2]Department of Orthodontics, Ankara Medipol University, Faculty of Dentistry, Ankara, Turkey
[3]Department of Orthodontics, Ankara University, Faculty of Dentistry, Ankara, Turkey

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Main Points

- Clinically significant anterior tooth size discrepancies were determined in 40.7% of Class III surgical patients.
- No significant correlation was found between anterior Bolton ratios and dentoskeletal measurements.
- Tooth size discrepancy should be considered in the diagnosis and treatment planning of Class III orthognathic surgery patients.

ABSTRACT

Objective: The purpose of the present study was to specify whether there are mesiodistal tooth size discrepancies in the anterior region in patients with dentoskeletal Class III malocclusion who underwent orthognathic surgery and orthodontic treatment and to assess the relationship between anterior Bolton ratio and dentoskeletal cephalometric measurements.

Methods: The diagnostic dental casts and lateral cephalometric radiographs of 113 nongrowing patients (54 females and 59 males; mean age: 19.96 $\pm$ 4.42 years) with dentoskeletal Class III malocclusion who underwent orthognathic surgery and orthodontic treatment were included in the study. The mesiodistal widths of the 6 anterior teeth were measured from dental casts using a digital caliper accurate to 0.01 mm and anterior Bolton ratios were calculated. Lateral cephalograms were digitalized and used to measure 4 skeletal and 4 dental parameters.

Results: The mean anterior ratio of Class III surgical patients was 80.1% with a standard deviation of 2.8%. Clinically significant anterior tooth size discrepancies (greater than $\pm$2 standard deviation) were found in 40.7% of the sample, 97.8% of those patients having anterior mandibular tooth excess. No significant correlation was found between the anterior Bolton ratio and cephalometric measurements.

Conclusion: Clinicians should consider the probability of tooth size discrepancy in the diagnosis and treatment planning of Class III surgical patients and should perform interventions to eliminate these discrepancies during presurgical orthodontic treatment.

Keywords: Anterior ratio, tooth size discrepancy, Class III malocclusion, orthognathic surgery

INTRODUCTION

Treatment alternatives for nongrowing patients with skeletal Class III malocclusion are orthodontic camouflage treatment or orthognathic surgery. Appropriate treatment options are determined based on the severity of the malocclusion, the patient's chief complaint, cephalometric analysis, and clinical examinations.[1]

Conventional orthodontic surgical treatment of Class III dentofacial deformities includes presurgical orthodontics, followed by surgical correction and postsurgical orthodontics for detailing and finishing the occlusion.[2] The goals of presurgical orthodontics include decompensation of the incisors to their ideal positions (retroclining proclined maxillary incisors and proclining retroclined mandibular incisors), establishing correct torque, and

Corresponding author: Ezgi Sunal Aktürk, e-mail: sunalezgi@gmail.com

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eliminating tooth size discrepancies to ensure Class I canine and molar relationships after surgery.[3] Identifying tooth size imbalances at initial diagnosis and considering these in the treatment plan facilitates optimal occlusion and ideal interdigitation, overbite, and overjet at the finishing stage of treatment.[4]

Several studies have described the significance of an accurate tooth size ratio between both arches.[5,6] Bolton[7,8] analyzed 55 individuals with excellent occlusions and developed the most commonly used method to calculate the ratio between the mesiodistal width of the upper and lower teeth. According to his analysis, the ideal anterior ratio is 77.2% (standard deviation (SD) 1.65%) and the ideal overall ratio is 91.3% (SD 1.91%).

Numerous studies have evaluated tooth size discrepancies in different malocclusion types. Many of these studies indicated that tooth size discrepancies are more common in Class III malocclusions than in Class I and II.[9-12] Araujo and Souki[4] later reported that patients with Class I and Class III malocclusions indicate a significantly greater prevalence of tooth size discrepancies than those with Class II malocclusions, and mean anterior tooth size discrepancies were significantly greater for Class III subjects. In contrast, Uysal et al.[13] and Cançado et al.[14] found no differences in the anterior and overall Bolton ratios between different malocclusion types.

Although there are studies in the literature evaluating tooth size discrepancy in surgical patients,[15,16] to our knowledge, there are no studies that analyzed the relationship between Bolton ratios and dentoskeletal measurements.

The purpose of this study was (1) to determine whether patients with dentoskeletal Class III malocclusion who underwent orthognathic surgery and orthodontic treatment have any mesiodistal tooth size discrepancies in the anterior region that may influence aesthetics and occlusion and (2) to examine the relationship between anterior tooth size ratio and skeletal and dental cephalometric measurements.

METHODS

Ethical approval of this retrospective study was obtained from Bezmialem Vakif University Non-Invasive Ethics Committee (Approval number: 2021/136). One hundred thirteen patients (54 females and 59 males; mean age: 19.96 ± 4.42 years) with dentoskeletal Class III malocclusion who underwent orthognathic surgery and orthodontic treatment were included in the study. Diagnostic casts and lateral cephalometric radiographs of the individuals taken between January 2015 and December 2020 were obtained from the archives of Bezmialem Vakif University and Ankara University, Faculty of Dentistry, Department of Orthodontics.

Inclusion criteria were as follows:

- Nongrowing patients (Ru stage as determined by hand-wrist radiograph);
- Skeletal Class III malocclusion (ANB < 0);
- Anterior crossbite or incisor edge-to-edge relationship;
- Presence of all anterior teeth from canine to canine in both arches; and
- Good-quality study models.

Exclusion criteria were as follows:

- Presence of more than one missing posterior teeth (except third molars) of each quadrant;
- History of previous orthodontic treatment;
- Cleft lip and palate or any craniofacial syndromes; and
- History of procedures that affect tooth mesiodistal width (buildups, crowns, restorations, or enamel stripping).

The largest mesiodistal widths of the upper and lower 6 anterior teeth were measured using a digital caliper (Qingdao Tlead International Co., Ltd.,Qingdao, China) with an accuracy of 0.01 mm. All measurements were performed and recorded by the same examiner (E.S.A.). Anterior Bolton ratio was calculated using the following formula:

$$\text{Anterior ratio } (\%) = \frac{\text{Sum of mandibular } 13-23}{\text{Sum of maxillary } 33-43} \times 100.$$

Anterior Bolton ratios within ±1 SD of the mean (77.2% ± 1.65%) were classified as normal, ratios greater than ±1 SD and less than ±2 SD from the mean as tooth size discrepancy, and ratios greater than ±2 SD from the mean were described as clinically significant tooth size discrepancy.[8]

Cephalometric analysis was done using Dolphin Imaging Software (version 10.0, Chatsworth, Calif, USA) by the same examiner (O.M). Four skeletal (SNA°, SNB°, ANB°, and GoGn-SN°) and 4 dental (PPU1°, IMPA°, overjet (mm), and overbite (mm)) measures were recorded (Figure 1).

Statistical Analysis

Statistical analyses were performed with the Statistical Package for Social Sciences version 22.0 software (IBM Corp., Armonk, NY, USA). Statistical significance was established with a *P* value less than .05.

In order to determine measurement error, the diagnostic casts and cephalometric radiographs of 25 randomly selected subjects were remeasured by the same examiner after an interval of 2 weeks. The paired *t* test was performed to assess the difference between 2 measurements. The results indicated no significant difference between the first and second sets of measurements.

Shapiro–Wilk test was used to test the variables for normal distribution. The mean, SD, maximum, minimum values, and 95% confidence interval for mean were obtained for each variable. The independent *t* test was used to determine whether there were sex differences in the anterior ratio. The Pearson's correlation coefficient (for normally distributed variables) and the Spearman's correlation coefficient (for non-normally distributed variables) were used to analyze the correlation between dentoskeletal measurements and anterior ratio.

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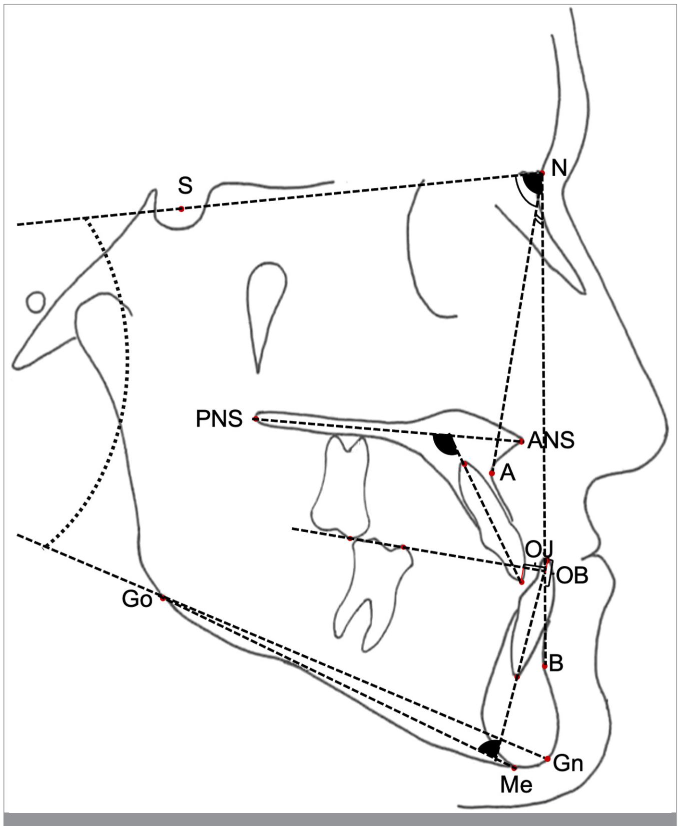

Figure 1. Skeletal and dental lateral cephalometric variables used in the study. SNA°, angle between anterior cranial base (Sella-Nasion) to the A point; SNB°, angle between anterior cranial base to the B point; ANB°, difference between SNB° and SNA°; GoGn-SN°, angle between mandibular plane (Go-Gn) to the anterior cranial base; PPU1°, angle between the upper incisor long axis and the palatal plane (ANS-PNS); IMPA°, angle between the mandibular incisor long axis and the mandibular plane (GoMe); Overjet (OJ), horizontal distance between upper and lower central incisors with reference to the occlusal plane; Overbite (OB), vertical distance between the incisal edges of the upper and lower central incisors.

RESULTS

The descriptive statistics of the subjects' ages and skeletal and dental measurements (mean, SD, minimum and maximum, and 95% confidence interval) are given in Table 1.

Descriptive statistics and comparison of sex differences in the anterior tooth size ratio were given in Table 2. The anterior ratios of males and females were combined because there were no significant sex differences ($P < 0.05$).

The distribution and descriptive statistics of anterior tooth size discrepancies according to Bolton norms are given in Figure 2 and Table 3. Anterior ratio was more than 1 SD above the mean in a total of 75 patients (63.9%) and more than 1 SD below the mean in 5 patients (4.4%). Clinically significant anterior tooth size discrepancies (greater than ±2 SD) were found in 40.7% of the sample (n = 46), 97.8% of those patients (n = 45) having anterior mandibular tooth excess (anterior ratio more than 2 SD above the mean). There was no significant correlation between the anterior Bolton ratio and cephalometric measurements (Table 4).

DISCUSSION

This study was based on observations that when presurgical dental casts of Class III orthognathic surgical patients were manipulated into positive overjet, the canines were in Class II relationship in most cases, leading us to wonder about the prevalence of tooth size discrepancies in these patients. We evaluated anterior tooth size discrepancies due to the fact that most patients were missing posterior teeth and differences in anterior tooth size, in particular, could affect treatment stability and the finishing quality of orthodontic treatment.[4,17]

The study included young adults with a mean age of 19.91 ± 4.16 years. In order to investigate the correlation between dentoskeletal measurements and Bolton anterior ratio, we analyzed only nongrowing skeletal and dental Class III individuals. In this study, sex difference has been found to have no significant effect on the anterior ratio. Although there are contradictory results reported in the literature, our results are in harmony with the findings of many previous studies.[4,13,18]

Individuals with Class III malocclusion treated with orthognathic surgery and orthodontic treatment had a mean anterior Bolton ratio of 80.09% (SD 2.84%). Anterior discrepancies of ±1 SD were

Table 1. Descriptive statistics (Mean, SD, Minimum, Maximum, and 95% CI) of cephalometric measurements

	n	Mean	SD	Minimum	Maximum	95% CI	
						Lower	Upper
Age (years)	113	19.91	4.16	15.83	31		
SNA (°)	113	78.54	3.84	70.50	87.40	77.76	79.23
SNB (°)	113	82.90	4.04	72.00	93.10	82.09	83.73
ANB (°)	113	−4.40	2.66	−11.60	−0.30	−4.90	−3.90
GoGnSN (°)	113	34.07	6.39	17.70	48.00	32.88	35.26
IMPA (°)	113	79.83	7.27	61.60	105.00	78.48	81.19
PPU1 (°)	113	115.94	6.63	94.00	129.90	111.33	117.05
Overjet (mm)	113	−3.14	2.42	−11.00	0.00	−3.58	−2.67
Overbite (mm)	113	−0.08	2.57	−8.20	7.90	−0.58	0.40

SD, standard deviation.

Table 2. Descriptive statistics and comparison of sex differences in the anterior tooth size ratio

		Female (n = 54)	Male (n = 59)	*P*
Mean		80.35	79.86	.358
SD		2.90	2.78	
Minimum		73.96	73.34	
Maximum		89.42	86.26	
95% CI	Lower	79.56	79.13	
	Upper	81.14	80.58	

SD, standard deviation.

present in 68.3% and clinically significant anterior discrepancy (>±2 SD) was present in 40.7% of the patients. It is noteworthy that the majority of discrepancies were caused by mandibular tooth excess.

Sperry et al.[11] showed that tooth size excess in the mandibular arch was more frequent among Class III patients with mandibular prognathism than in Class I and Class II groups. Strujić et al.[12] evaluated Bolton ratios for groups including both dentoskeletal Class I, II, and III cases. They reported that subjects with Class II malocclusion tend to have maxillary tooth size excess, while those with Class III malocclusion tend to have mandibular tooth size excess. Similarly, Lavelle[9] and Nie and Lin[10] reported that among different malocclusion groups, the mesiodistal dimensions of lower teeth were larger and those of the upper teeth were smaller in Class III subjects.

Fattahi et al.[19] compared Bolton discrepancies in 4 different malocclusion groups categorized using Angle's classification with corresponding skeletal relationships. It was reported that all ratios except the anterior ratios were significantly greater in the individuals with Class III malocclusion than in the others. While the Bolton ratio in the anterior region was greater in the Class III group compared to the Class II division 1 and division 2 groups, no significant difference was found when compared with the Class I group.

Similarly, Uysal et al.[13] compared the overall and anterior tooth size ratios of different malocclusion groups with those of untreated individuals with normal occlusion. Although no significant difference in both ratios was found between the malocclusion groups, they reported that the overall ratio was statistically significantly higher in all malocclusion groups compared to the normal occlusion group. The anterior ratio was 78.83 ± 3.46 in the Class III malocclusion group, and no significant difference was observed between the normal occlusion group. Although the present study was conducted in individuals with the same ethnic background as those studied by Uysal et al.[13] their relatively higher anterior ratio in our study may be due to the fact that the Class III patients in our study had more severe skeletal deficiencies to correct with orthognathic surgery. Similarly, McSwiney et al.[16] reported that the prevalence of clinically significant tooth size discrepancy was higher in the surgical patients compared to the non-surgical patients with Class III malocclusion.

Sassouni[20] was the first to notice that patients with Class III dentofacial deformities and retrognathic maxilla demonstrated a higher incidence of shape variation and agenesis in the anterior teeth. Fattahi et al.[19] reported that mandibular prognathism may be an etiological factor in the greater mesiodistal width of the lower teeth in individuals with Class III malocclusion compared to other malocclusion groups. The authors also stated that further studies are needed to clarify this theory. The relationship between anterior ratio and selected skeletal parameters was analyzed to check whether there was a correlation between them in the present study. Although no significant correlations were detected, we found that a substantial proportion of Class III orthognathic surgery patients (a total of 39.8% of the patients) who had tooth size discrepancy in the anterior region greater

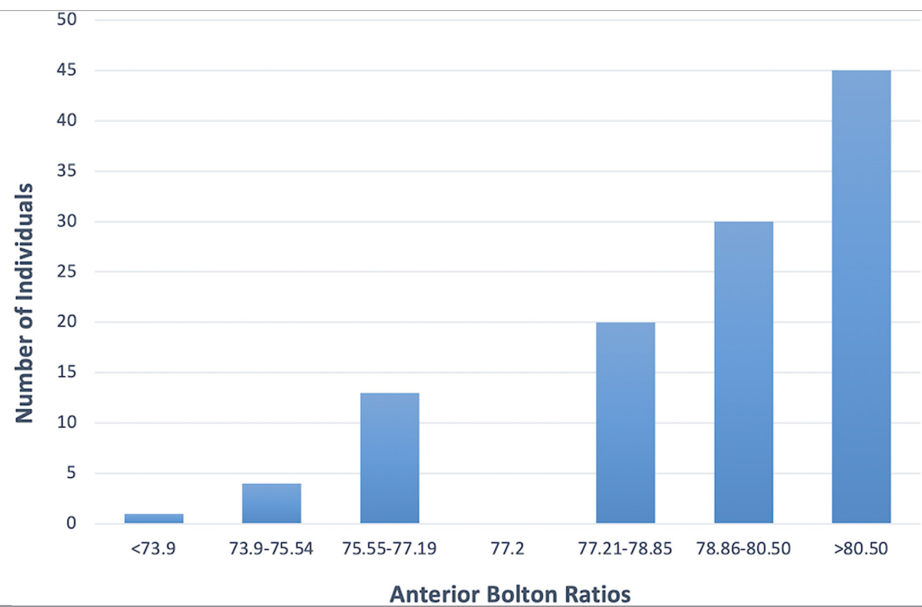

Figure 2. Distribution of patients' anterior tooth size ratios categorized by the standard deviations of Bolton norms.

Table 3. Percentage of subjects and descriptive statistics of anterior tooth size discrepancy according to Bolton norms

	n	%	Mean	SD	Minimum	Maximum	95% CI Lower	95% CI Upper
<2 SD	1	0.9	73.34	-	-	-	-	-
−2 SD to 1 SD	4	3.5	75.02	0.70	73.96	75.41	73.89	76.14
−1 SD to mean	13	11.5	76.52	0.40	75.85	77.19	75.83	76.23
Mean to 1 SD	20	17.7	78.14	0.49	77.22	78.82	77.20	77.47
1 SD to 2 SD	30	26.5	79.74	0.47	78.86	80.50	78.75	79.16
>2 SD	45	39.8	82.83	1.87	80.57	89.42	80.47	80.93
Total	113	100	80.09	2.84	73.34	89.42	79.56	80.62

SD, standard deviation.

Table 4. Correlations between anterior Bolton discrepancy and skeletal and dental measurements

		SNA (°)	SNB (°)	ANB (°)	GoGnSN (°)	IMPA (°)	PPU1 (°)	Overjet (mm)	Overbite (mm)
Anterior Bolton discrepancy (%)	*r*	−0.046[a]	0.032[b]	−0.089[b]	−0.081[a]	−0.013[b]	−0.077[a]	−0.051[a]	0.124[a]
	P	.629	.736	.348	.391	.891	.420	.591	.189

r, correlation coefficient.
[a]Pearson's correlation coefficient; [b]Spearman's correlation coefficient.

than 2 SD above the mean, which indicates clinically significant mandibular tooth size excess.

The findings of our study indicate that tooth size discrepancy should be considered in the diagnosis and treatment planning of Class III orthognathic surgery patients. Tooth size discrepancies between the upper and lower teeth in the anterior region can prevent achieving ideal occlusion with satisfactory interdigitation and intercuspation of the teeth and a correct overbite and overjet. These discrepancies not only adversely affect the quality of orthodontic treatment but also impact treatment stability, leading to relapse during the retention period (post-treatment crowding).[4,21]

During presurgical orthodontic treatment, reduction of tooth excess by interproximal stripping or extraction or creating space for the addition of tooth tissue by restorations should be performed to eliminate tooth size discrepancies. In addition, changes in incisors inclination and angulation can be performed to manage tooth size discrepancy. Tuverson[22] reported that diastemas in the upper anterior region can be compensated by adding distal root tip and palatal root torque to the maxillary incisors. Besides, Bolton[8] indicated that the inclinations of the incisors and their labiolingual thickness could affect the anterior tooth size discrepancy. In light of this information, whether there is a relationship between incisor inclinations and anterior tooth size discrepancy in patients with dentoskeletal Class III malocclusion was the subject of interest in the present study. However, no correlation was observed between incisor inclinations (IMPA°, U1-PP°) and anterior ratio. Lack of correlation between anterior ratio and incisor inclination might be explained by the fact that patients had skeletal discrepancies in addition to the dental malocclusion. Moreover, the fact that dental compensation did not occur as expected in all the patients and that the incisors' inclinations showed a wide standard deviation may also explain the lack of correlation.

