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TURKISH JOURNAL of ORTHODONTICS

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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.

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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.

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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.

Manuscripts Accepted for Publication, Not Published Yet: Slots J. The microflora of black stain on human primary teeth. Scand J Dent Res. 1974.

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Manuscripts Published in Electronic Format: Morse SS. Factors in the emergence of infectious diseases. Emerg Infect Dis (serial online) 1995 Jan-Mar (cited 1996 June 5): 1(1): (24 screens). Available from: URL: http:/ www.cdc.gov/ncidodlElD/cid.htm.

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Original Article

Stress Distribution and Displacement of Craniofacial Structures Following Rapid Maxillary Expansion in Different Types of Cleft Palate: A Three-Dimensional FEM Study

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Main Points

- Different types of clefts demonstrated different patterns of stress distribution.
- The highest stress accumulation was observed in the isolated cleft model.
- The level of stress distributed at the cleft side was greater than that at the non-cleft side.
- The maximum transversal expansion was observed in the bilateral cleft model.

ABSTRACT

Objective: To evaluate displacements and stress distributions in finite element models (FEMs) of the craniofacial complex of 13-year-old male patient with complete unilateral cleft palate (UCP), a 15-year-old female patient with complete bilateral cleft palate (BCP), and a 15-year-old female patient with isolated cleft palate (ICP), which may respond differently to expansive forces.

Methods: The FEMs were based on computed tomography scans of patients with UCP, BCP, and ICP who needed maxillary expansion. Von Mises stress distribution after 0.2 mm of expansion and displacements after 5 mm of expansion were investigated.

Results: The highest amount of stress was observed in the ICP model. Surprisingly, no stress was noted around the nose in the BCP model. The amount of dentoalveolar expansion decreased from anterior to posterior on the cleft side of the UCP, BCP, and ICP models. In contrast, on the non-cleft side of the UCP model, the maximum dentoalveolar expansion occurred at the molar area, decreasing toward the anterior parts. Anatomical structures expressed posterior displacement in the UCP model. In the ICP model, structures close to midline showed anterior displacement, while structures in the lateral parts showed posterior displacement. In contrast with the other 2 models, the structures in the BCP model showed anterior displacement. Vertically, all the anatomic structures in the BCP model showed inferior displacement, while in the ICP and UCP models, only the structures close to the midline showed inferior displacement.

Conclusion: Maxillary expansion caused different patterns of stress distribution and displacement in different types of clefts. Clinicians should consider the type of the cleft, and may expect differing patterns of widening following maxillary expansion.

Keywords: Unilateral, bilateral, isolated, cleft palate, rapid maxillary expansion, finite element method

INTRODUCTION

Cleft lip and palate (CLP) is one of the most common congenital anomalies affecting the facial structure, characterized by underdeveloped maxilla in the transverse, sagittal, and vertical planes.[1] Both environmental and genetic factors are involved in their formation. This condition requires a meticulous multidisciplinary approach for dental treatments and orthognathic rehabilitation.[2]

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It is common to see a maxillary transverse deficiency, constricted upper arch, and crossbite in patients with CLP, related to underdeveloped maxilla and scar tissue contractions following repair surgeries.[3] Even though the necessity of long-term retention because of the tendency to relapse are mentioned in the literature, rapid maxillary expansion (RME) is often applied to correct the transverse discrepancies in CLP patients.[3]

The finite element method (FEM) is a helpful mathematical tool to use in dentistry, in which the shape of complex geometric objects and their physical properties are simulated digitally. The greatest advantage of this method is the ability to predict changes in areas where measurement is not possible in living individuals. However, the FEM results are highly dependent on the quality of the constructed models. Therefore, the models must be developed to approximate the real object as closely as possible in various aspects. Increasing the number of elements used in the FEM increases the accuracy of the results.[4,5]

Many studies in the literature examined the effects of RME in patients without a cleft. It has been documented in clinical and finite element analysis studies that circummaxillary and craniofacial structures are affected with and displaced by this orthopedically effective procedure.[5,6] The effects of the RME vary depending on the design of the expansion appliances, the supporting structures, and the resistance of the anatomical structures depending on the age of the patients.[4] However, there is no study on the changes related to RME in patients with different cleft types, in whom the outcomes of this procedure might have particularly crucial importance due to lack of integrity of the surrounding anatomic units.