As mentioned above, anterior tooth size discrepancy can negatively affect the relationship between overjet and overbite in an ideal occlusion.[4,21] In the presence of dentoskeletal Class III malocclusion, overjet and overbite showed no correlation with the anterior ratio. In the present study, individuals were classified only according to the sagittal pattern. The fact that patients with different vertical patterns were included and that the expected dental compensation was not observed in all patients may explain the lack of correlation. Apart from tooth size discrepancy, many dental and skeletal parameters can also affect the overjet and overbite (incisor inclination, vertical patterns, etc.).[23,24]

The main limitation of the current study is that Bolton discrepancy was evaluated only in the anterior region. It would be beneficial to carry out further studies with more Class III surgical patients who do not have missing teeth from the first molar to the first molar in order to evaluate the overall ratio.

CONCLUSION

Based on the findings of the present study:

- Clinically significant anterior tooth size discrepancies were found in 40.7% of the sample.
- No significant correlation was found between anterior Bolton ratios and dentoskeletal measurements.

Ethics Committee Approval: Ethics committee approval was received for this study from the Non-Invasive Ethics Committee of Bezmialem Vakif University (Approval number: 2021/136).

Informed Consent: The study was retrospective, so (in accordance with the ethical approval) no written informed consent was obtained.

Peer-review: Externally peer-reviewed.

Author Contributions: Concept - E.S.A.; Design - E.S.A.; Supervision - T.U.T.M.; Materials - Ö.M.; Data Collection and/or Processing - E.S.A., Ö.M.; Analysis and/or Interpretation - E.S.A., Ö.M.; Literature Review - E.S.A., Ö.M., T.U.T.M.; Writing - E.S.A.; Critical Review - Ö.M., T.U.T.M.

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Original Article

An assessment of the Quality of Information for Patients on YouTube™ Regarding Orthodontic Elastics

Tuğba Haliloğlu Özkan[1], Derya Dursun[2]

[1]Department of Oral and Dental Health Program, Üsküdar University, Vocational School of Health Services, İstanbul, Turkey
[2]Department of Orthodontics, University of Health Sciences, Faculty of Dentistry, İstanbul, Turkey

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Main Points

- Patients mainly refer to YouTube™, which is currently the second most visited video-sharing platform, to obtain information about orthodontic elastics (OEs).
- YouTube™ is a poor source of information concerning OE for patients.
- Clinicians should create their own YouTube™ accounts and refer their patients to these videos in order to provide high-quality information regarding OEs.

ABSTRACT

Objective: The study aimed to investigate the quality of the information available to patients on YouTube™ concerning orthodontic elastics.

Methods: A systematic search was carried out on YouTube™ using the keyword "elastics." The first 120 videos were viewed by 2 independent reviewers, and after the inclusion criteria were applied, 39 videos were excluded from the study. Demographic data of the videos were collected for the remaining 81 videos. For each video, its purpose, target audience, and source were also recorded. A 10-point content scale was used to evaluate the video content. The Global Quality Scale was also used to determine the quality of the videos. Statistical analyses were performed using the Kruskal–Wallis and Mann–Whitney *U* tests, and correlation coefficient analyses were performed using Spearman's rho.

Results: In total, 36% of the included videos were uploaded by dentists and 22% by laypersons. In 77% of the videos, the purpose was to inform laypersons, and in 4%, the purpose was to inform professionals only. The content discussed the most (85.2%) was the instruction of orthodontic elastics use. The mean 10-point Content Scale score and Global Quality Scale score of the videos were 2.25 ± 1.99 (poor) and 2.60 ± 0.73 (moderate), respectively. There was a positive correlation between 10-point Content Scale and Global Quality Scale score ($r = 0.258$).

Conclusion: The information available on YouTube™ regarding orthodontic elastics is quite poor and can be misleading for patients. Therefore, health professionals with evidence-based knowledge and clinical experience should improve the way they use YouTube™ to inform patients about the correct use of orthodontic elastics and to improve compliance with wearing orthodontic elastics.

Keywords: Dentistry, internet, orthodontic elastics, orthodontics, YouTube™

INTRODUCTION

Orthodontic elastics (OE)/rubber bands were first discussed by Calvin S. Case in 1893 at the Columbia Dental Congress and have been routinely used as an active component of fixed orthodontic therapy ever since. Orthodontic elastics are one of the most versatile materials available to the orthodontist. Correct use of OEs combined with cooperative patients allows orthodontists to improve both anteroposterior and vertical discrepancies.[1] While technology has developed significantly and clear aligner treatments are gradually becoming more widespread in orthodontic practice, currently, it is difficult to imagine orthodontic treatment without OEs.

Corresponding author: Tuğba Haliloğlu Özkan, e-mail: dttuuba@gmail.com

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Orthodontic elastics can be applied in various ways regarding the direction of force applied to the teeth to be moved. Therefore, patients must cooperate to ensure regular and correct usage, which directly affects the success of the treatment. Clinicians may choose to apply a number of methods, such as patient education, verbal praise, positive and negative reinforcement, use of charts and rewards in order to ensure patient compliance in the use of OEs.[2] In addition, it seems obvious that recommending reliable videos previously identified by the clinician would facilitate the patient's perception of treatment due to their visual content.[3] Therefore, video-sharing platforms such as YouTube™ are becoming more prominent as they provide health-related information which can be easily accessed by the public. On average, 100 h of video are uploaded to YouTube™ every minute, and each user spends at least 15 min per day watching videos on this platform worldwide.[4] A key consideration of YouTube™ is that it is a source of user-generated content, and due to the uncontrolled nature of the platform, many videos can unfortunately misinform the viewer.[5] Such misinformation may affect patients' communication with their dentists and disrupt the cooperation with the treatment.

It is apparent that using social media to access health-related information will probably become even more significant in the future; thus, studies regarding the quality of video content and other shared visual information have become more crucial.[6] As the volume of information patients find on the internet to make decisions about their health gradually increases, it becomes more critical for healthcare professionals to examine the information patients have been accessing. It is for this reason that several studies have been conducted to evaluate the quality of dentistry-related information (clear aligners, rapid palatal expansion, orthognathic surgery, accelerated orthodontics, impacted canines, root canal treatment, dental implants, early childhood caries, fluoride therapy, obstructive sleep apnea, genioplasty) on YouTube™.[3,6-16] The majority of these studies evaluating the content in YouTube™ videos demonstrated that this tool is not an adequate source from which patients might obtain reliable information.[6-11] In terms of OEs, this issue may lead to incorrect use and, therefore, may adversely affect the success of the treatment.

To our knowledge, there have been no studies investigating the quality of OE-related information on YouTube™ to date. Considering the significant role of OEs in orthodontic practice, the aim of this study was to evaluate videos dealing with OEs on YouTube™ in terms of characteristics, content, and quality of the information.

METHODS

Search strategy

There was no requirement for this study to obtain the ethical approval of the Institutional Review Board due to its publicly available nature. The Google Trends application was used to determine the most used search terms regarding "orthodontic elastics" [Google Trends 2020]. Possible related keywords such as "orthodontic rubber bands," "orthodontic tires," and "intraoral elastics" were also tried in the application, but "orthodontic elastics" was found as the search term most frequently used by patients. The search parameters were set as the "past 5 years," "Worldwide," and "YouTube™ Search." A YouTube™ search was systematically conducted on December 23, 2020, using the keyword "orthodontic elastics." In a recent study, it was noted that 95% of people only viewed the first 3 pages, corresponding to 60 videos of an online search, and looked no further than this.[17] The majority of previous YouTube™ studies used this research method by Desai et al.[17] Similarly, in the current study, the first 120 videos corresponding to the first 6 pages were sorted in order of relevance (a default option on YouTube™ which uses a complex algorithm based on view count, upload date, rating, comments, bookmarks, age of user, etc.) and were stored in the "Watch later" list in a specially created account to avoid duplications. All videos were examined by 2 independent researchers (T.H.Ö and D.D.) who had experience in the management of orthodontic treatment. The exclusion criteria for videos were as follows: (1) presentation in a language other than English, (2) having poor visual or audio quality, (3) exceeding 15 min in duration, (4) including duplicate parts, and (5) focusing on an unrelated topic (Figure 1). The uniform resource locators and titles of all the videos meeting the inclusion criteria were saved in a document to compare the results of the 2 researchers.

Data extraction

The following descriptive characteristics of each video were recorded: number of views, likes, dislikes, comments, video length (in minutes), and days since upload. The upload sources were classified as (1) dentist/orthodontists, (2) commercials, (3) health institutions, and (4) laypersons; the target audiences were classified as (1) laypersons, (2) professionals, and (3) both; and the purposes of the videos were classified as (1) patient information, (2) patient experiences, (3) product introductions, and (4) education. All videos were classified and recorded according to these categories. Since there is currently no tool available that can assess the quality of online information regarding OE, a novel 10-point content scoring system was used for this study. Each item on the checklist was given 1 point, with a maximum

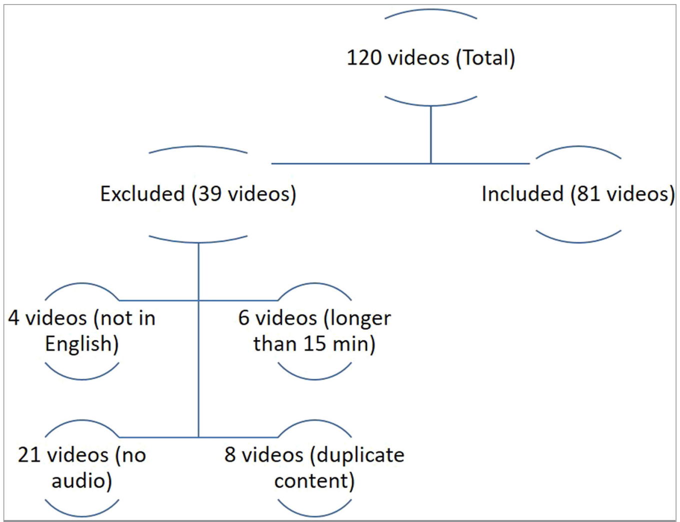

Figure 1. Flowchart diagram for the selection process of videos

Table 1. GQS criteria proposed by Bernard et al.[18]

GQS Definition	GQS Score
Poor quality, poor flow of the video, most information missing, not at all useful for patients	1
Generally poor quality and poor flow, some information listed but many important topics missing, of very limited use to patients	2
Moderate quality, suboptimal flow, some important information is adequately discussed but others poorly discussed, somewhat useful for patients	3
Good quality and generally good flow, most of the relevant information is listed but some topics not covered, useful for patients	4
Excellent quality and flow, very useful for patients	5

of 10 points for each video. Based on the sum of the points, the videos were scored as having poor content (score 0-3), moderate content (score 4-7), or rich content (score 8-10). Additionally, the quality of videos was classified using Global Quality Scale (GQS) according to the criteria proposed by Bernard et al.[18] as in Table 1.

Data Analysis

The Statistical Package for the Social Sciences for Windows version 15.0 (SPSS Inc., Chicago, Ill, USA) was used for statistical analyses. A total of 20 videos were randomly extracted to calculate the interobserver agreement using Cohen's kappa. Descriptive statistics (mean, standard deviation, median, frequency, and percentage) were calculated to examine the data. The Shapiro–Wilk test was used to approximate the normality of the quantitative data. The Kruskal–Wallis test for intergroup comparisons and the Mann–Whitney *U* test for 2-group comparisons were used for non-normally distributed variables. A *P* value of less than .05 was considered significant. Spearman's test was used to evaluate the correlation between scores.

RESULTS

A total of 120 videos were reviewed for the keyword "orthodontic elastics," of which 39 videos were excluded due to the following reasons: 4 videos were not in English, 6 videos were longer than 15 min, 21 videos did not have audio, and 8 videos included duplicate content. The videos were uploaded between September 2010 and October 2020.

All video demographics, including the mean number of views, likes, dislikes of the videos, and days since upload are presented in Table 2. The mean number of views for all the videos was 498 848.05, with a variation between videos ranging from 187 to 7 441 177 views. The overall mean of number of "likes" was 3071.91 (ranging from 0 to 77 000), while the overall mean of number of "dislikes" was 183.26 (ranging from 0 to 2500). The mean number of comments was 366.79 (ranging from 0 to 5775), and the mean video length was 3:84 min (ranging from 0:25 to 13:45). Finally, the mean value of the days since upload was 1091.01 days (ranging from 60 to 3557 days). Other video characteristics including video source, target audience, and video purpose are summarized in Table 3.

In total, 85% of the videos presented clear instructions of the use of OE, 31% a correct definition of OE, 24% removability of OE, and 17% pain caused by OE. Only 15% of the videos mentioned the effect of OE on speech and 7.4% the psychological

Table 2. Descriptive statistics for included videos

Video Characteristics	Minimum	Maximum	Mean	SD
Views	187	7,441.177	498,848.05	1,430,273.9
Likes	0	77.000	3.071.91	223.00
Dislikes	0	2.500	183.26	15.00
Comments	0	5.775	366.79	1,049.713
Length	0:25	13:45	3:84	2.85
Days since upload	60	3.557	1,091.01	945.067
CS	0	10	2.2593	1.99861
GQS	1	5	2.6049	.73619

GQS, Global Quality Scale; CS, content score; SD, standard deviation

effect of OE (Figure 2), and 36% of all videos were uploaded by a dentist/orthodontist, 31% by a health institution, and 27% by a layperson. While the purpose of 95% of the videos was to inform laypersons, only 10% of the videos were intended for professionals. The purpose of 62% of the videos was to share patient information, 27% to share patient experience, 6% to provide a product introduction, and 4% to educate. The majority of GQS scores were classified as "moderate" (40%), followed by "generally poor" at 33%. The number of likes were significantly higher in videos targeting laypersons than those targeting professionals ($P < .05$). The number of comments were also higher in videos uploaded by laypersons than those uploaded by dental professionals ($P < .05$). Videos uploaded by laypersons had significantly longer video duration than those uploaded by dentists ($P < .05$). Videos with a purpose of patient experience had significantly longer video duration than those with other purposes ($P < .05$). The number of views were significantly higher in videos targeting both laypersons and professionals than those targeting only one of these groups ($P < .05$), (Table 4).

The Cohen's kappa coefficient was 0.76, indicating an admissible degree of similarity between the scores. The mean content score and GQS scores of the videos were 2.25 $\pm$ 1.99 (poor) and 2.60 $\pm$ 0.73 (moderate), respectively (Table 2). There was a positive correlation between the total CS score and GQS score ($r = 0.258$). The majority of the videos (86.4%) were classified as having "poor content," 9% as having "moderate content," and 5% as having "rich content" in terms of the CS score. There were no statistical differences in terms of demographic data between the 3 content groups. A total of 84.5% of the videos targeting laypersons were in the poor content group. Most of the videos informing patients

Table 3. Video demographics according to source, purpose, and target of videos

Video Demographics	Poor Content (n = 70) (86.4%)	Moderate Content (n = 7) (8.6%)	Rich Content (n = 4) (4.9%)	Total
Source of video				
Dentist/orthodontist	26 (89.7%)	3 (10.3%)	0 (0)	29
Commercial	5 (100%)	0 (0)	0 (0)	5
Health institution	23 (92%)	1 (4%)	1 (4%)	25
Layperson	16 (72.7%)	3 (13.6%)	3 (13.6%)	22
Purpose of video				
Patient information	46 (92%)	4 (8%)	0 (0)	50
Patient experience	16 (72.7%)	3 (13.6%)	3 (13.6%)	22
Product introduction	4 (80%)	0 (0)	1 (20%)	5
Education	4 (100%)	0 (0)	0 (0)	4
Target of video				
Layperson	60 (84.5%)	7 (9.9%)	4 (100%)	71
Professional	4 (100%)	0 (0)	0 (0)	4
Both	6 (100%)	0 (0)	0 (0)	6

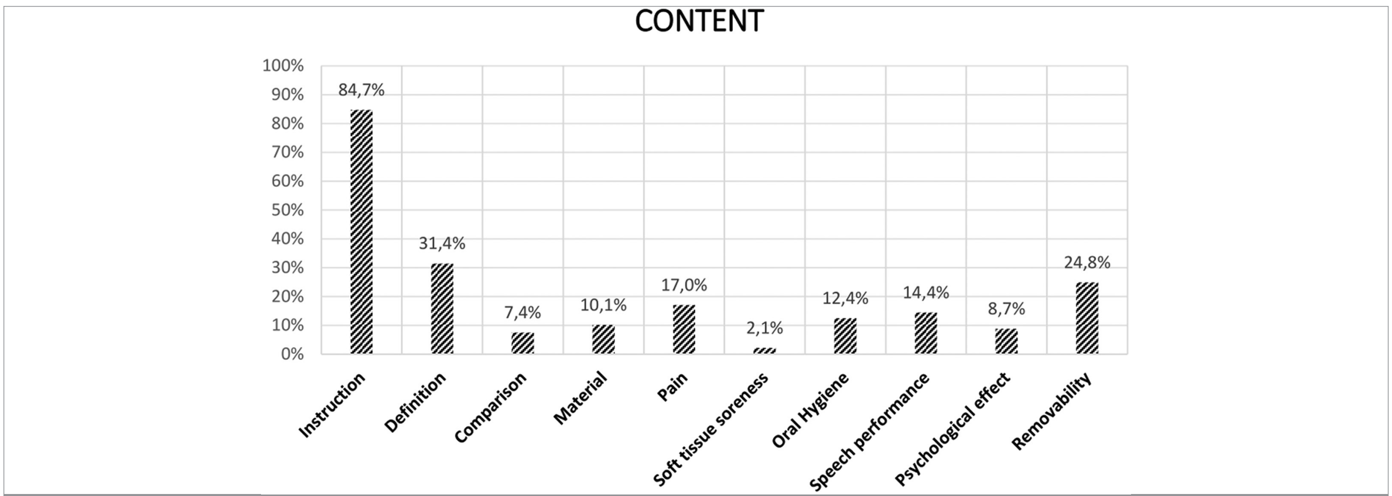

Figure 2. Percentage of each content type regarding orthodontic elastics

were uploaded by dentists/orthodontists (46%) and health institutions (48%). A total of 30% of videos targeting laypersons were uploaded by dentists/orthodontists, 34% by health institutions, and 31% by laypersons.

DISCUSSION

Millions of people use the internet as the shortest way to access information on a global level today. Since orthodontics is a field where numerous visual and complex instructions are given to the patient, it seems that patients are likely to search for more information on the internet. Patients are mostly curious about the timings of the use of OE and the effect of OE in terms of pain, eating, speech, and so on.[19] For these reasons, they mostly use YouTube™ as a social platform that provides rich visual content and easy access instead of scientific platforms where it can be harder to access information. Although this website is the second most visited video-sharing platform today, much of the information can be misleading as it is not peer reviewed. Two independent reviewers evaluated all the videos. The researchers agreed on a new score by consensus in cases where there was an inconsistency in scores. We created a content scale considering the major concerns of patients regarding OE. As expected, most of the videos included instructions on the usage of OE. In a study, the authors reported that patients were mostly concerned about the effect of OE in terms of pain that might be experienced and social status.[8] However, in the current study, only 17% of videos included content related to the pain associated with OEs and only a few videos were found that covered the psychological effects. Moreover, the effects of OE on speech, oral hygiene, and soft tissue soreness were under-represented topics in the videos. In terms of those questions most asked by patients such as alternatives (comparison content) of OEs, their effect on treatment duration, and the material from which they are made, YouTube™ seems a poor source of information. Even though 74% of videos were uploaded by dental professionals and 65% of videos

Table 4. Mean values of the descriptive characteristics and statistical analysis of the data

	Views	P	Likes	P	Dislikes	P	Comments	P	Days Since Upload	P	Duration	P
Source												
Dentist/ orthodontist	176,523.45	.267	1395.72	.061	48.28	.051	225.86[a]	.024	1021.66	.800	232.93[b]	.000
Layperson	696,615.32		6240.82		332.86		599.68[a]		981.14		385.36[b]	
Commercial	1,558,009.40		2812.20		488.40		1034.40		1639.40		72.80	
Health instution	486,877.12		2279.60		147.16		191.80		1158. .48		128.48	
Purpose												
Patient information	295,837.74	.085	1941.12	.209	93.60	.081	214.82	.070	1032.40	.698	161.78[c]	.000
Patient experience	806,725.41		5581.73		316.64		620,32		1014.09		397.95[c,d,e]	
Product introduction	469,783.40		1664.60		123.80		141.00		1667.40		255.80[d]	
Education	1,379,482.25		5162.00		644.75		1154.25		1526.25		171.50[e]	
Target												
Layperson	429,600.20[f]	.014	2794.61[h]	.037	165.39	.081	378.04	.083	967.65	.069	226.06	.490
Professional	101,441.75[g]		512.00[h]		30.50		58.50		1359.50		257.50	
Both	1,583,218.50[f,g]		8060.00		496.50		439.17		2371.83		288.17	

Same superscripts indicate a statistical significance.

targeting laypersons were also uploaded by these professionals, most of the content of these videos was classified as being "poor" quality, indicating the deficiencies in these videos.

Although the content scores and GQS scores presented a positive correlation, the GQS scores were higher. This can be explained by the fact that the videos flow well despite their poor content. Similarly, Lena et al.[19] and Ustdal et al.[16] stated a moderate correlation between GQS and CS in their YouTube™ studies evaluating lingual orthodontics and accelerated orthodontics, respectively. Surprisingly, all "rich" content videos had been uploaded by laypersons. This may be because people like to share their experiences in detail on their personal blogs, especially including content on removability, pain, psychological effects, speech performance, and oral hygiene. Nevertheless, there was 1 video shared by an adolescent who believes it is possible to close his maxillary median diastema with OEs at home on his own, without referring to the risks involved in attempting this action. This means that videos uploaded by laypersons are always at risk of including misleading information. Therefore, the content of the videos uploaded by dental professionals should be improved to better inform those patients who want to find out more about OEs.

The video content was found poor in several previous dentistry-related YouTube™ studies.[6-16] However, Yavuz et al.[3] reported good content in videos concerning accelerated orthodontics and they attributed this to the fact that the majority of the videos they analyzed were uploaded by professionals. In contrast, previous YouTube™ studies demonstrated that the majority of analyzed videos were uploaded by laypersons rather than dentists or academicians.[6,9,16] The majority of videos targeting laypersons were in poor content group. These videos, most of which were shared by dental professionals in our study, once again showed how important it is to examine the available information to patients on YouTube™. In addition, the quality of the videos evaluated in this study was found to be moderate, as in similar studies.[3,16,21]

Viewers can interact with uploaders by commenting or liking/disliking their videos.[11] Considering that the videos uploaded by laypersons had a significantly higher number of comments than the videos uploaded by professionals, it is disappointing that users preferred to interact with laypersons than professionals in order to obtain information regarding OEs. In addition, the duration of videos uploaded by professionals was found significantly shorter than videos uploaded by laypersons. The quality of videos on YouTube™ should be improved by professionals via extending the duration and detailing the accurate content. As expected, the videos targeting both laypersons and professionals were viewed more than videos targeting only one of these groups.

The current research has several limitations. First, as YouTube™ is a dynamic site, the results might vary due to the monitoring date of the videos. However, since "orthodontic elastics" is not a constantly changing and developing subject, this limitation may not have critically affected the study results. Second, laypersons may try searching for different keywords to find information concerning OEs. To limit the impact of this issue, the most searched term in Google Trends application was used for this research. Third, only videos in English were analyzed. Fortunately, the majority of videos were already in the English language (n = 116). In the current study, videos longer than 15 min were excluded. It has been reported that the audience will lose interest with the prolongation of video duration on YouTube™.[20] Previous studies also demonstrated that short videos were viewed more on internet.[9,22] However, only 6 videos were excluded in this study due to this reason.

In this study, the content of YouTube™ videos regarding OEs for patients was found to be of moderate and poor quality. Clinicians should create their own YouTube™ accounts and refer their patients to these videos in order to avoid the spread of misinformation and achieve more successful treatment results. Dental professionals should also warn their patients about any online platforms where they may encounter misleading and inaccurate information.

CONCLUSION

The content of the majority of YouTube™ videos regarding OEs for patients was found to be poor quality. In the light of these results, health professionals with evidence-based knowledge and clinical experience should improve the way they use YouTube™ to inform patients about the correct use of OEs and to improve compliance with wearing OEs.

Ethics Committee Approval: As the study does not deal with humans or any material previously collected from humans, no ethical approval was taken.

Informed Consent: As the study does not deal with humans or any material previously collected from humans, no informed consent was taken.

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Original Article

Cephalometric Mandibular Dimensions in Growing Turkish Children: Trends of Change, Sex-Specific Differences, and Comparisons with Published Norms

Hande Pamukçu[1], Nilüfer İrem Tunçer[1], İsmail Can Pelin[2], Hatice Yağmur Zengin[3]

[1]Department of Orthodontics, Başkent University, Faculty of Dentistry, Ankara, Turkey
[2]Department of Anatomy, Başkent University, School of Medicine, Ankara, Turkey
[3]Department of Biostatistics, Hacettepe University, School of Medicine, Ankara, Turkey

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Main Points

- Girls show significant increase for effective mandibular length between ages 8-10, 10-12 and 11-13 years, while boys between ages 8-10, 9-11 and 13-15 years. This finding not only demonstrates that boys and girls have distinctive timing for growth spurt but also both sexes manifest not one but more growth spurts.
- Ethnic differences and secular trends result with a continuous change in mandibular dimensions; therefore, using recent norms representative of the studied population is advised.
- The growth curves obtained in this study can be used to designate a patient as early-, average- or late-maturer, as well as to predict the approximate mandibular dimensions at a particular age.

ABSTRACT

Objective: The aims of this study were to investigate cephalometric mandibular dimensions in growing Anatolian Turkish children and to identify the periods of rapid growth for boys and girls. Furthermore, the secondary aim was to compare obtained values with published standards in the literature.

Methods: A total of 528 pretreatment lateral cephalometric radiographs, grouped according to age and sex, were analyzed. Effective mandibular length, ramus height, and corpus lengths were comparatively evaluated within age groups for boys and girls and between sexes for the same age group. Data acquired from this study were compared with American, Canadian, Chinese, and European norms. Growth curves for mandible were constructed for each sex group.

Results: Effective mandibular length was almost always significantly longer in boys, except for 9- and 12-year-age groups. Effective mandibular length in girls increased significantly between ages 8 and 10, 10 and 12, and 11 and 13 years, while in boys between ages 8 and 10, 9 and 11, and 13 and 15 years. Turkish girls had significantly shorter effective mandibular lengths than American girls at age 14. No significant difference was found between Turkish and Chinese girls and boys. Turkish girls and boys had significantly shorter corpus lengths from their Norwegian counterparts at age 12.

Conclusion: Except for 9- and 12-year-age groups, effective mandibular length was almost always significantly longer in boys compared to the girls. It is suggested to use norm values from more recently conducted studies and which are representative of the studied population. Growth curves can be used to predict the approximate mandibular dimensions at a particular age.

Keywords: Corpus length, mandibular dimensions, mandibular length, ramus height, Turkish children

INTRODUCTION

Among the bones of the craniofacial region, mandible has a unique development pattern and a growth rate which changes over the development period.[1] The success of orthopedic treatment modalities for skeletal Class II discrepancies characterized with retrognathic mandible depends on accurate estimation of the most rapid growth period. Therefore, it is clear that diagnosis, treatment planning, and prognosis of mandibular

Corresponding author: Nilüfer İrem Tunçer, e-mail: iremtuncher@gmail.com

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growth disorders depend on clinician's knowledge of mandibular growth and development.

During its growth, the mandible shows a simultaneous antero-inferior movement as a result of the expansion of the orofacial matrix.[2] On the average, mandibular length increases by 2.4 mm/year which is almost entirely provided by the condylar growth.[3] A peak at the rate of mandibular growth has been found in many studies, and the timing tends to occur 1.6 years earlier in girls than boys. Furthermore, a considerably higher percentage of boys shows annual mandibular increase of more than 1 mm when compared to girls.[4]

Radiographic cephalometric analysis is an essential tool for orthodontic diagnosis and treatment planning, as well as for examining treatment- and growth-related changes besides predicting residual growth potential for an individual patient. Athanasiou[5] highlighted the importance of cephalometric data for monitoring populations based on age, and ethnic and racial differences. Furthermore, norm values for 1 group should not be considered normal for every other population. Different ethnic groups must be treated according to their norms, and patients' cephalometric findings must be compared with the norms of the included ethnic group for accurate diagnosis.[5-10]

Some studies investigated the Turkish population's ideal norms but none of them evaluated mandibular dimensions in growing children according to age and sex.[6-10] The objectives of this study were to (1) determine cephalometric mandibular dimensions in a large group of patients to provide the clinician normative values for growing Anatolian Turkish children, (2) compare the differences between sex and age groups, (3) compare the Turkish data with other published standards, and (4) create mandibular growth curves in order to predict dimensions of the mandible in the following years.

METHODS

This retrospective study was approved by the Ethics Committee and Institutional Review Board of Başkent University (Protocol Number D-KA17/23). Written informed consents had already been collected at the beginning of treatment as a standard procedure. Complete pretreatment records (demographic, radiographic, and medical) of patients who were referred to the Orthodontics Department of Başkent University were evaluated according to the following inclusion criteria: (1) patients who are Turkish Anatolian citizens with Turkish parents, (2) who are 8-17 years old, (3) with skeletal Class I relationship (ANB angle between 1° and 5°),[11] (4) with normo-divergent facial type (SN-MP angle between 27° and 37°), (5) presenting normal growth and development, and no history of significant medical problem or trauma, (6) without previous history of orthodontic treatment and any kind of maxillofacial surgery, and (7) who have high-quality digital lateral cephalometric radiographs.

A total of 528 lateral cephalometric radiographs which met the inclusion criteria were included in the study. Of these radiographs, 306 belonged to girls (median age 13 years, range 8-17 years) and 222 belonged to boys (median age 12 years, range 8-17 years). These radiographs were first grouped according to sex to assess differences between boys and girls at the same age. Then within each sex group, subgroups were formed according to consecutive age intervals to study the trend of growth and periods of rapid growth, as well as for comparison with the published norms. Mandibular growth curves were constructed for each parameter for boys and girls in order to reveal the growth trend figuratively and to create an easy tool to predict future dimensions of the mandible.

Lateral cephalometric radiographs were obtained in a standard position with Frankfort horizontal plane parallel to the floor, lips relaxed, and teeth in centric occlusion. All of the radiographs were in digital format, taken with the same x-ray device (Veraviewepocs 2D, Morita, Calif, USA) and radiology technician team who were educated on dental radiography.

Image enlargement was 11%. As the objectives of this study entailed the use of actual measurements, image enlargement was eliminated using the standardized metallic ruler image on the right-hand side of the radiograph. The data of this study were compared with the norms from McNamara's Bolton-Brush and Burlington samples, the norms of Chinese population, and Oslo sample of Norwegian children.[12-14] Bolton-Brush and Burlington studies, and Chinese norms were used to compare effective mandibular length (Co-Gn), while Oslo sample of Norwegian children was used to compare corpus length 1 (Go-Me). Data from Chinese population and Oslo sample were available for 12-year-old children only. Therefore, comparisons were made with the concerning age group. McNamara's Bolton-Brush and Burlington data which had 8% enlargement, Chinese data which had 8.8% enlargement, and Norwegian data which had 6% enlargement were adjusted to the actual dimensions for accurate comparison.

Cephalometric Analysis

Lateral cephalometric radiographs were digitally traced and measured using Dolphin Imaging program (Vers 11.5 Premium, Patterson Dental, Calif, USA).

Cephalometric landmarks used in the study were as follows:

S: Sella (the center of sella turcica), *N:* Nasion (the most anterior limit of nasofrontal suture), *A:* A point/subspinale (the point at the deepest midline concavity on the maxilla between the anterior nasal spine and prosthion), *B:* B point/supramentale (the point at the deepest midline concavity on the mandibular symphysis between infradentale and pogonion), *Co:* Condylion (the most superior point on the head of the mandibular condyle), *Go:* Gonion (the most outward point on the angle formed by the junction of the ramus and body of the mandible), *Me:* Menton (the most inferior midline point on the mandibular symphysis), *Gn:* Anatomical gnathion (the most anteroinferior point of the mandibular symphysis), *Ar:* Articulare (the point of intersection of the images of the posterior border of the condylar process of the mandible and the inferior border of the basilar part of the occipital bone).

Parameters used in the study were as follows:

- *Co-Go:* Ramus height (the distance from condylion to gonion),
- *Go-Me:* Corpus length 1 (the distance from gonion to menton),
- *Go-Gn:* Corpus length 2 (the distance from gonion to anatomic gnathion),
- *Co-Gn:* Effective mandibular length (the distance from condylion to anatomic gnathion).

Landmark identification was performed by 2 experienced investigators working independently. Intra-examiner reliability was tested by remeasuring 20% of the radiographs 3 weeks after the initial evaluation. Inter-examiner reliability was tested by comparing the data of the two investigators.

Statistical Analysis

Statistical analysis was performed using SPSS software package (SPSS for Windows, version 23.0, IBM SPSS Corp., Armonk, NY, USA) and R-4.0.4 (R Core Team (2021). R: A language and environment for statistical computing. R Foundation for Statistical Computing, Vienna, Austria). Inter- and intra-examiner reliability levels were assessed by using intra-class correlation coefficient (ICC) with 2-way mixed effect model.

Normality of the numerical variables was assessed by using Shapiro–Wilk normality test in age and sex groups. Homogeneity of variances was tested using Hartley's and Levene tests while comparing the results of this study with published norms.

Student's *t*-test was used to compare mandibular dimensions between boys and girls, and the results of this study with published norms when parametric test assumptions were met. If not, Mann–Whitney *U* and Welch's *t*-tests were used to compare mandibular dimensions between sexes and the results of this study with published norms, respectively. In order to compare mandibular dimensions between different age groups within each sex, one-way analysis of variance and Kruskal–Wallis variance analysis were used. Median, minimum, and maximum values were given as descriptive statistics since both parametric and nonparametric hypothesis testing approaches were used within the study.

Nonparametric quantile regression method with smoothing by B-splines (quadratic) was used to construct growth curves. Knots were selected as leap points of growth for each sex depending on the literature. To obtain growth curves R splines, quantreg and ggplot2 packages were used. Significance level was set at $\alpha = 0.05$.

RESULTS

Intra-class correlation coefficient values for intra- and inter-examiner reliabilities ranged between 0.954 and 0.986 and between 0.913 and 0.978, respectively. Ramus height (Co-Go) had the lowest and effective mandibular length (Co-Gn) had the highest repeatability rates for both intra- and inter-examiner reliabilities (Table 1).

Descriptive statistics and significance levels for mandibular dimensions according to age and sex are presented in Table 2. In general, all parameters increased by age. Ramus height (Co-Go) and corpus lengths (Go-Me and Go-Gn) after age 15 and effective mandibular length (Co-Gn), except for 9- and 12-year-age groups, were significantly greater for boys than girls.

Multiple comparisons, conducted to detect significant increases in the mandibular dimensions within age groups, showed significant differences in effective mandibular length (Co-Gn) when assessed biyearly. According to this, girls showed significant increase between ages 8 and 10, 10 and 12, and 11 and 13 years, while boys between ages 8 and 10, 9 and 11, and 13 and 15 years.

Effective mandibular length (Co-Gn) and corpus length 1 (Go-Me) were compared with children of American, Canadian, European, and Asian descent using published norms in the literature (Table 3). When compared with the 14-year-old group in Bolton-Brush and Burlington studies reported by McNamara, it was found that Turkish girls had significantly shorter mandibles than 14-year-old American girls in the Bolton-Brush study (*P* = .003). Comparisons with Chinese norms revealed no significant difference between neither girls nor boys. On the contrary, corpus length 1 (Go-Me) from Oslo sample of Norwegian children proved to be significantly longer in Norwegian boys and girls when compared to their Turkish counterparts (*P* = .001).

Growth curves were established by using nonparametric quantile regression method for a set of 7 percentiles (5%, 10%, 25%, 50%, 75%, 90%, and 95%) (Figure 1 and 2). These growth curves can be interpreted as when a group of 100 children of the same age, sex, and ethnicity gather; a child with a mandibular dimension on the 25th centile would be expected to have a longer

Table 1. Intra- and inter-examiner reliability analyses for the cephalometric measurements

	Intra-Examiner Reliability			Inter-Examiner Reliability		
Measurement	**ICC (3,1)**	**95% CI for ICC**	***P***	**ICC (3,1)**	**95% CI for ICC**	***P***
Ramus height (Co-Go)	0.954	0.889-0.982	<.001*	0.913	0.784-0.967	<.001*
Corpus length 1 (Go-Me)	0.971	0.929-0.988	<.001*	0.963	0.904-0.986	<.001*
Corpus length 2 (Go-Gn)	0.974	0.935-0.990	<.001*	0.962	0.901-0.986	<.001*
Effective mandibular length (Co-Gn)	0.986	0.963-0.994	<.001*	0.978	0.942-0.992	<.001*

ICC (3,1), intraclass correlation coefficient in form of 2-way mixed effects model.
Significance level was set at 0.05.

Table 2. Descriptive statistics for mandibular dimensions and patient distribution

		Age											Comparisons Between Age Groups
		8	9	10	11	12	13	14	15	16	17	$P^{\ddagger}$	Multiple Comparisons
Ramus height (Co-Go) (mm)	Female	44.3 (36.5-53.2)	46.3 (35-53.1)	47.4 (40.9-54.9)	49.2 (40.4-56.4)	51.3 (44.8-61.9)	51.5 (44.9-61.7)	53.7 (39.4-59.7)	52 (47.3-64.5)	54.1 (47.3-64.1)	55.7 (48.1-69.8)	<.001[a]	8-12, 13, 14, 15, 16, 17 9-12, 13, 14, 15, 16, 17 10-13, 14, 15, 16, 17 11-14, 15, 16, 17
	Male	46.6 (39.4-50.7)	46 (40.7-52.9)	45.2 (41.8-60.3)	51.2 (45.4-59.6)	49.6 (40.5-60.4)	54 (47.7-59.3)	53.4 (47.9-61.9)	56.8 (50.6-69.8)	58.1 (50.4-70)	61.7 (49.4-69.3)	<.001[a]	8-13, 14, 15, 16, 17 9-11, 13, 14, 15, 16, 17 10-15, 16, 17 11-15, 16, 17 12-15, 16, 17
	$P^{\dagger}$	.142[c]	.493[c]	.549[d]	.004[c]	.150[c]	.158[c]	.622[d]	<.001[c]	<.001[c]	.026[c]		
Corpus length 1 (Go-Me) (mm)	Female	56.7 (52.9-63.1)	60.8 (54.6-67.3)	62.2 (56.9-69.7)	62.8 (49.8-77.4)	64.6 (54-71.3)	67 (57-74.3)	66.8 (56.8-74.3)	66.2 (61.9-76.2)	67.1 (61.5-75.3)	68.4 (59.7-76.8)	<.001[a]	8-11, 12, 13, 14, 15, 16, 17 9-13, 14, 15, 16, 17 10-13, 15, 16, 17 11-15, 16, 17 12-17
	Male	59.1 (50.7-65.7)	60.5 (52.2-67.2)	63.2 (58-70.1)	63.8 (54.2-71.9)	65.3 (57.4-74.8)	66.6(59.7-78.7)	66.9 (63-77.6)	69.9 (62.7-77.3)	70.3 (62-79.7)	70.2 (63.9-81.5)	<.001[b]	8-10, 11, 12, 13, 14, 15, 16, 17 9-12, 13, 14, 15, 16, 17 10-15, 16, 17 11-15, 16, 17 12-15, 16, 17
	$P^{\dagger}$	.084[c]	.974[c]	.167[c]	.451[c]	.177[c]	.534[c]	.070[c]	.023[d]	.006[c]	.142[c]		
Corpus length 2 (Go-Gn) (mm)	Female	64.3 (59.1-70.2)	67.2 (60.9-75)	68.9 (61.2-76.1)	70.1 (57.3-85.2)	70.9 (44.9-76.9)	72.6 (64.5-83.7)	72.8 (62.2-81.9)	73.1 (65.4-82.9)	75.4 (68.4-82.6)	76.2 (67.1-85.1)	<.001[a]	8-11, 12, 13, 14, 15, 16, 17 9-13, 14, 15, 16, 17 10-13, 14, 15, 16, 17 11-16, 17 12-16, 17
	Male	66.2 (57.5-72.5)	67.9 (60.2-72.6)	70.3 (62-77.3)	71.6 (63.8-77.8)	72.2 (65.8-81.7)	72.7 (65.5-85.7)	74.4 (67.8-85.1)	76.5 (67.4-84.4)	78.3 (68.4-87.2)	77.1 (70.9-87)	<.001[a]	8-12, 13, 14, 15, 16, 17 9-13, 14, 15, 16, 17 10-15, 16, 17 11-15, 16, 17 12-16
	$P^{\dagger}$	.107[c]	.828[d]	.068[c]	.424[c]	.148[d]	.487[c]	.095[c]	.003[c]	.008[c]	.382[c]		

(*Continued*)

Table 2. Descriptive statistics for mandibular dimensions and patient distribution (*Continued*)

		Age											Comparisons Between Age Groups
		8	9	10	11	12	13	14	15	16	17	$P^‡$	Multiple Comparisons
Effective mandibular length (Co-Gn) (mm)	Female	93.5 (86.7-104.6)	97.5 (91.8-106.8)	98 (89.2-105.1)	99.6 (86.8-115.3)	104.7 (93-114.6)	105.6 (95.5-115.6)	106.1 (96.5-115.1)	107.7 (98.3-122.9)	108.7 (100.7-124.2)	110.8 (101.1-127.5)	<.001[b]	8-10, 11, 12, 13, 14, 15, 16, 17 9-12, 13, 14, 15, 16, 17 10-12, 13, 14, 15, 16, 17 11-13, 14, 15, 16, 17 12-16, 17 13-16, 17 14-17
	Male	97.4 (88.1-107.6)	98.8 (89.8-108)	101.2 (94.4-113.2)	105.5 (96.2-112.6)	103.8 (96.1-115.6)	108.5 (99.3-117.3)	107.8 (100.2-120.3)	115 (102.2-122.9)	116.2 (107.2-128.4)	116.5 (109.3-126.1)	<.001[b]	8-10, 11, 12, 13, 14, 15, 16, 17 9-11, 12, 13, 14, 15, 16, 17 10-13, 14, 15, 16, 17 11-15, 16, 17 12-15, 16, 17 13-15, 16, 17 14-15, 16, 17
	$P^†$	.008[c]	.127[c]	.030[c]	.005[c]	.487[c]	.037[c]	.020[c]	<.001[c]	<.001[c]	.001[c]		
Patient distribution per age group	Female (n = 306)	23	23	22	41	39	36	41	31	26	24		
	Male (n = 222)	20	25	16	26	30	22	19	20	24	20		

$P < .05$, descriptive statistics are represented as median, and minimum and maximum values in parenthesis.
[a]: Kruskal–Wallis variance analysis (with Dunn–Bonferroni post hoc test results).
[b]: One-way analysis of variances (with Tukey post hoc test results).
[c]: Independent samples *t*-test.
[d]: Mann–Whitney *U* test.
$P^†$ Comparison between sexes.
$P^‡$ Comparison between age groups.
Significance level was set at 0.05 for all analysis and represented as bold.