This study aimed to evaluate the patterns of displacement and stress distribution in the craniofacial complex using an RME appliance in 3 models with different types of CLP—bilateral, unilateral, and isolated cleft palate—by using finite element analysis (FEA).

METHODS

3D finite element models (FEMs) were generated using data extracted from archived dental volumetric tomography (DVT) scan images of a 13-year old male patient with complete unilateral cleft palate (UCP), a 15-year-old female patient with complete bilateral cleft palate (BCP), and a 15-year-old female patient with isolated cleft palate (ICP) (isolated cleft of the secondary palate) with institutional review board approval. In addition, the bilateral cleft patient had posterior bilateral crossbite, the unilateral cleft patient had anterior crossbite, and the isolated cleft patient had posterior bilateral crossbite. All the patients previously signed an informed consent form stating that their archive data could be used for scientific purpose.

CT scan images recorded with 5-mm intervals were taken in the axial direction while the Frankfort plane was parallel to the horizontal plane. The Digital Imaging and Communications in Medicine (DICOM) data of the DVT scan was imported using Mimics software (Version 10.01; Materialize, Leuven, Belgium), the bone tissue was calibrated, and models containing only the nasomaxillary complex and the cranial bones were obtained by subtracting the mandibular and vertebral parts from the whole cranium. The models' surfaces were smoothened by clearing the sharp bone margins or filling the bone defects using Geomagic Design X (Rock Hill, SC, USA).

Solid models were created using SOLIDWORKS 2016 software (SOLIDWORKS Corp, Waltham, MA, USA) and, geometric points along the detectable centerline of the facial bones were defined and assigned X, Y, and Z coordinates, which were fed into the preprocessor of the software for grid generation. An expansion appliance containing a Hyrax screw (Leone, Florence, Italy) was modeled and positioned parallel to the midpalatal suture, as close to the palate as possible (Figure 1). ANSYS Version 17.0 (Canonsburg, PA, USA) was used for the FEA. In addition, a zero-displacement and rotation boundary condition was defined on the nodes along with the foramen magnum. This study was approved by the ethics committee of the clinical researches (03.06.2015-11/16), and DVTs used in the study were selected from previous images taken for clinical orthodontic treatment.

The bone volumes were meshed with 10-node tetrahedral elements. The UCP model consisted of approximately 1 799 565 tetrahedral elements and 2 785 413 nodes, the BCP model consisted of approximately 1 609 498 elements and 2 508 593 nodes. The ICP model consisted of approximately 2 117 163 tetrahedral elements and 3 198 386 nodes (Figure 2).

The material properties were assigned to the various structures, referring to previous studies (Table 1).[7-9] Materials in the analysis were assumed to be linearly elastic, isotropic, and homogeneous.

Zero-displacement and rotation boundary conditions were defined on the nodes around the foramen magnum, and all the displacements were restricted to this area. Von Mises stress