Table 3. Comparison of effective mandibular length (Co-Gn) and Go-Me between Anatolian Turkish Children and published data (McNamara Bolton-Brush, Burlington, Chinese, and European norms)

Sex	Age	Anatolian Turkish Co-Gn (Corrected for 11% Enlargement)	Anatolian Turkish Go-Me (Corrected for 11% Enlargement)	McNamara Bolton-Brush Co-Gn (Corrected for 8% Enlargement)	McNamara Burlington Co-Gn (Corrected for 8% Enlargement)	Chinese Norms Co-Gn (Corrected for 8.8% Enlargement)	Oslo Norms Go-Me (Corrected for 6% Enlargement)	*P* Bolton-Brush	*P* Burlington	*P* Chinese	*P* Oslo
Female	9	96.98 ± 3.845	60.63 ± 3.006	98.24 ± 3.150	95.65 ± 4.907	-	-	.291[a]	.256[a]	-	-
	12	104.13 ± 4.586	63.87 ± 4.651	104.72 ± 3.330	102.04 ± 5.926	104.15 ± 4.991	68.58 ± 3.768	.641[a]	.056[b]	.974[a]	<.001[a]
	14	105.8 ± 4.664	65.96 ± 4.205	110.09 ± 4.630	106.39 ± 6.574	-	-	.003[a]	.623[b]	-	-
	16	109.9 ± 4.945	67.86 ± 3.456	111.11 ± 3.150	108.98 ± 4.167	-	-	0.388[a]	0.388[a]	-	-
Male	9	98.84 ± 4.305	60.6 ± 4.118	99.72 ± 3.520	97.22 ± 3.843	-	-	0.500[a]	0.104[a]	-	-
	12	104.95 ±5.086	65.36 ± 4.323	105.93 ± 3.980	104.63 ± 4.731	104.73 ± 5.267	70.38 ± 3.493	0.509[a]	0.780[a]	0.837[a]	<.001[a]
	14	109.09 ± 5.615	68.06 ± 3.84	111.67 ± 3.980	110.37 ± 5.278	-	-	0.134[a]	0.380[a]	-	-
	16	116.54 ± 5.568	70.83 ± 3.862	117.41 ± 4.350	115.28 ± 5.528	-	-	0.603[a]	0.361[a]	-	-

[a]Independent samples *t*-test.
[b]Welch's t-test (used when the result of the Hartley's test for equal variances are significant).

mandible than 24 children and a shorter mandible than 75 children who constitute the group. If the child's mandibular dimension is on 50th centile, this shows a normal development. Early maturers were represented in the 90th and the 95th centiles, whereas late maturers were represented in the 5th and the 10th centiles.

DISCUSSION

Different ethnic groups have different dentofacial traits and norm values. Therefore, the primary aim of this study was to determine normative values for mandibular dimensions in Anatolian Turkish children. For this purpose, patients with skeletal Class I malocclusion with an ANB angle value of 1-5° according to Gazilerli's Turkish norm study and ones with Turkish parents were included in the study to be representative of the population we treat.[11] Furthermore, the reason for focusing on Anatolia was because it involves the majority of the Republic of Turkey. Also, we targeted growing subjects in various stages of puberty to examine different mandibular growth rates and to deduce the best age range to treat mandible-related growth problems.

Sex-Related Differences

The data were comparatively evaluated between boys and girls for sex-specific differences. Girls showed significant increase for effective mandibular length between ages 8 and 10, 10 and 12, and 11 and 13 years, while boys between ages 8 and 10, 9 and 11, and 13 and 15 years. These changes can be explained with the effect of sex chromosomes on sexual dimorphism which determines the distinctive timing of pubertal growth spurt between boys and girls and with the intensity of adrenarche.[15] It is acknowledged that Y chromosome contains genes which increases the quantitative outcome of general body growth resulting from increased height and body size in men.[16] This is also why cartilage tissue at the male epiphyseal plates ossifies in a much slower manner.[17] On the other hand, girls encounter adolescent growth spurt approximately 2 years earlier than boys and reach the end of growth much sooner, which is in accordance with the finding that girls between ages 11 and 13 and boys between ages 13 and 15 show a rapid growth period.[18] Also, even though growth of the mandible usually follows the general growth curve, a "juvenile acceleration" in the jaw growth, especially in girls, is reported which is related to the intensity of adrenarche, the activation of adrenal androgen production.[19] This "juvenile acceleration" takes place 1-2 years prior to the pubertal growth spurt and has a similar intensity as the pubertal acceleration.[17-19] Maj and Luzi[20] also reported that condylar growth is not constant but occurs in spurts; therefore, it does not follow a straight line but instead a curved path. All of these literature data support our finding that boys and girls manifest not one but more rapid growth periods as documented above.

Comparisons with Other Norms

In general, Turkish girls only at age 12 and 14 presented significant differences in mandibular dimensions with the published norms. Norwegian children have significantly longer mandibular dimensions than their Turkish counterparts. No significant differences were detected between Turkish and Chinese girls.

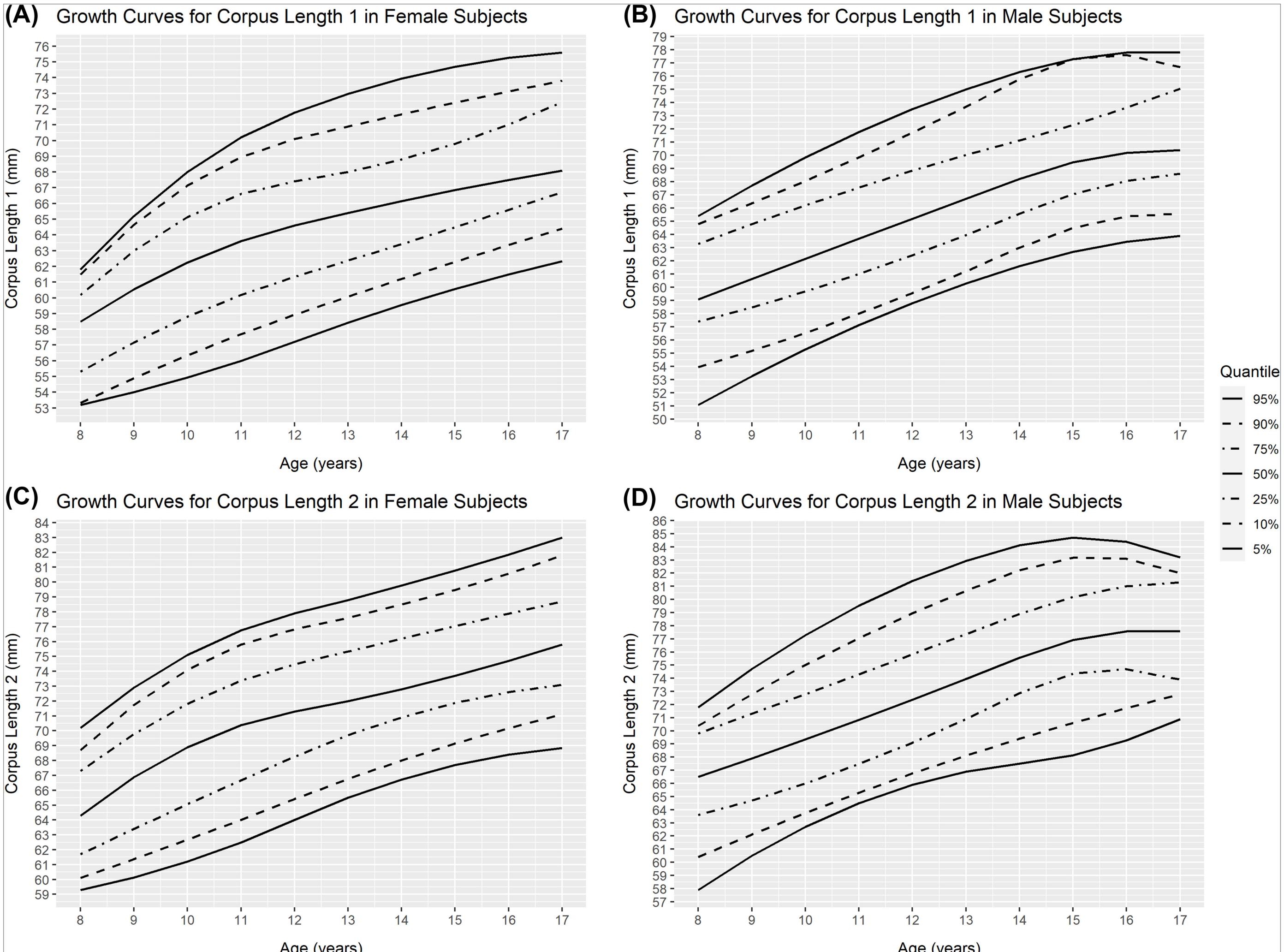

Figure 1. A-D. Growth curves for corpus length 1 in (A) female subjects and (B) male subjects. Growth curves for corpus length 2 in (C) female subjects and (D) male subjects.

Turkish boys, on the other hand, were always in close proximity with the published norms. Variations between different populations' norms are an inherent possibility. These variations may derive from genetic, national, ethnic, seasonal, environmental, and cultural factors.[17] For example, some ethnic groups may mature later than others, as in Dutch boys being 5 cm taller than their American peers at age 10.[17] Furthermore, seasonal factors are also effective on the rate of growth, such as growth being faster in summer and spring and slower in winter and fall.[17] This is also true for the climatic state of the land that a population resides which basically changes the genetic material to adapt for the living conditions. Another environmental factor is proper nourishment that helps city children to mature faster than their rural peers as seen especially in less developed countries.[17] Last but not least, the amount of body fat is an important factor in alleviating estrogen levels to start menstruation in girls.[17] Therefore, physical traits and lifestyle habits, such as professional sportsmanship, defines the timing and even the continuity of menstruation. These facts prove that evolutionary changes in the genetic material and environmental factors that an individual is exposed to can define the morphologic differences between populations to a large extent. American girls at age 14 have significant differences with their Turkish peers. American norms for the 14-year-old group were significantly greater than Turkish norms for the corresponding age groups. These findings are in accordance with what Kılıç et al.[8] demonstrated in their study.

Using other populations' norms may mislead the clinician, especially during differential diagnosis of skeletal problems. For example, if Canadian norms are used for a 12-year-old skeletal Class III Turkish patient with a normal mandible and a deficient maxilla, the clinician can consider the mandible faulty and prefer to treat the "supposedly overgrowing mandible," although the real problem lies within the sagittal maxillary deficiency.

A very important concept worth mentioning under this section is "secular trend."[21] This concept basically refers to the changes in the average size and shape of individuals in a population that occur from one generation to the next.[22] The secular trends depend on the improvements in healthcare and living conditions. Also, a small contribution of heterosis, cross-breeding species for a genetically superior offspring, is mentioned to be present.[23,24] As shown by a recent study, secular trends are

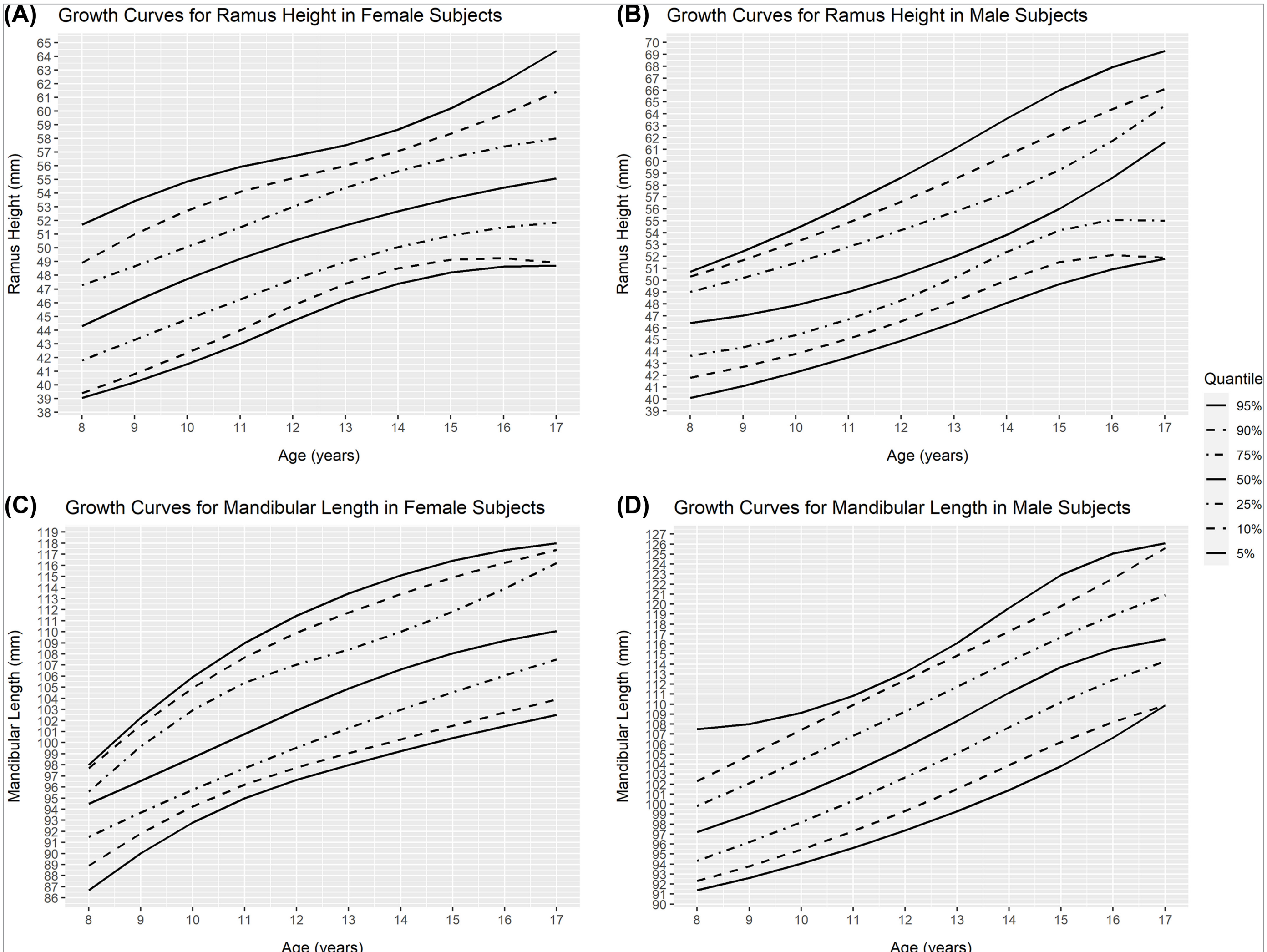

Figure 2. A-D. Growth curves for ramus height in (A) female subjects and (B) male subjects. Growth curves for mandibular length in (C) female subjects and (D) male subjects

evident in the cephalometric measurements derived from 9 historical studies (including Bolton-Brush and Burlington), and year of birth plays an important role on the magnitude of cephalometric variables.[25] The authors of the same study underlined the fact that significant growth changes can be detected between growth studies that are more than a few decades apart.

Growth Curves and Other Fields of Use

Several methods can predict mandibular growth but it is not clear which is the most accurate one. The growth curve method is a promising and practical method because it is easy for visual evaluation in clinical practice.[26] Therefore, data from this study are plotted as growth curves to present the growth-dependent changes. Growth curves can be used to designate the patient as early-, average- or late maturer, as well as to predict the approximate mandibular dimensions at a particular age. Furthermore, expected and achieved mandibular dimensions after functional orthopedic treatment can be comparatively evaluated for scientific purposes.

Other fields of use of cephalometric data are mostly legal medicine and forensic anthropology. These data help to determine sex and ethnicity and also to estimate age of the victim at the time of death. Furthermore, cephalometric data can also be used in combination with dental records in facial recognition systems to reveal the identity of an unknown person.[27] Although Demirjian's stages for dental development is a reliable method for age estimation, validity of this method is questionable after complete development of tooth roots.[28,29] Therefore, cephalometrics have been a fruitful field for forensic sciences for the past decades.

Although we have attempted to support out findings with scientific facts, we cannot rule out the impact of methodological differences between studies and cross-sectional nature of this study on the results. Growth studies can be designed as cross-sectional, longitudinal, or mixed-longitudinal. Longitudinal studies provide valuable information about growth variations and velocity, but it is not ethically appropriate to take annual cephalometric radiographs just for study purposes. The most common form of growth studies, on the other hand, is cross-sectional studies, by which mean annual growth can be estimated, but the data are not well-distributed like longitudinal studies, since the same individual is not followed at regular intervals.

To overcome the shortcoming of cross-sectional study design and to obtain a more homogeneous data that reflect the characteristics of a population, we kept the number of randomly selected individuals as high as possible.

CONCLUSION

Under the light of the findings of this study, the following points were concluded:

1. Effective mandibular length was almost always significantly longer in boys, except for 9- and 12-year-age groups.
2. Girls showed significant increase for mandibular length between ages 8 and 10, 10 and 12, and 11 and 13 years, while boys between ages 8 and 10, 9 and 11, and 13 and 15 years.
3. We suggest using norm values from more recent studies and that are representative of the studied subjects.
4. Growth curves can be used to predict the approximate mandibular dimensions at a particular age.

Ethics Committee Approval: Ethics committee approval was obtained from the Ethics Committee and Institutional Review Board of Başkent University (Protocol Number: D-KA17/23).

Informed Consent: Written informed consent was obtained from the patients.

Peer-review: Externally peer-reviewed.

Author Contributions: Concept - İ.C.P., H.P.; Design - İ.C.P., H.P.; Data Collection and/or Processing - H.P., N.İ.T.; Analysis and/or Interpretation - H.P., H.Y.Z., N.İ.T.; Writing - H.P., N.İ.T., H.Y.Z.; Critical Review - H.P., N.İ.T., H.Y.Z., İ.C.P.

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Original Article

Alterations in Facial Soft Tissue Thickness Post-Facemask Treatment in Noncleft Skeletal Class III and Bilateral Cleft Lip Palate Class III Patients

Esra Ulusoy Mutluol[1], Sema Koyuncu[1], Rıdvan Ceylan[1], Mehmet Akın[2]

[1]Department of Orthodontics, Selçuk University, Faculty of Dentistry, Konya, Turkey
[2]Department of Orthodontics, Alanya Alaaddin Keykubat University, Faculty of Dentistry, Antalya, Turkey

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Main Points

- As a result of rapid maxillary expansion with facemask treatment (RME/FM) treatment, significant changes were observed in hard and soft tissues of Class III patients with bilateral cleft lip and palate (BCLP) and noncleft Class III patients.
- Although the response of BCLP and noncleft Class III groups to RME/FM treatment may differ, an improved soft tissue profile was obtained in both groups.
- Rapid maxillary expansion with facemask treatment-related differences were found in the position and inclination of upper incisors, and in thickness of gnathion, subnasale, and upper lip of BCLP and noncleft Class III groups.

ABSTRACT

Objective: The purpose of this retrospective study was to assess the alteration in the facial soft tissue thickness after rapid maxillary expansion with facemask treatment in bilateral cleft lip and palate (BCLP) Class III patients and noncleft Class III patients.

Methods: Case records including lateral cephalograms of 30 patients (19 females, 11 males) treated using a rapid maxillary expansion with facemask treatment were analyzed. Group I (age: 11.4 ± 1.02 years) (10 females, 5 males) consisted of noncleft skeletal Class III patients, and group II (age: 10.8 ± 0.84 years) (9 females, 6 males) comprised skeletal Class III patients with bilateral cleft lip and palate. Fifteen hard tissue and 10 soft tissue measurements were made at the beginning and at the end of the treatment to evaluate the change with rapid maxillary expansion combined facemask treatment.

Results: The bilateral cleft lip and palate group displayed a statistically significant increase in the thickness of the subnasale, labrale superius, labrale inferius, labiomentale, and pogonion, whereas the thickness of the stomion was found to be significantly decreased. The noncleft group demonstrated a statistically significant decrease in the thickness of the stomion and gnathion. There was a statistically significant difference between the bilateral cleft lip and palate and noncleft groups in the facial soft tissue thickness measurements at labrale superius, gnathion, and subnasale points and in Y axis, U1-SN, U1-NA in the hard tissue measurements.

Conclusion: The results of the study indicated that the rapid maxillary expansion with facemask treatment produced diverse alterations in the facial soft tissue thickness of bilateral cleft lip and palate patients and noncleft Class III patients.

Keywords: Cleft lip and palate, facial soft tissue thickness, skeletal Class III

INTRODUCTION

The main objectives of Class III malocclusion treatment include obtaining optimal functional occlusion as well as delivering facial harmony because the main complaint of these patients is their concave profile, retrusive nasomaxillary area, and protrusive lower face and lips.[1-4] Numerous studies have evaluated facial soft tissue thickness (FSTT) in the literature,[5-12] and FSTT has been shown to be important in determining the facial profile.[5]

Corresponding author: Esra Ulusoy Mutluol, e-mail: mutluolesra@hotmail.com

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Class III malocclusion can develop due to maxillary deficiency, mandibular prognathism, or their coexistence.[13] Cleft lip and palate (CLP) is a widespread birth defect[14] that takes part in the progression of Class III malocclusion due to maxillary deficiency.[15] Rapid maxillary expansion with facemask treatment (RME/FM) is the most common orthopedic correction approach of Class III malocclusion with maxillary retrusion.[16]

In the current literature, there are studies regarding the soft tissue response to RPE and/or FM therapy in Class III patients,[1-4,17,18] differences in FSTT of varied skeletal malocclusions,[5-8,10] and FSTT in patients with bilateral cleft lip and palate (BCLP).[11,12,19] To the authors' knowledge, no data are available in the literature comparing the alterations in FSTT between the BCLP Class III patients and noncleft Class III patients after RME/FM treatment. The purpose of the present retrospective study is to evaluate the changes in FSTT after RME/FM treatment in patients with BCLP and to compare the findings with those of the noncleft Class III group. The null hypothesis of the study was that RME/FM treatment produced the same changes in the FSTT of BCLP patients and noncleft Class III patients.

METHODS

Lateral cephalometric radiographs of 30 patients (19 females, 11 males) treated with RME/FM were assessed in the current study. The ethical approval for the present retrospective study was obtained from the Local Ethics Committee of Selçuk University, Faculty of Dentistry (2012/12), and the study was conducted in accordance with the Declaration of Helsinki.

Individuals to be included in the study were selected through the records of all patients who received RME/FM treatment in the Selçuk University, Faculty of Dentistry, Department of Orthodontics, between 2013 and 2018. Written informed consent was obtained from each participant and/or their legal representative permitting scientific investigations including the patients' records prior to dental or orthodontic treatment. The research groups were formed after the evaluation of the records containing information on chronological age, daily wear time of removable appliances, cooperation, the treatment method, and lateral cephalometric radiographs of all patients. It was determined that there were 156 patients who received RME/FM treatment. Of these patients, 24 patients were found to have BCLP.

The sample size was calculated according to a formula,[20] with a significance level of .05 and a power of 85% to observe a difference of 3.4 mm ($\pm$3.4 mm) in subnasale thickness (distance from point A to subnasale) between the groups, in accordance with a study conducted by Celikoglu et al.[11] The sample must consist of 14 patients in each group according to the power analysis.

The inclusion and exclusion criteria of the study are presented in Table 1. Fifteen patients with BCLP were detected who met the criteria in Table 1. The study was carried out with the records of 15 individuals in both groups in order to have an equal number of individuals in the groups. Group I consisted of 15 subjects (10 females, 5 males; mean age, 11.4 $\pm$ 1.02 years) who had skeletal Class III malocclusion. Group II included 15 subjects (9 females, 6 males; mean age, 10.8 $\pm$ 0.84 years) who had BCLP with Class III malocclusion. All subjects were operated, and the identical primary surgical correction was performed at the same hospital. The lip, hard and soft palate were surgically closed before one year of age. In the present study, there was no control group due to ethical reasons, and the groups were compared with each other.

Table 1. Inclusion and exclusion criteria of the study

Inclusion Criteria
Retrognatic upper jaw detected in the cephalometric analysis of the individual (SNA $\leq$ 79°)
Presence of skeletal class III malocclusion (ANB $\leq$ 0°)
Mild skeletal malocclusion (ANB $>-2°$)[29]
Skeletal class III malocclusion due to maxillary retrusion or a combination of maxillary retrusion and mandible protrusion
Presence of class III molar relationship with anterior crossbite
Normal or horizontal growth pattern
Skeletal maturation at the prepubertal stage according to the cervical vertebra maturation method (CS1 or CS2)[30]
No previous orthodontic treatment
Cooperative patient according to the information obtained from the patient files
The net facemask wear-time reported as 6 months in the patient files
Positive overjet reported in the patient files after 6 months of face mask treatment
For group I, absence of any metabolic or systemic disorders and craniofacial deformities
For group II, presence of BCLP without any other syndromes or congenital anomalies, metabolic or systemic disorders
Exclusion Criteria
Pseudo class III malocclusion (functional shift)
Severe skeletal malocclusion (ANB $<-2°$)[29]
Vertical growing pattern
The net facemask wear-time reported as more than 6 months in the patient files
Completed growth and development
Normal position of the maxilla and skeletal class III malocclusion due to mandibular protrusion only
Incomplete or unclear patient records
Patient has received previous orthodontic treatment
For group I, presence of any metabolic or systemic disorders and craniofacial deformities
For group II, presence of any syndrome, metabolic, or systemic disorder accompanying BCLP

BCLP, bilateral cleft lip and palate group.

A full-coverage Hyrax (Forestadent, St. Louis, Mo, USA) acrylic cap splint-type rapid maxillary expansion appliance with vestibular hooks (Figures 1 and 2) was cemented to the maxilla and activated 2 times a day for 7 days. The midpalatal suture was monitored with occlusal radiographs to detect a suture opening. After the sutural separation, the midline expansion screw

Figure 1. Intraoral frontal view of the rapid maxillary expansion appliance

was activated once a day, until the lingual cusps of the upper first molar teeth were aligned with the buccal cusps of the lower first molar teeth. At the time that the face masks (Petit-type) were assigned, a force of 300 g per side was applied. It has been determined from the clinical records that in the first month the protraction force between the facemask and the intraoral anchor system was 300 g from the front hook only, whereas in the second month, a force of 300 g from the front hook and 200 g from the rear hook (a total of 500 g for each side) was applied. This force was applied in forward and downward motions at an angle of 30-45° with the occlusal plane, and the patients were instructed to use the facemask appliance 24 hours a day (excluding meals).[21]

Each patient underwent a lateral cephalogram before (T1) and after (T2) the treatment. All radiographs of the 30 cases included in the investigation were taken using a standard digital imaging device (Planmeca Promax, Dimax 3 Ceph, Helsinki, Finland) and by the same researcher. For the standardization, a cephalostat was used to ensure that the patient's head was fixed in proportion to the film. Ear rods were placed into the ear canals. The cephalometric radiographs were taken under standard conditions. X-ray images were obtained with the lips in a relaxed position, the teeth in centric occlusion, and the Frankfort plane parallel to the horizontal plane.

Figure 2. Intraoral occlusal view of the rapid maxillary expansion appliance

Dentoskeletal measurements (SNA, SNB, ANB, Y axis, FMA, SN-GoGn, SN-PP, U1-SN, U1-PP, U1-NA (mm), U1-NA, IMPA, L1-NB (mm), L1 – NB, interincisal angle) and FSTT measurements (glabella (G), rhinion (Rhi), subnasale (Sn), labrale superior (Ls), stomion (Sto), labrale inferior (Li), labiomentale (Labm), nasion (N), pogonion (Pog), gnathion (Gn)) (Table 2 and Figure 3) on the lateral cephalometric radiographs were analyzed by the same researcher (SK) using a computer program (Quick Ceph Image, Quick Ceph Systems Inc., Calif, USA). The details concerning the process of FSTT analysis have been explained in previous studies[6,9,12]. For each measurement, the mean and standard deviation values of all groups were determined.

Statistical Analysis

Twenty radiographs were selected randomly to detect any errors associated with the measurements. All measurements were repeated with an interval of 3 weeks by the same researcher (SK). A paired sample *t*-test was performed to assess the random error. There were no statistically significant differences between the 2 sets of measurements. The intra-class correlation coefficients were above 0.938, thus confirming reliability. Statistical analysis was conducted using Statistical Package for the Social Sciences 22.0 (IBM SPSS Corp., Armonk, NY, USA). A paired sample *t*-test was performed for the intra-group comparisons, while an independent sample *t*-test was used for the inter-group comparisons. The association between craniofacial measurements and the FSTT was evaluated through regression analysis.

RESULTS

Table 3 presents the demographics and characteristics of the groups. There were no statistically significant differences between the groups in any of the variables at T1.

In Table 4, the pre-treatment (T_1) and post-treatment (T_2) values of dentoskeletal and soft tissues of the 30 cases (15 patients with BCLP and skeletal Class III; 15 patients with skeletal Class III without any cleft) treated via RME/FM are presented. In both groups, the maxilla was significantly protracted, while the mandible was retracted although this motion was not statistically significant. The angle of ANB increased substantially with the treatment. The BCLP group demonstrated a significant increase in FSTT at the Sn, Ls, Li, Labm, and Pog points, whereas a substantial decrease was observed in the thickness at the Sto. Additionally, in the noncleft group, the Sto and Gn values decreased significantly.

As can be seen in Table 5, the investigated parameters differ (T2-T1) among the groups. The post-treatment changes between the groups show a significant difference at Y axis, U1-SN, and

Table 2. Dentoskeletal and soft tissue variables

Variables	Definition
Hard tissue variables and their definition	
SNA	Angle between Sella-Nasion (SN) plane and Nasion-A (NA) plane
SNB	Angle between Sella-Nasion (SN) plane and Nasion-B (NB) plane
ANB	Angle between Nasion-A (NA) plane and Nasion-B (NB) plane
Y axis	Angle between Frankfort horizontal plane and sella-gnathion line
FMA	Angle between Frankfurt horizontal plane and mandibular plane
SN-GoGn	Angle between SN plane and gonion-gnathion (GoGn) plane
SN-PP	Angle between SN plane and palatal plane
U1-SN	Angle between SN plane and the long axis of the maxillary incisor
U1-PP	Angle between palatal plane (PP) and the long axis of the maxillary incisor
U1-NA (mm)	Distance between the anterior point of the maxillary incisor and NA line
U1-NA	Angle between NA plane and the long axis of the maxillary incisor
IMPA	Angle between the mandibular plane and the long axis of the mandibular incisor
L1-NB (mm)	Distance between the anterior point of the mandibular incisor and NB line
L1 – NB	Angle between the NB plane and the long axis of the lower mandibular incisor
Interincisal angle	Angle between the long axis of the maxillary incisor and the mandibular incisor
Soft tissue variables and their measurements	
Glabella (G)	Perpendicular to Frankfort horizontal plane or to the bony surface
Rhinion (Rhi)	Perpendicular to Frankfort horizontal plane or to the bony surface
Subnasale (Sn)	The distance between point A and subnasale
Labrale superior (Ls)	The distance between prosthion and labrale superius
Stomion (Sto)	The shortest distance between the upper incisor and the attachment points of the upper and lower lip
Labrale inferior (Li)	The distance between infradentale and the vermillon border of the lower lip
Labiomentale (Labm)	The distance between point B and the deepest point of the labiomental crease
Nasion (N)	Perpendicular to Frankfort horizontal plane or to the bony surface
Pogonion (Pog)	Perpendicular to Frankfort horizontal plane or to the bony surface
Gnathion (Gn)	Perpendicular to Frankfort horizontal plane or to the bony surface

U1-NA in the hard tissue measurements and at the Ls, Gn, and Sn in the FSTT measurements.

The results of multiple linear regression analysis are reported in Table 6. This analysis was performed to describe the statistically significant differences of Sn, Ls, and Gn as dependent variables and the skeletal measurements as predictors. Regression models revealed statistically insignificant relationships between Sn (R^2 = 27.2, P = .089), Ls (R^2 = 17.3, P = .218), and Gn (R^2 = 12.6, P = .313).

DISCUSSION

The present study compared the changes in the FSTT due to the RME/FM treatment in BCLP patients and noncleft Class III patients using lateral cephalometric radiographs. In many studies, the effect of maxillary traction on facial soft tissues has been evaluated through cephalometric films.[1,2,4] Multiple imaging methods (two-dimensional (2D) or three-dimensional (3D)) are used to evaluate craniofacial measurements and the surrounding facial soft tissue. The most frequently preferred 3D systems are computed tomography (CT), cone-beam computed tomography (CBCT), stereophotogrammetry, magnetic resonance imaging, and laser surface; CBCT in particular is broadly used.[22,23] However, 3D systems are costlier in comparison to conventional 2D systems. The radiation dose that CBCT offers is lower than CT, nevertheless higher in comparison to cephalometric radiography. Furthermore, poor soft tissue contrast and artifacts can be observed in CBCT imaging. Overall, the main imaging method for orthodontic treatment remains as cephalometric radiography.[24]

In the literature, the findings concerning the difference in FSTT between the sexes are inconsistent. While some studies have reported a sex-related difference in FSTT,[5,8] others have reported no differences.[6,11] It was reported that there was no statistically significant difference in FSTT between the sexes in Class III individuals by Perović and Blažej[7] and in individuals with BCLP by Celikoglu et al.[11] In the present study, the groups were not divided by sex. In view of the fact that ethical principles do not allow the treatment of diagnosed Class III patients to be postponed for scientific purposes, a control group was not formed in the study, and the groups were compared with each other.

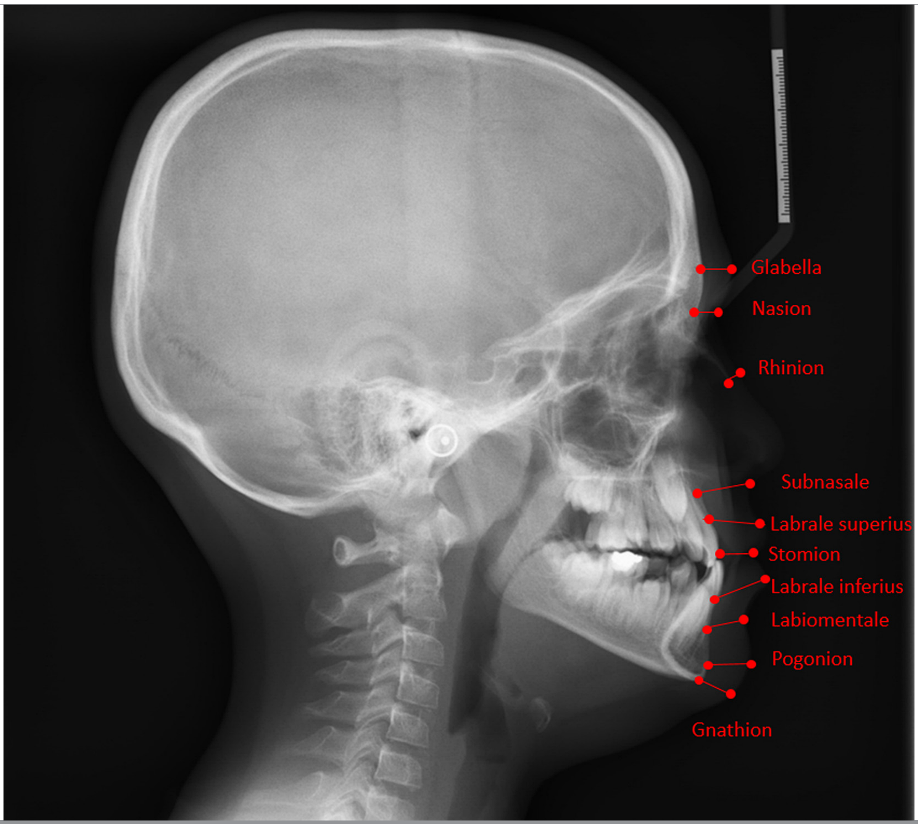

Figure 3. The selected measurement points of the facial soft tissue thickness

Table 3. Demographics and characteristic features of the groups

	BCLP group		Noncleft group		
	Mean	SD	Mean	SD	*P*
Mean age	10.08	0.84	11.4	1.02	.054
Hard tissue measurements					
SNA	76.91	4.59	78.75	4.62	.062
SNB	76.43	3.58	79.39	4.53	.057
ANB	0.87	2.95	−0.64	2.35	.052
Y axis	60.21	3.33	55.51	2.84	.081
SN-GoGn	38.12	6.64	35.46	7.10	.060
SN-PP	10.50	3.59	9.91	4.99	.208
IMPA	85.51	6.99	85.68	3.13	.418
Soft tissue measurements					
Glabella (G)	6.06	1.27	6.60	1.27	.608
Rhinion (Rhi)	2.75	0.64	2.81	0.61	.598
Subnasale (Sn)	10.54	2.60	12.52	2.46	.072
Labrale superior (Ls)	12.41	2.17	13.06	2.47	.128
Stomion (Sto)	8.74	2.63	7.65	2.31	.117
Labrale inferior (Li)	14.74	1.43	15.73	1.80	.136
Labiomentale (Labm)	9.96	1.36	11.64	2.33	.052
Nasion (N)	6.09	2.13	6.90	1.56	.304
Pogonion (Pog)	11.06	2.10	12.09	1.80	.090
Gnathion (Gn)	8.41	1.63	8.51	1.87	.469

BCLP, bilateral cleft lip and palate; SD, standard deviation.

The same appliance and force system were used on all patients participating in the study at the same period, and no additional orthodontic therapy was used. Thus, the factors that could affect the interpretation of the data were eliminated. In some recently conducted studies, it has been reported that rapid maxillary expansion does not have a significant effect on maxillary protraction.[25-28] Yavuz et al.[27] reported in 2012 that similar dentoskeletal and facial soft tissue changes were observed in groups that underwent facemask treatment regardless of rapid maxillary expansion and that the mean duration of treatment was similar. Zhang et al.[28] reported in their meta-analysis that the effect of facemask was similar in groups with and without rapid maxillary expansion. The alterations in the present study are thought to be due to facemask treatment since in recent studies, no statistical difference was found between the effects of facemask treatment applied in the presence and absence of rapid maxillary expansion.

In studies evaluating the effect of RME/FM treatment on soft tissues in the literature, a statistically significant anterior movement in the upper lip and midface region has been reported as a result of anterior movement of the maxilla with maxillary protraction treatment. It has been shown that this condition tends to alter the soft tissue profile from concave to a more orthognathic or convex profile.[1,2,4,17,18,25] To the authors' knowledge, no data are available in the literature comparing the alterations in FSTT between the BCLP Class III patients and noncleft Class III patients succeeding RME/FM treatment.

Table 4. Changes in dentoskeletal and soft tissue measurements after treatment, and the significance of these changes in each group

	BCLP Group (n = 15)					Noncleft Group (n = 15)				
	T1		T2			T1		T2		
Hard tissue measurements	**Mean**	**SD**	**Mean**	**SD**	***P***	**Mean**	**SD**	**Mean**	**SD**	***P***
SNA	76.91	4.59	79.10	4.26	.001***	78.75	4.62	80.72	3.72	.044**
SNB	76.43	3.58	75.91	3.33	.208	79.39	4.53	79.08	3.25	.799
ANB	0.87	2.95	3.20	3.05	.001***	−0.64	2.35	1.65	2.35	.001***
Y axis	60.21	3.33	60.57	4.68	.566	55.51	2.84	56.10	2.04	.357
FMA	27.06	5.66	27.34	6.81	.661	22.59	4.11	23.77	2.55	.114
SN-GoGn	38.12	6.64	38.94	7.15	.151	35.46	7.10	37.15	4.23	.255
SN-PP	10.50	3.59	8.06	4.44	.001***	9.91	4.99	8.28	3.36	.233
U1-SN	85.47	11.13	93.49	9.74	.001***	102.61	6.58	105.72	5.90	.128
U1-PP	−84.02	11.33	−78.24	11.20	.014*	−67.48	7.76	−65.99	6.75	.284
U1-NA (mm)	−0.94	4.31	1.49	4.04	.007**	4.25	2.00	5.03	1.86	.058
U1-NA	7.69	12.74	14.84	11.72	.004**	23.85	7.10	25.01	5.85	.411
IMPA	85.51	6.99	84.46	7.75	.404	85.68	3.13	87.21	5.32	.276
L1-NB (mm)	3.26	2.06	3.71	2.49	.185	3.28	1.12	3.66	1.41	.191
L1 – NB	19.35	6.59	19.79	7.27	.710	20.51	4.82	23.43	5.04	.060
Interincisal angle	150.88	11.72	143.09	13.81	.005**	136.26	8.07	129.93	7.49	.003**
Soft tissue measurements										
Glabella (G)	6.06	1.27	6.60	1.27	.610	6.07	1.28	6.20	1.26	.611
Rhinion (Rhi)	2.75	0.64	2.81	0.61	.590	2.31	0.64	2.33	0.76	.902
Subnasale (Sn)	10.54	2.60	12.52	2.46	.001***	15.59	1.71	15.45	1.17	.725
Labrale superior (LS)	12.41	2.17	13.06	2.47	.048*	14.65	1.66	14.18	1.43	.203
Stomion (Sto)	8.74	2.63	7.65	2.31	.017*	7.01	1.29	5.26	1.16	.001***
Labrale inferior (Li)	14.74	1.43	15.73	1.80	.036*	13.81	1.21	14.35	1.37	.145
Labiomentale (Labm)	9.96	1.36	11.64	2.33	.005**	10.68	1.50	11.20	1.94	.320
Nasion (N)	6.09	2.13	6.90	1.56	.154	5.88	1.52	5.52	1.91	.404
Pogonion (Pog)	11.06	2.10	12.09	1.80	.014*	11.13	2.15	11.29	2.04	.502
Gnathion (Gn)	8.41	1.63	8.51	1.87	.769	9.97	2.39	9.03	2.43	.017*

Paired Sample *t*-Test, BCLP, bilateral cleft lip and palate group; SD, standard deviation.
*$P \leq .05$; **$P \leq .01$; ***$P \leq .001$.

Utsuno et al.[10] in their study evaluating FSTT in different skeletal malocclusions reported statistically significant differences between the Sn and Ls points, regarding the comparison of Class I and Class III patients in the upper lip region and the influence of maxillary growth on FSTT at the Sn and Ls points. They also found that the mental area of the mandible was more anteriorly positioned in Class III patients due to the reduced maxillary growth or overgrowth of the mandible. As a result of this, increased FSTT was expected in these 2 points in Class III patients. They reported that the FSTT was the thinnest in Class III at the Labm and Pog points. They found no significant differences at the Sto or Li point. In the present study, in the noncleft group, there was a significant decrease in the thickness of Sn, Ls, and Sto, following RME/FM treatment, while the thickness of Labm and Pog points increased although this difference was not statistically significant. The inconsistency in the study conducted by Utsuno et al.[10] regarding the Sto point may be due to the fact that the results reported a comparison of treatment-related alterations rather than directly pointing out the difference between classes. Moreover, the angulation of the teeth could affect the thickness of the Sto.[6]

Kamak and Celikoglu[6] stated that the thickest FSTT at the Ls and Sto points and the thinnest Li belonged to Class III patients. In the present study, Sto thickness decreased and Li thickness increased with RME/FM treatment in both groups, although the increase in the thickness of Li was not statistically significant in the noncleft group. While there was a decrease in the thickness of Ls in the noncleft group, it was increased in the group with BCLP.

Utsuno et al.[8] reported that in skeletal Class III patients, there is a concave facial profile showing excessive growth in the mandible or decreased growth in the maxilla, and FSTT from the Sn to the Labm was greater in the less growth site. According to the data obtained from studies evaluating FSTT in different skeletal patterns in the literature,[6,8,10] a decrease in FSTT in the upper lip region is expected with RME/FM treatment.

Table 5. Comparison of the treatment-related changes between the groups

	BCLP Group T2-T1		Noncleft Group T2-T1		
	Mean	SD	Mean	SD	*P*
Hard tissue measurements					
SNA	2.19	1.38	1.97	5.07	.872
SNB	−0.52	1.53	−0.31	4.69	.872
ANB	2.33	1.71	2.29	1.55	.947
Y axis	0.37	2.40	3.11	1.68	.001***
FMA	0.27	2.35	0.59	2.41	.716
SN-GoGn	0.81	2.08	1.18	2.71	.681
SN-PP	−2.43	2.12	1.69	5.53	.012
U1-SN	8.02	7.60	2.10	2.05	.005**
U1-PP	5.78	7.93	3.11	7.45	.351
U1-NA (mm)	2.43	2.96	1.49	5.19	.550
U1-NA	7.15	8.03	0.77	1.45	.005**
IMPA	−1.04	4.70	1.15	5.28	.239
L1-NB (mm)	0.45	1.25	1.53	5.21	.445
L1 – NB	0.44	4.52	0.38	1.07	.960
Interincisal angle	−7.79	9.02	−6.33	6.94	.623
Soft tissue measurements					
Glabella (G)	0.54	0.80	0.13	0.94	.206
Rhinion (Rhi)	0.06	0.40	0.02	0.62	.835
Subnasale (Sn)	1.99	1.41	−0.13	1.44	.001***
Labrale superior (Ls)	0.65	1.16	−0.47	1.35	.022*
Stomion (Sto)	−1.09	1.56	−1.75	1.21	.206
Labrale inferior (Li)	0.99	1.66	0.54	1.35	.419
Labiomentale (Labm)	1.67	1.93	0.52	1.95	.115
Nasion (N)	0.81	2.08	−0.36	1.62	.097
Pogonion (Pog)	1.03	1.42	0.15	0.86	.052
Gnathion (Gn)	0.09	1.20	−0.93	1.05	.019*

Independent Sample *t*-Test, BCLP, bilateral cleft lip and palate group; SD, standard deviation.
$^{*}P \leq .05$; $^{**}P \leq .01$; $^{***}P \leq .001$.

Ngan et al.[2] and Vaughn et al.[25] reported that there was an anterior and inferior movement in the upper lip, an increase in the length and a decrease in the thickness of the upper lip, a posterior and inferior shift in the lower lip, and an increase in the lower lip length and thickness as a result of maxillary protraction. Arman et al.[4] reported that the upper lip thickness decreased and the lower lip thickness increased after maxillary protraction. In the present study, the decrease in the FSTT in the upper lip region seen in the noncleft group, the increase in the Li thickness although not statistically significant, and the increase in the Li thickness in the BCLP group are consistent with these studies.

When the 2 groups were compared pertaining to facemask treatment and the maxillary expansion treatment, SNA and ANB angles increased while the interincisal angle decreased in both groups. There was a statistically significant increase in the measurements showing the angle and position of the maxillary incisors in the BCLP group. A significant treatment-related difference was found between the 2 groups in the angles of the upper incisors. In general, the upper incisors are inclined labially, while lower incisors are inclined lingually in Class III subjects.[6] However, the upper and lower incisors of Class III patients with CLP are generally in a retrusive position. The upper lip scar may be responsible for this condition.[11] A statistically significant decrease was found at the Sn and Ls points in the noncleft Class III, while in the BCLP group, a significant increase was observed at these points. A significant decrease was found in the noncleft group at the Gn point in comparison with the BCLP group. The difference between the Sn and Ls points is considered to be due to the contrast in the inclination of incisors.

In the current study, although the skeletal pattern in the BCLP group differed from Class III to Class I, the increase in FSTT at the Sn and Ls points was attributed to the fact that the upper incisors were in the retrusive position in the BCLP group, unlike in the noncleft Class III group. Celikoglu et al.[11] reported significant correlations between U1-SN among the Sn and Ls thicknesses. Moreover, they reported that patients with BCLP had thinner Sn and Ls. Hasanzadeh et al.[19] and Erdur et al.[12] reported in their studies that BCLP patients had a thinner Sn compared with noncleft healthy individuals.

Table 6. The association between craniofacial measurements and subnasale, labrale superior and gnathion thicknesses according to the multiple linear regression analyses

	Subnasale R^2=27.2, P=0.089			Labrale superior R^2=17.3, P=0.218			Gnathion R^2=12.6, P=0.313		
	R	P	R^2	r	P	R^2	r	P	R^2
SNA	-0.186	0.118	3.2	-0.236	0.206	4.1	-0.243	0.185	0.8
SNB	-0.026	0.614	0.001	-0.042	0.302	0.002	-0.018	0.428	0.001
ANB	-0.212	0.084	5.2	-0.198	0.408	0.4	-0.312	0.106	3.1
FMA	-0.098	0.242	0.8	-0.162	0.094	1.2	-0.201	0.088	2.1
SN-GoGn	-0.144	0.318	1.6	-0.112	0.146	2.1	-0.111	0.161	2.3
U1-SN	0.268	0.046	5.2	0.176	0.108	4.1	0.208	0.143	6.4
IMPA	0.169	0.074	7.2	0.097	0.136	0.9	0.097	0.254	1.9

R^2, coefficient of determination; P, 1-tailed significance level of correlation of each variable; r, Pearson correlation coefficient.

The results of the multiple linear regression analysis for the present study, which was performed to determine the relation of the craniofacial measurements, indicated that there was no association among Sn, Ls, and Gn.

The limitations of the study are that there is no sex assortment, the duration of appliance use was determined only through the information obtained from the patients, and 2D imaging method was used for the evaluation and the absence of a control group. An extensive investigation is required to achieve a more accurate comparison. Although the sample size is small, it is noted that in both groups, the soft tissue thickness is prone to change with treatment. In addition to hard tissue measurements, soft tissue measurements are necessary to determine the best treatment option and to provide an ideal facial appearance. The presented study contains information that may be helpful when planning the treatment of patients with BCLP and noncleft individuals.

CONCLUSION

1. As a result of RME/FM treatment, there were significant changes in hard and soft tissues and incisor inclinations in both groups. The maxilla was significantly protruded, while the mandible was retracted although this alteration was not statistically significant. The ANB angle increased following the increase in the SNA angle and the decrease in the SNB angle.
2. In the BCLP group, there was a statistically significant decrease in interincisal angle values and a statistically significant *increase in the values associated with upper incisor proclination and protrusion*. In the noncleft group, the interincisal angle was statistically significantly decreased.
3. In both groups, the facial profile changed from a concave profile to a more orthognathic profile with treatment.
4. The BCLP group exhibited a statistically significant increase in subnasale, upper lip, lower lip, and labiomentale thickness and a statistically significant decrease was observed at the stomion point ensuing RME/FM treatment.
5. The noncleft Class III group presented a statistically significant decrease at the stomion and gnathion points.
6. When the treatment-related changes between the groups were evaluated, a statistically significant difference was found in the Y axis, *upper incisor proclination and protrusion* values in the hard tissue, and upper lip, gnathion, subnasale thickness in the soft tissue.
7. Based on the differences between the BCLP and noncleft groups, the null hypothesis of the study can be rejected.

Ethics Committee Approval: Ethical Committee approval was received from the Ethics Committee of Selçuk University, Faculty of Dentistry (Approval No: 2012/12).

Informed Consent: Written informed consent was obtained from each participant and/or their legal representative.

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Case Report

Orthodontic Management of the Edentulous Space Caused by Surgical Removal of a Large Dentigerous Cyst

Yuko Yamada[1], Chihiro Arai[1], Kazutoshi Nakaoka[2], Takumasa Yoshida[3], Keita Sasaki[4], Go Arai[2], Yoshiki Hamada[2], Hiroshi Tomonari[1]

[1]Department of Orthodontics, School of Dental Medicine, Tsurumi University, Yokohama, Japan
[2]Department of Oral and Maxillofacial Surgery, School of Dental Medicine, Tsurumi University, Yokohama, Japan
[3]Department of Endodontology, School of Dental Medicine, Tsurumi University, Yokohama, Japan
[4]Department of Crown and Bridge Prosthodontics, School of Dental Medicine, Tsurumi University, Yokohama, Japan

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Main Points

- This case report presents the orthodontic management of the growing patient who had a large dentigerous cyst, spaced arch and bone loss.
- Age and alveolar bone status should be considered when determining treatment for such cases of excessive bone loss.
- The second premolar was slowly mesialized into the the edentulous region. As a result, a wide bony ridge was obtained, which allowed us to autotransplant the maxillary lateral incisor.

ABSTRACT

Herein, we report the orthodontic management of a patient with excessive bone and permanent tooth loss after surgical cyst removal. The patient was a 13-year-old Japanese boy who was referred to our department by an oral surgeon. He had an edentulous space with alveolar bone loss and loss of 2 permanent molars in the left mandibular region, following surgical removal of a large dentigerous cyst. We decided to close this space orthodontically. First, we moved the left mandibular second premolar into the edentulous region and autotransplanted the left maxillary lateral incisor in the adjacent distal space. We then performed comprehensive orthodontic treatment to establish stable occlusion. Following treatment, functional and stable occlusion of all permanent teeth was achieved without any spaces. The findings from this case suggest that orthodontic treatment is effective in growing patients with edentulous spaces and alveolar bone loss.

Key words: Alveolar bone loss, autotransplantation, dentigerous cyst, orthodontics

INTRODUCTION

Dentigerous cysts comprise approximately 20% of all jaw cysts.[1,2] Large dentigerous cysts require surgical intervention that can lead to alveolar bone loss in the edentulous space.[3] Clinicians should ideally plan treatment that allows reconstruction of occlusion after surgery, especially in growing patients. In this case report, we present the orthodontic management of an edentulous space in a patient with excessive bone loss and loss of 2 permanent teeth following the surgical removal of a dentigerous cyst.

CASE PRESENTATION

DIAGNOSIS

A 13-year-old boy, referred to the clinic of Oral and Maxillofacial Surgery, Tsurumi University Dental Hospital, was diagnosed with a dentigerous cyst in the region of an impacted left mandibular canine and first premolar

Corresponding author: Chihiro Arai, e-mail: arai-chihiro@tsurumi-u.ac.jp

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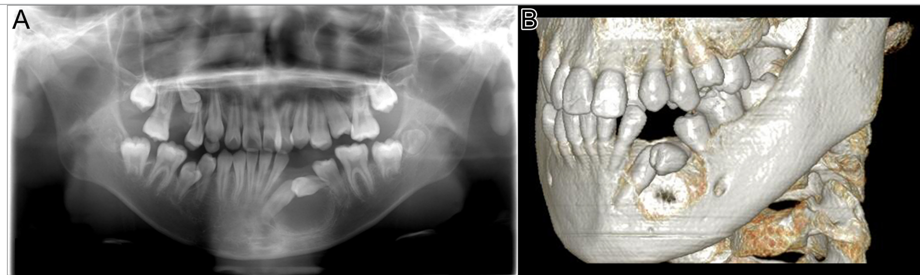

Figure 1. A, B. Pre-surgery radiographs. (A) Panoramic radiograph and (B) computed tomography

(Figure 1). Cystectomy was performed with extraction of the impacted teeth. At the 12-month follow-up, the cyst cavity had disappeared on the panoramic radiograph (Figure 2B); however, occlusal destruction was observed (Figures 2 and 3). Therefore, the patient was referred to the Department of Orthodontics. The patient had a straight facial profile with no asymmetry (Figure 3). Intraorally, the left mandibular canine and first premolar were missing with bone loss in the edentulous space. The overbite and overjet were +3.5 mm and +3.0 mm, respectively. The molar relationship was Class III on both sides, and the mandibular right first molar had a scissor-bite (Figure 3). the panoramic radiograph showed bilateral third molars in the maxilla and mandible (Figure 2B), and computed tomography (CT) images showed buccal bone loss in the edentulous region of the mandible (Figure 2C). Lateral cepharometric analysis showed that the patient had a skeletal Class I malocclusion (ANB = 1.2°), slightly high angle (Frankfort mandibular plane angle [FMA] = 34.1°), average upper incisors (upper incisor to SN plane [U1-SN] = 109.2°) and extreme lingual inclination of lower incisors (Incisor mandibular plane angle [IMPA] = 71.1°) (Table 1, Figure 2). The patient was diagnosed with an Angle Class III malocclusion associated with loss of the lower left canine and first premolar.

Table 1. Cephalometric measurements

Variables	Norm (SD)	Pretreatment	Posttreatment
Maxillomandibular relationships			
SNA (°)	81.4 (3.6)	83.8	84.9
SNB (°)	79.6 (3.9)	82.6	83.6
ANB (°)	1.8 (1.6)	1.2	1.3
Vertical skeletal relationships			
FMA (°)	25.6 (5.6)	34.1	32.2
Gonial angle (°)	112.4 (6.0)	135.7	133.3
Dental relationships			
U1 to SN (°)	105.0 (6.1)	109.2	110.5
U1 to FH (°)	111.2 (5.2)	116.3	117.1
FMIA (°)	58.0 (6.0)	74.8	66.3
IMPA (°)	94.7 (6.9)	71.1	81.5
Interincisal angle (°)	128.3 (8.8)	138.5	129.1
Soft tissues			
Upper lip to E-line (mm)	−1.0 (0.86)	−2.8	−3.2
Lower lip to E-line (mm)	0.0 (0.56)	2.3	0.0

FMIA, Frankfort mandibular incisor angle; IMPA, Incisor mandibular plane angle.

Treatment Objectives and Treatment Plan

The following treatment objectives were established: (1) closure of space in the edentulous region, (2) correction of maxillary crowding, and (3) establishment of functional occlusion.

We considered moving the lower left second premolar mesially and transplanting the extracted upper left lateral incisor or first premolar. Written informed consent was obtained from the patient's parents.

Treatment Progress

We bonded a button to the lower left second premolar lingual surface and placed a lingual arch with a hook. The premolar gradually moved mesially from the lingual button to the hook by an elastic chain. After 5 months, we removed the lingual arch and attached standard edgewise appliances with 0.018-inch slots. The lower left second premolar was again subjected to mesial bodily movement using a 0.016 × 0.016-inch stainless steel wire with a NiTi open-coil (100 gf) spring. We radiographically checked for root paralleling and observed bone formation (Figure 4). Dental

Figure 2. A-C. Pretreatment radiographs. (A) Lateral cephalogram, (B) panoramic radiograph, and (C) axial slice of computed tomography

Figure 3. Pretreatment facial and intraoral photographs

CT showed sufficient space and bone formation not only at the transplanted site but also at the edentulous site (Figure 5). We decided to autotransplant the upper left lateral incisor because its root width was almost coincident with the labiolingual bone width. We confirmed the position of the buccal cortical bone surrounding the second premolar that was moved (Figure 6). Two months after autotransplantation, we performed a root canal of the transplanted upper left lateral incisor (Figure 7). We instructed the patient to wear a Begg retainer for retention.

CASE RESULTS

Posttreatment facial and intraoral photographs showed a normal overbite and overjet (Figure 8). Panoramic radiographs showed a recognizable periodontal space surrounding the root of the autotransplanted lateral incisor (Figure 9B). Lateral cephalometric analysis and superimposition of the pre- and posttreatment lateral cephalograms showed facial growth during the treatment period. (Table 1, Figure 10). Since treatment completion 1 year 7 months ago, the transplanted tooth and occlusion have been stable (Figure 11).

DISCUSSION

In this patient, surgical dentigerous cyst removal caused destruction of occlusion and extensive bone loss. Autotransplantation is known to enhance the alveolar height and tooth eruption process,[4,5] which makes this procedure possible in growing patients rather than

Figure 4. A-C. Dental radiographs during mesial movement of the left mandibular second premolar. (A) 4 months, (B) 10 months, and (C) 14 months

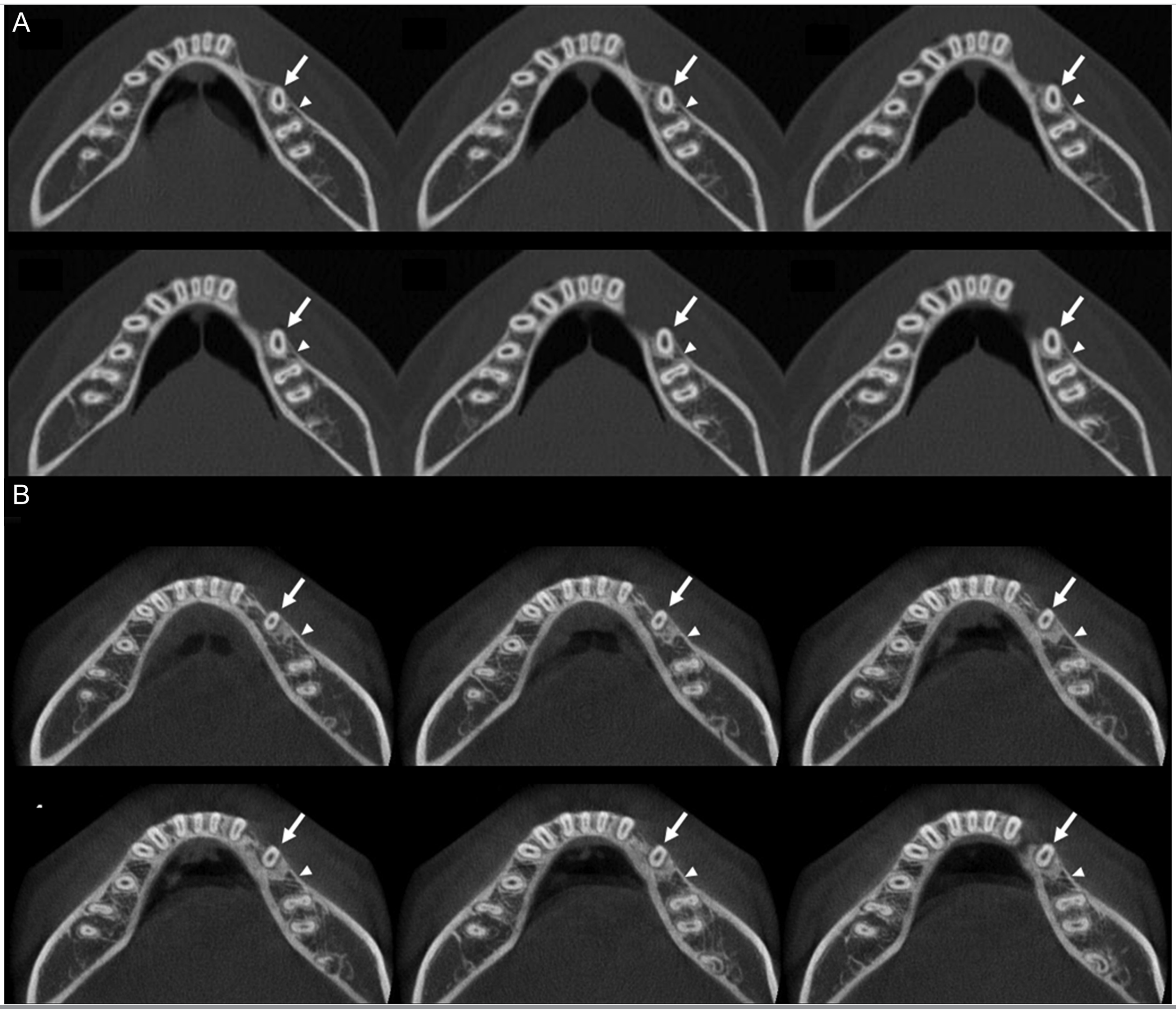

Figure 5. A, B. Axial slice of serial dental computed tomography images (A) before tooth movement and (B) before autotransplantation. Arrow: left mandibular second premolar; arrowhead: autotransplantation site

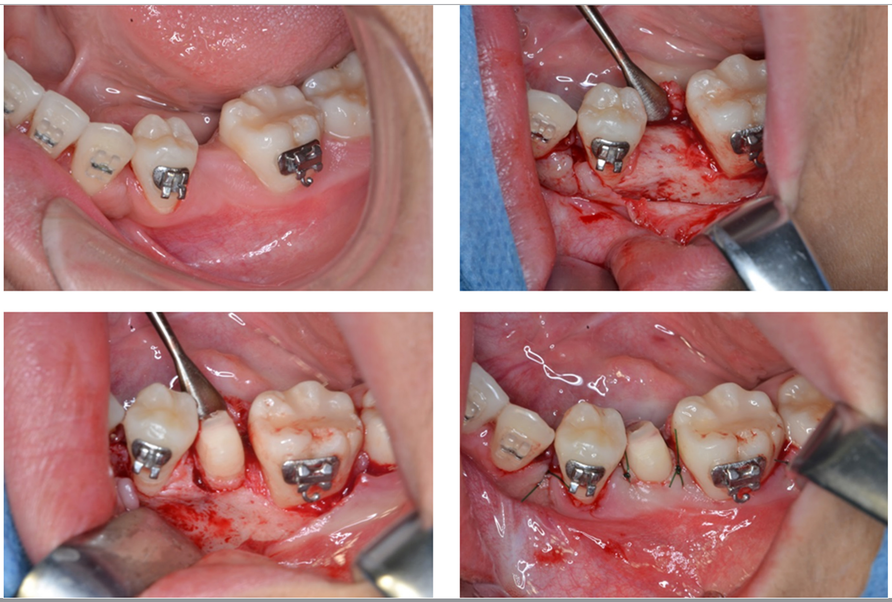

Figure 6. Photographs during autotransplantation

Figure 7. A-C. Dental radiographs after autotransplantation at (A) 2 weeks, (B) 3 months, and (C) 21 months

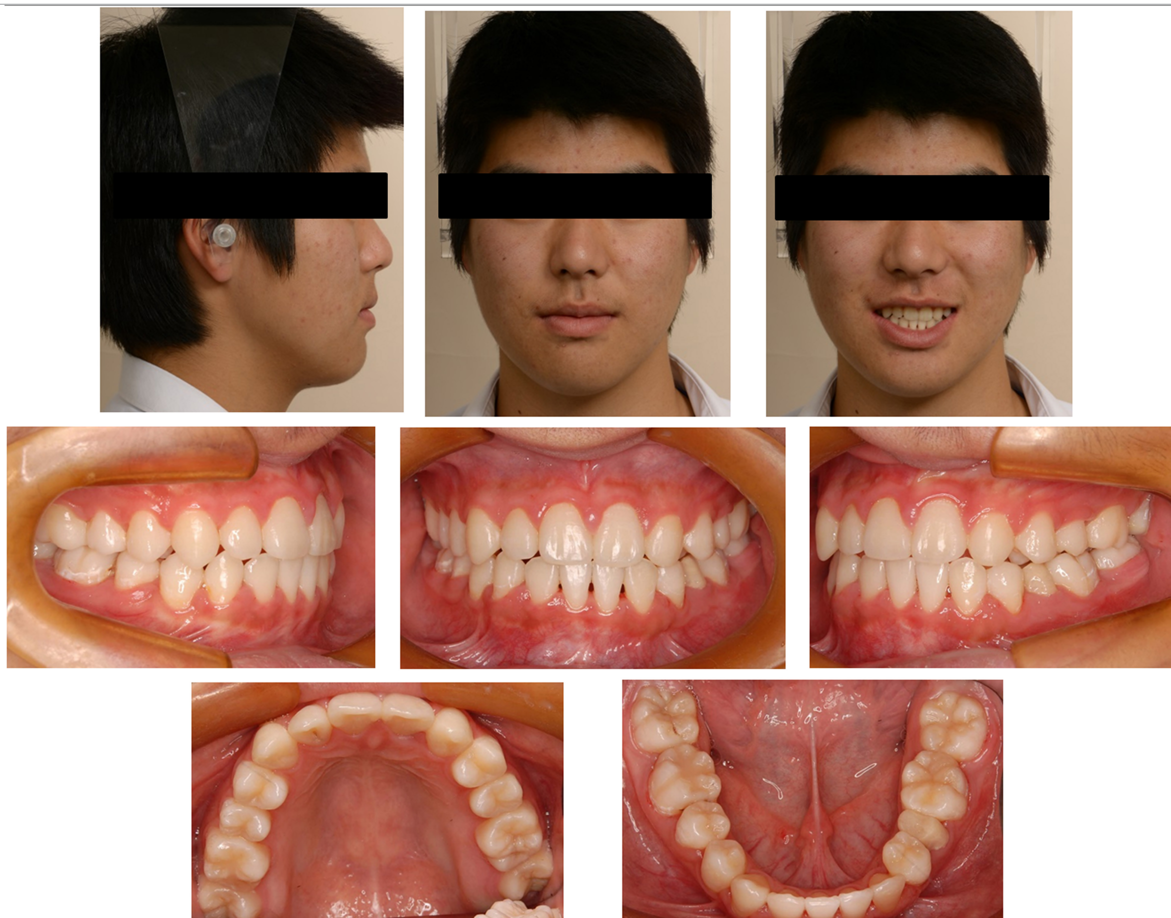

Figure 8. Posttreatment facial and intraoral photographs

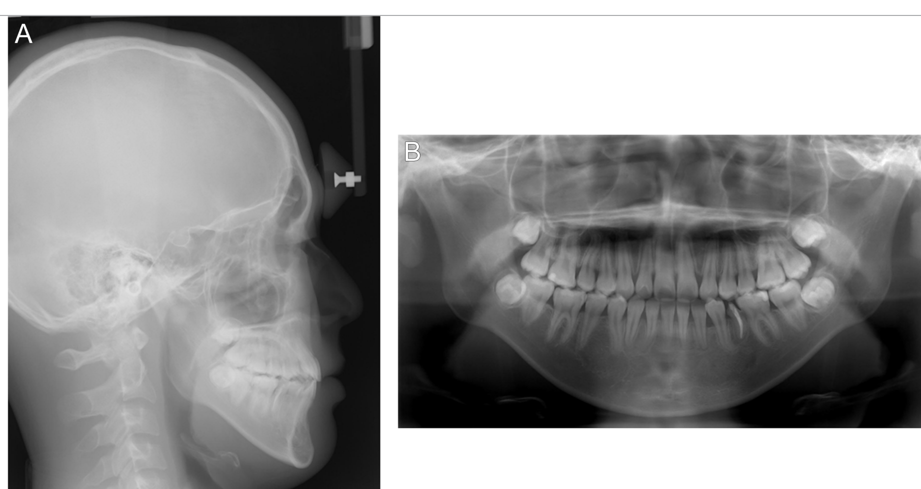

Figure 9. A, B. Posttreatment radiographs. (A) lateral cephalogram and (B) panoramic radiograph

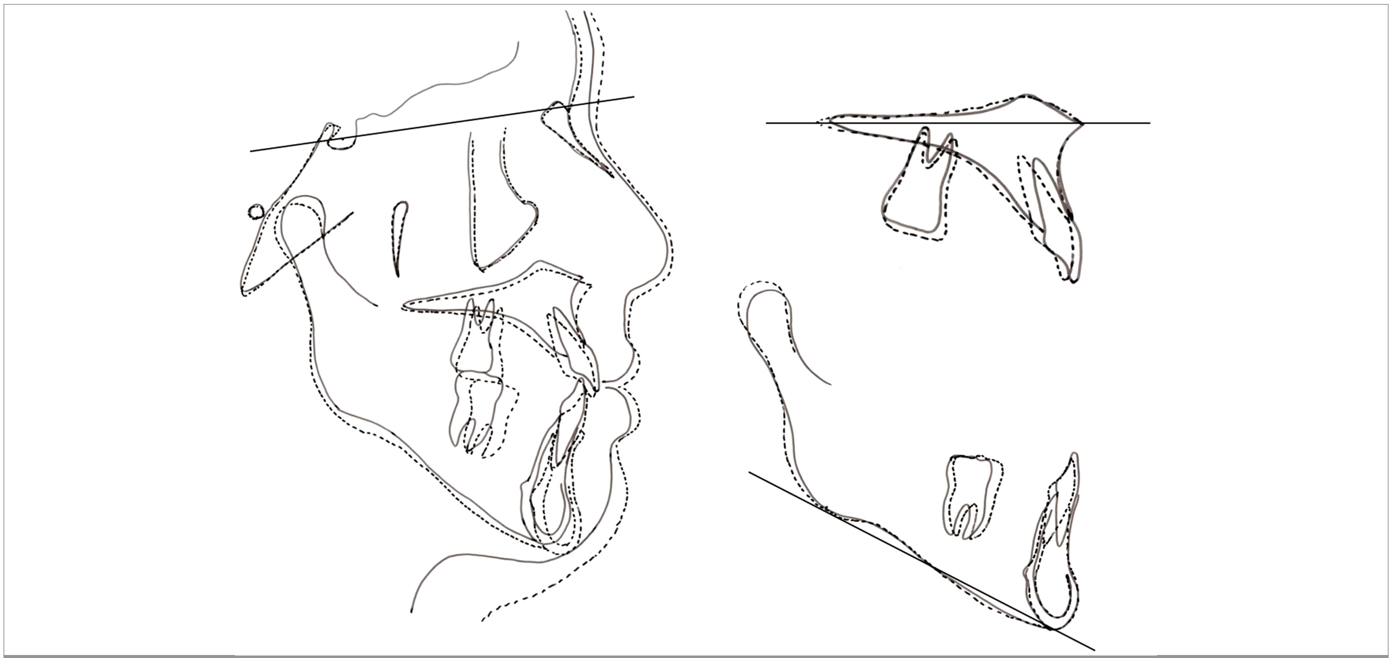

Figure 10. Cephalometric superimpositions. Solid line: pretreatment; dotted line: posttreatment

Figure 11. Postretention intraoral photographs at 1 year 7 months after treatment

dental implants and bridges. However, in our patient, the alveolar ridge was very thin labiolingually. According to Zachrisson,[6] tooth movement can be considered as an alternative to bone grafting. Based on this study, we attempted to move the second premolar to the edentulous region (Figure 4). As a result, we obtained a wide bony ridge on the tension side of the second premolar, which allowed us to autotransplant the maxillary lateral incisor (Figure 6).

However, this method of continuous force using superelastic coil springs has the risk of lateral root resorption.[6] Our patient showed a slight degree of lateral root resorption of the second premolar; we speculated that this was because of the difference in patient age and method of tooth movement.

The survival rate of an autotransplanted tooth ranges from 75.3% to 91%.[7] However, most studies used transplanted teeth with incomplete root formation.[8-11] It is necessary for clinicians to carefully consider whether autotransplantation should be performed or not. Andreasen et al.[8] reported that the healing rate of the pulp in transplanted teeth with complete root formation was only 15%. In our patient, the root of the autotransplanted upper left lateral incisor had formed completely. To prevent tooth loss due to pulp inflammation, pulp extirpation was performed on the incisor 2 months after autotransplantation.

Currently, at 2.5 years after the autotransplantation, the transplanted tooth is stable (Figure 7). It was important to consider the aesthetics and functionality because the canine was moved to the position of the lateral incisor. We reduced the cusp tip and lingual surface of the canine and also lingually torqued the canine root.[12,13] While moving the first premolar to the position of the canine, we reduced the lingual cusp of the premolar and torqued it buccally.[12,13] Using these steps, a functional occlusion was obtained.

CONCLUSION

This case report suggests that orthodontic treatment is effective and safe for growing patients with edentulous spaces and alveolar bone loss. Preserving stable occlusion ultimately improves the masticatory function, aesthetics, and long-term quality of life in patients.

Informed Consent: Written informed consent was obtained from the patient's parents.

Peer-review: Externally peer-reviewed.

Author Contributions: Concept - Y.Y., C.A.; Design - Y.Y., C.A., K.N., T.Y., K.S., G.A., Y.H., H.T.; Supervision - C.A., Y.H., H.T.; Materials - Y.Y., C.A., K.N., T.Y., K.S., G.A.; Data Collection and/or Processing - Y.Y., C.A., K.N., T.Y., K.S., G.A.; Analysis and/or Interpretation - Y.Y., C.A., K.N., T.Y., K.S., G.A., Y.H., H.T.; Literature Review - Y.Y., C.A.; Writing - Y.Y., C.A.; Critical Review - Y.Y., C.A., Y.H., H.T.

Declaration of Interests: The authors have no conflict of interest to declare.

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Review

Preventive Effect of Professional Fluoride Supplements on Enamel Demineralization in Patients Undergoing Fixed Orthodontic Treatment: A Systematic Review and Meta-Analysis

Elham Babadi Oregani[1], Alireza Jafari[2], Seyed Masoud Sajedi[3], Saeed Reza Motamedian[4]

[1]Under graduate student, Student Research Committee, School of Dentistry, Shahid Beheshti University of Medical Sciences, Tehran, Iran
[2]Department of Prosthodontics, School of Dentistry, Bushehr University of Medical Sciences, Bushehr, Iran
[3]Department of Oral and Maxillofacial Medicine, School of Dentistry, Shahed University, Tehran, Iran
[4]Department of Orthodontics, Dentofacial Deformities Research Center, Research Institute of Dental Sciences, School of Dentistry, Shahid Beheshti University of Medical Sciences, Tehran, Iran

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Main Points

- Following evaluation of a total of 615 articles, 7 articles were included in this systematic review and 3 of them were analyzed quantitatively.
- Application of fluoride varnish with at most 3 months interval or daily use of mouthwash or high-fluoride toothpaste reduces the number of white spot lesions (WSLs) in patients undergoing orthodontic treatment.
- One study reported that one-time use of fluoride varnish has no significant effect on WSLs, and orthodontists should apply fluoride varnish multiple times (4-20 times, at least every 12 weeks) during treatment.

ABSTRACT

Objective: The current study aimed to systematically review the randomized clinical trials assessing the preventive effect of professional fluoride interventions on enamel demineralization in patients undergoing fixed orthodontic treatment.

Methods: The electronic search was performed in PubMed and Cochrane library in September 2021. No restriction was set on the publication date. Randomized clinical trials assessing the preventive effect of fluoride varnish, gel, mouthwash, and high-fluoride toothpaste on white spot lesions compared to the control group by clinical or radiographic methods in more than 10 patients were included.

Results: A total of 7 articles consisting of 1418 participants were included. In 4 articles, fluoride varnish (contained a range of 1000-50 000 ppm fluoride) was applied multiple times (4-20 times) in test groups. Their results indicated that the test groups significantly had lesser new white spot lesions or advanced white spot lesions. One study used fluoride varnish only once at the beginning of treatment and reported no significant difference in white spot lesions compared to the control group. Application of high-fluoride toothpaste as well as fluoride mouthwash, also, showed significantly lower white spot lesions. Three studies were included in the meta-analysis and revealed that the relative risk of white spot lesions was 0.64 (95% CI = 0.40 to 0.89; $P < .01$) in favor of fluoride varnish.

Conclusion: Multiple applications (4-20 times) of fluoride varnish or daily use of fluoride mouthwash or high-fluoride toothpaste seem to reduce white spot lesions in patients undergoing orthodontic treatment. However, single use of fluoride varnish was not effective. Further research is needed to establish the required number of fluoride applications for the prevention of white spot lesions during orthodontic treatment.

Keywords: Fluorides, fluoride varnish, orthodontics, white spot lesion, systematic review

Corresponding author: Saeed Reza Motamedian, e-mail: drmotamedian@gmail.com

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INTRODUCTION

Orthodontic treatments are performed not only to correct the jaw and teeth malpositions but also to improve the aesthetic aspects of patients.[1] However, its potential disadvantages such as tooth demineralization must be considered because it harms the esthetic outcome of orthodontic treatment and untreated white spot lesions (WSLs) may progress to tooth caries. Orthodontic brackets affect the oral cavity and microbial variables and also provide a large area for cariogenic bacteria to adhere to the teeth and make oral hygiene more difficult.[2,3] So, enamel demineralization or WSLs formation is one of the most common adverse effects of orthodontic treatments including fixed appliances.[4] A meta-analysis reviewing 14 articles reported a total of 68.4% for prevalence and a total of 45.8% for incidence of WSLs after orthodontic treatment.[5] Tufekci et al.[6] revealed that WSLs had occurred rapidly during the first 6 months of treatment that continued to rise at a slower rate to 12 months (prevalence of WSLs before, at 6 months, and 12 months were 11%, 38%, and 46%, respectively). Similar findings were reported in the studies of Lucchese et al.[7] Farishta et al.[8] and Kawsar et al.[9] Although several methods have been proposed to remineralize the enamel (e.g., topical fluoride, amorphous calcium phosphate, or self-assembling peptides) or to mask and improve the esthetic appearance of these lesions (e.g., bleaching, micro-abrasion, or resin infiltration), there is little reliable scientific evidence of the efficacy of remineralization methods,[10] hence, it would be better to prevent tooth demineralization during orthodontic treatment.

There are different methods to prevent or reduce the development of tooth demineralization, including improvement of oral hygiene,[11] casein phosphopeptide-amorphous calcium phosphate application,[12] toothpaste or gel with a high concentration of fluoride,[13,14] different sealants,[15] using bioactive resin adhesive,[16] as well as fluoride mouthwash and varnish.[17-22] Fluoride supplements such as varnish release fluoride ions during the treatment period.[23] Fluoride ions substitute some hydroxyl ions of hydroxyapatite in the tooth structure and create fluorohydroxyapatite. The solubility product constant (K_{sp}) for fluorapatite is lower because of its more compact crystal structure, and therefore, it resists acid attack better.[24] Also, fluoride has cariostatic mechanisms that improve oral hygiene and prevent enamel demineralization.[25] Ekenback et al.[26] revealed that fluorides could reduce lactic acid formation in associated growing biofilms of *Streptococcus mutans*.[26] Amine fluorides in enough concentration could reduce the number of *Streptococcus sobrinus* and inhibit glucosyltransferase activity in the biofilm system.[27] Also, fluoride agents could lead to mineral crystallite growth with preferential calcium uptake.[28]

There is a controversy regarding the effectiveness of fluoride supplements on WSL prevention during orthodontic treatment. Some studies revealed that fluorides can reduce enamel demineralization,[18,19] whereas some others reported that the fluorides have no significant effect on WSLs formation.[17,22] In addition, a recent study[17] that had opposite results compared to previous reviews necessitated updating previous systematic reviews. The current study aimed to systematically review articles assessing the preventive effect of professional fluoride interventions on the prevention of enamel demineralization in patients undergoing fixed orthodontic treatment.

METHODS

Eligibility Criteria

The title of the current systematic review was according to the Participants-Intervention-Comparison-Outcome-Study design framework as follows: (I) Preventive effect of professional fluoride supplements (C) compared to placebo or control group on (O) enamel demineralization in (P) patients undergoing fixed orthodontic treatment. Preferred reporting items for systematic review and meta-analysis (PRISMA[29]) reporting guidelines were followed to conduct this study. The inclusion and exclusion criteria for articles are presented in Table 1.

Information Sources

The electronic search was performed in Medline via PubMed and Cochrane library in November 2020 and updated in September 2021. The references of included studies and previous systematic reviews were also reviewed to identify any potential study to be included in this study.

Table 1. Inclusion and Exclusion Criteria

	Inclusion	Exclusion
P = fixed orthodontic patient	More than 10 orthodontic patients with fixed appliances. No restriction on sex, age, or systematic condition.	Assessing the effects of fluorides after debonding on the treatment of WSLs
I = professional fluoride supplements	Fluoride varnish, mouthwash or gel, and toothpaste with a high concentration of fluoride.	Combination of fluoride with other agents
C = control group	No treatment or placebo	
O = enamel demineralization	Prevention of orthodontically induced white spot lesion formation Clinical visual assessment or radiographic methods should be performed to assess the amount of enamel demineralization.	Treatment of orthodontically induced WSLs Evaluation of tooth demineralization by sectioning methods
S	Randomized clinical trials	

WSLs, white spot lesions.

Search
Table 2 presents the search queries, including the combination of keywords. The search was restricted to the English Language. No restriction was set on the publication date.

Study Selection
After the electronic search, the lists of obtained studies were entered into Endnote20 software and duplicate papers were excluded. Then, one of the authors (E.B.) screened the titles and abstracts of the remaining studies according to inclusion and exclusion criteria. Full texts of the selected studies were assessed for eligibility to include in the current study. Any uncertainty over the final inclusion was resolved through discussion with the second author (S.R.M.).

Data Collection Process
The characteristics and data from included studies were extracted by one of the authors (E.B.) and checked independently by the second author (S.R.M.).

Data Items
The data extraction includes items as follows: author and year of publication, study design, sample size, demographic details of the study participants, type of intervention (fluoride varnish, mouthwash, or toothpaste), type of control (placebo or no treatment), frequency of application, duration of follow-up, type of outcome assessment, and results. For the meta-analysis, the number of patients without WSLs and who had at least 1 WSL in both test and control groups were also extracted.

Risk of Bias in Individual Studies
The included articles were assessed according to the Cochrane risk of bias tool. The following domains were used to evaluate the risk of bias: random sequence generation and allocation concealment, blinding of participants and personnel, blinding of outcome assessment, incomplete outcome, selective reporting, and other bias. The articles were considered in the low risk of bias (if it was a low risk of bias for all key domains) or unclear risk of bias (if it was low or unclear risk of bias for all key domains) or high risk of bias (if it was high risk of bias for one or more key domains).[30]

Summary Measures
To evaluate the preventive effect of fluoride varnish on WSLs, relative risks (RR) were computed. In collecting information, where data were missing, they were calculated based on data presented in tables or graphs in the articles.

SYNTHESIS OF RESULTS

Meta-analysis was performed by STATA 16 software on RR and its 95% CI. The impact of between-study heterogeneity was assessed by interpreting the forest plot by calculating the I^2 statistics and Cochrane Q statistics. As heterogeneity was detected among included studies, a random model following maximum likelihood was used.

RESULTS

Study Selection
Figure 1 shows the PRISMA flowchart of study selection. A total of 615 articles were obtained in search, and after the screening, the full texts of 34 articles were assessed for eligibility and quality. Ultimately, 7 articles were included in this systematic review, and 3 of them were entered into quantitative analysis.

Study Characteristics
The study characteristics are presented in Table 3. A total of 1418 participants were included;188 participants were in the high-fluoride toothpaste group, 36 participants were in the fluoride mouthwash group, 418 participants were in the varnish fluoride groups, and 636 participants were in the control groups. Also, 140 participants were in other test groups whose interventions were not considered in the current study.

The design of all articles was parallel-group RCTs.[14,17-22] In 5 of them,[17,18,20-22] the effect of varnish fluoride, in one of them,[19] the effect of fluoride mouthwash, and in another one,[14] and the effect of high-fluoride toothpaste were assessed.

In 4 varnish fluoride studies, participants in test groups received fluoride varnish several times (4-20 times) during their treatment, whereas, those in control groups received placebo varnish or no treatment.[17,18,20,21] Kirschneck et al.[22] applied 2 types of fluoride varnish for patients in the test groups just once at the beginning of the treatment and used placebo varnish for patients in the control group. In the study of van der Kaaij et al.[19], participants used fluoride and placebo mouthwash in test and control groups at home, respectively. In the study of Sonesson et al.[14], participants in the test group had to brush twice a day with high-fluoride toothpaste (contains 5000 ppm fluoride), whereas

Table 2. Search query

Database	Search Query
PubMed	(“Orthodontic appliances, Fixed”[MeSH] OR “Orthodontic bracket”[MeSH] OR “Orthodontics”[MeSH] OR “Orthodontic treatment”) AND (“Dental cavity lining”[MeSH] OR “Allsolution fluoride varnish”[MeSH] OR “Bifluoride 12”[MeSH] OR “Fluorides”[MeSH] OR “Mouthwashes”[MeSH] OR “Paint”[MeSH] OR “Fluorides, Topical”[MeSH] OR “amine fluoride solution”[MeSH] OR “amine fluoride gel”[MeSH] OR “toothpastes”[MeSH] OR “dentifrices”[MeSH] OR “Varnish fluoride” OR “fluoride gel” OR “gel” OR “amine fluoride”) AND (“Tooth demineralization”[MeSH] OR “early enamel lesion” OR “White spot lesion”)
Cochrane	(“Orthodontic appliances, Fixed” OR “Orthodontic bracket” OR “Orthodontics” OR “Orthodontic treatment”) AND (“Dental cavity lining” OR “Allsolution fluoride varnish” OR “Bifluoride 12” OR “Fluorides” OR “Mouthwashes” OR “Paint” OR “Fluorides, Topical” OR “amine fluoride solution” OR “amine fluoride gel” OR “toothpastes” OR “dentifrices” OR “Varnish fluoride” OR “fluoride gel” OR “gel” OR “amine fluoride”) AND (“Tooth demineralization” OR “early enamel lesion” OR “White spot lesion”)

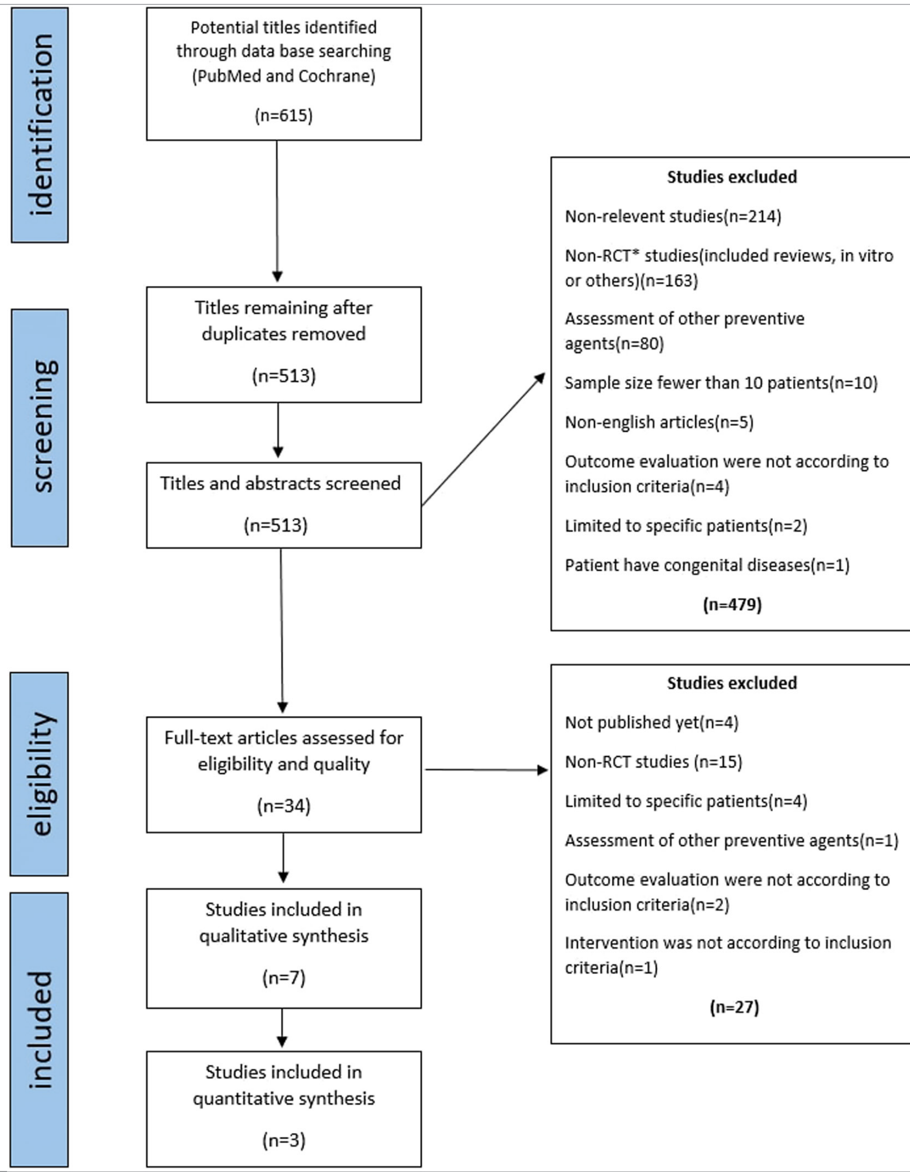

Figure 1. Preferred reporting items for systematic review and meta-analysis flowchart

participants in the control group had to use a toothpaste containing 1450 ppm fluoride for brushing.

In order to evaluate the numbers of WSLs, digital photographs,[14,17,18,20] quantitative light-induced fluorescence images,[19] clinical examinations,[21] as well as the ICAD index[22] were used.

Risk of Bias Within Studies

Figure 2 shows the risk of bias assessment of 7 included articles. Five out of 7 articles were low risk of bias and others were high risk of bias.

RESULTS OF INDIVIDUAL STUDIES

Results of 5 out of 7 studies[14,17-21] in which participants received varnish fluoride multiple times or they used fluoride mouthwash or high-fluoride toothpaste daily indicated significant differences between test and control groups; the number of WSLs or advanced WSLs or ICAD index value was lesser in the fluoride groups. In the study of Kirschneck et al.[22] in which the fluoride varnish was applied only once, there was no significant effect on WSLs compared to the control group.

SYNTHESIS OF RESULTS

The meta-analytical overall estimate of 3 studies with multiple applications of fluoride varnish is demonstrated in Figure 3. Meta-analysis indicated the studies were heterogeneous (I^2 = 63.63%; P = .01). The results of the meta-analysis revealed the data were in favor of using fluoride varnish and the RR was 0.64 (95% CI = 0.40 to 0.89; $P < .01$).

DISCUSSION

Summary of Evidence

Early enamel demineralization usually occurs during orthodontic treatment with fixed appliances. There are different methods to prevent this event. The current systematic review summarized

Table 3. Data extraction

Study	Design	Sample Size; Number of Arms	Age; Sex	Intervention	Control Group	Dose, Frequency, and duration	Duration of Follow-Up	Outcome Assessment	Result
Sonesson et al.[20]	Parallel group RCT	142 2 arms T* = 71 C* = 71	12-18 years F = 58% M = 42 %	Varnish contained 7700 ppm fluoride as ammonium fluoride	Varnish contained no fluoride	A thin layer every sixth week 13.2 times	1.7 years SD = 0.45	Digital photos	WSLs: test < control
Sonesson et al.[17]	Parallel group RCT	148 2 arms T = 75 C = 73	12-18 years F = 58% M = 42 %	Varnish contained 7700 ppm as ammonium fluoride	Varnish contained no fluoride	A thin layer every sixth week	1.7 years SD = 0.5	Digital photos	Advanced WSLs: test < control
Kirschneck et al.[22]	Parallel group RCT	90 3 arms T1 = T2 = C = 30	10-17 years	T1 = elmax fluid varnish (10 000 ppm fluoride as amine fluoride) T2 = fluor protector S varnish (7700/29 000 (dried) ppm fluoride as ammonium fluoride)	Placebo varnish	One time; a thin layer (0.2-0.3 mL) varnish	20 weeks	Assessment of ICADS index	ICADS index: No difference between groups
Van der Kaaij et al.[19]	Parallel group RCT	81 2 arms T = 36 C = 45	10-16 years M = 35 F = 46	Mouth rinse contained 250 ppm fluoride	Fluoride-free placebo rinse	Daily; 100 ppm amine fluoride and 150 ppm sodium fluoride	24.5 ± 5.5 months	Assessment of DMFT and ICDAS, QLF images for assessment of WSLs	WSLs: test < control
Sonesson et al.[14]	Parallel group RCT	380 2 arms T = 188 C = 192	11-16 years	T: high fluoride toothpaste (containing 5000 ppm sodium fluoride)	Regular fluoride toothpaste (containing 1450 ppm sodium fluoride)	Brushing twice a day; 2 cm (approximately 1 g) on brush	1.8 years SD = 0.53	Digital photos	WSLs: test < control
Stecksen Blicks et al.[18]	Parallel group RCT	257	12-15 years	Fluoride varnish	Placebo	Every check-up visit;	When the	Digital photos	WSLs:

(Continued)

Table 3. Data extraction (continued)

Study	Design	Sample Size; Number of Arms	Age; Sex	Intervention	Control Group	Dose, Frequency, and duration	Duration of Follow-Up	Outcome Assessment	Result
Stecksen Blicks et al.[18]		T = 132 C = 125		contained 1000 ppm fluoride as difluorosilane	varnish	0.2-0.3 mL 4-20 times	treatment ended		test < control
Ogaard et al.[21]	Parallel group RCT	320 3 arms T1 = 110 T2 = 110 C = 100	12-15 years	T1 = antimicrobial chlorhexidine and fluoride varnishes (50 000 ppm fluoride as difluorosilane) T2 = fluoride varnish (50 000 ppm fluoride as difluorosilane)	No treatment	Every 12 weeks	When the treatment ended	Clinical examination	WSLs: test2 < control

RCT, randomized clinical trials; T, test group; C, control group; F, female; M, male; SD, standard deviation; WSLs, white spot lesions; ICADS, International Caries Detection and Assessment System; DMFT, decayed, missing, and filled teeth; QLF, quantitative light-induced fluorescence.

evidence from RCTs on the preventive effect of professional fluoride supplements on enamel demineralization in undergoing fixed orthodontic patients. Results were favoring the multiple uses of fluoride varnish, toothpaste, and mouthwash to prevent WSLs. However, it seems that one-time use of varnish fluoride does not have a significant preventive effect.[22] Similarly, Rosin-Grget et al.[25] revealed that the use of topical fluoride agents only one-time has no more caries-protective effect, whereas a constant supply of low levels of fluoride in biofilm, saliva and toothpaste is considered the most beneficial in preventing dental caries.

Varnishes with different concentrations of fluoride are available. Since the current study included studies that had different protocols and frequencies for applying fluoride, and it was not feasible to compare the effect of fluoride concentration on the prevention of WSLs. Yongmei et al.[31] compared 4 varnishes with various concentrations (22 000, 10 000, 5000, and 2200 ppm) and concluded that acid resistance of enamel between 22 000 or 10 000 treatment groups was not significantly different, while both high-dose groups had significantly more acid resistance. Therefore, increasing the concentration of fluoride supplements to some level enhances the preventive effect. Further research is needed to compare the effect of varnishes containing different fluoride concentrations in the patients undergoing orthodontic treatments.

Although the current study included more articles compared to the previous systematic reviews, it was in line with their results. In meta-analysis of Sardana et al.[32] RR was 0.39 (95% CI = 0.26 to 0.59; P = .005), and in Tasios et al.[33] it was 0.46 (95% CI = 0.18 to 1.15).

Among 7 articles, 5 were adjudged to be of low overall risk.[14,17,19,20,22] The result of these articles had a controversy about the preventive effect of fluorides. Sonesson et al.[17,20] stated in their studies that the effect of fluoride supplements is only on advanced WSLs. Advanced WSLs are defined as the WSLs with scores 3 and 4 according to the 4-step index of Gorelick et al.[34] In this index, lesions with score 2 are named slight WSLs, and score 1 is associated with patients with no lesions. Kirschneck et al.[22] stated that there was no significant reduction in WSLs formation by using fluorides; however, it seems to be due to the use of varnish only in the initial treatment session and not repeated in subsequent sessions. Another 2 articles[18,21] were adjudged to be of high overall risk. These articles had similar results, using fluoride varnish reduces WSLs formation. Consequently, it is needed to perform studies with better design and pay attention to the risk of bias tools, particularly, blinding and allocation concealment.

The electronic search was performed in 2 search engines (PubMed and Cochrane) and was also limited to the English literature.

CONCLUSION

Evidence from included studies presented that the use of varnish fluoride multiple times (4-20 times) or daily use of high-fluoride

	sequence generation	allocation concealment	blinding of participants and personnel	blinding of outcome assessment	incomplete outcome	selective reporting	Other bias	**Overall**
Sonesson et al. (16)	+	+	+	+	+	+	+	Low
Sonesson et al.(13)	+	+	+	+	+	+	+	Low
Kirschneck et al.(18)	+	+	+	+	+	+	+	Low
Van der Kaaij et al.(15)	+	+	+	+	+	+	+	Low
Sonesson et al.(10)	+	+	+	+	+	+	+	Low
Stecksen Blicks et al.(14)	+	+	+	+	-	+	+	High
Ogaard et al. (17)	+	-	-	-	+	+	+	High

Figure 2. Risk of bias summary

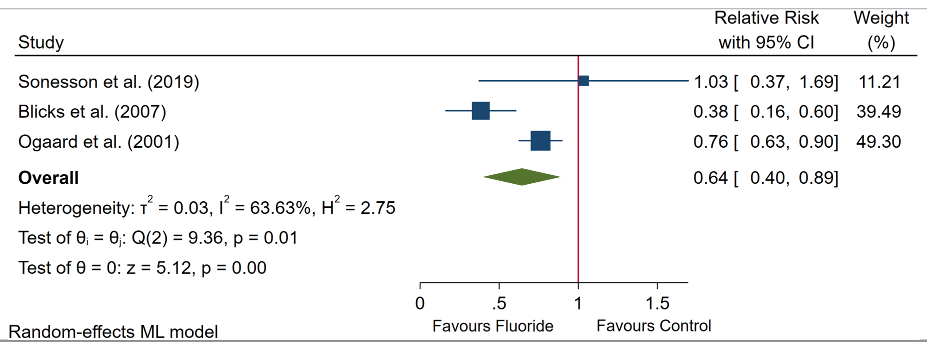

Figure 3. Forest plot comparing the relative risk of fluoride varnish and placebo on white spot lesions in patients undergoing fixed orthodontic treatment

toothpaste or fluoride mouthwash reduces the risk of enamel demineralization during fixed orthodontic treatment. However, a single application of fluoride varnish did not have a significant effect. Further research is needed to establish the most favorable interval of fluoride applications and dose (fluoride varnish, mouthwash, gel, or toothpaste) to prevent WSL formation in orthodontic patients.

Peer-review: Externally peer-reviewed.

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