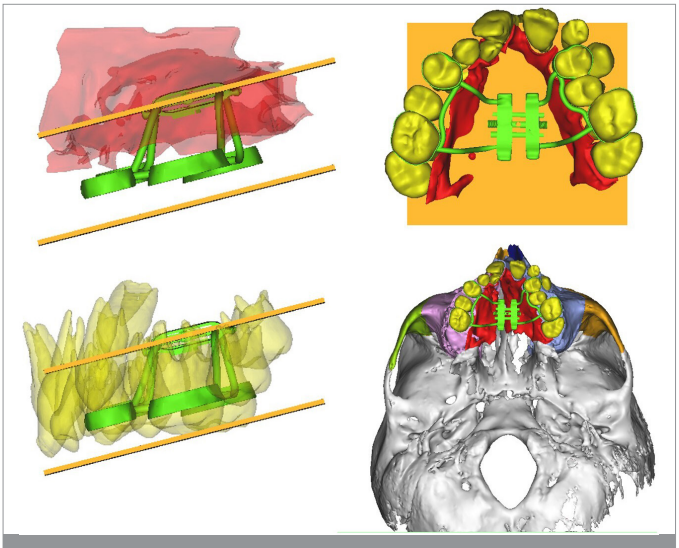

Figure 1. Modeling of the Hyrax appliance.

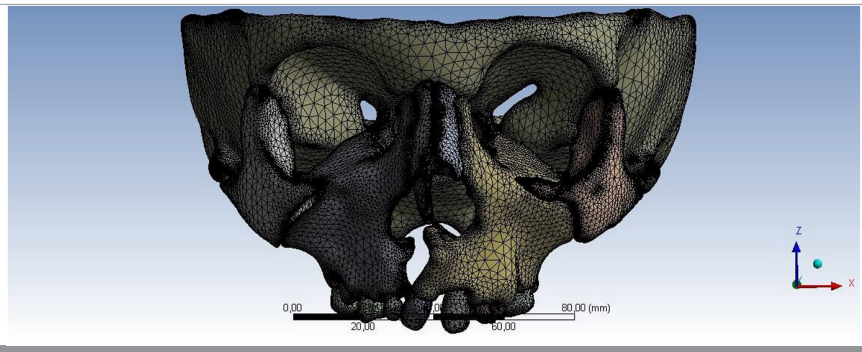

Figure 2. Finite element solid model.

distribution was evaluated following 0.25 mm of screw opening, and displacements resulting from 5 mm of expansion were analyzed.

RESULTS

Displacements

The 3D coordinates were recorded for various craniofacial structures before and after the screw activation in all 3 dimensions (x, transverse plane; y, sagittal plane; and z, vertical plane). Displacements of the anatomic units following 5 mm of screw opening in different types of cleft models are given in Table 2. Mean displacements were calculated for the bilateral and isolated cleft palate (CP). Positive changes indicated outward, backward, and downward displacements (Figure 3A-C, Table 2).

In the UCP model, the anatomic units showed more displacement at the cleft side than those located at the non-cleft side, indicating that expansion forces do not have symmetric outcomes. The maximum lateral displacement on the non-cleft side for maxillary teeth was observed at the molar area. On the other hand, the amount of displacements on the cleft side tended to decrease along the canine region toward the posterior segment. The amount of antero-posterior displacements in the cleft and non-cleft sides were once again uneven, but in general, structures in both cleft and non-cleft sides displaced posteriorly. The nasomaxillary complex opened in a triangular shape with the base downwards as expected. In the vertical plane, the structures close to the midline, such as the internasal, frontonasal, frontomaxillary, and nasomaxillary sutures, displaced downward. On the other hand, the structures located more laterally, such as zygomaticotemporal or zygomaticomaxillary sutures, showed upward displacement.

Table 1. Properties of materials used in the finite element model analysis

	Young's modulus (MPa)	Poisson's ratio
Compact bone	13 700	0.3
Cancellous bone	1370	0.3
Suture	10	0.49
Tooth	20 290	0.3
PDL	0.68	0.49
Stainless steel	210 000	0.3

In the BCP model, dental units showed a marked amount of displacement in the transverse plane. The amount of displacement tended to decrease along the canine region toward the posterior segment. The anterior displacement of the dentoalveolar units was decreasing toward the posterior part. The internasal and frontonasal suture regions showed no displacement in the transverse, anteroposterior, and vertical planes. All other anatomic structures showed a tendency to displace inferiorly.

In the ICP model, the expansion resulted in a wedge-shaped opening in the transverse plane. The lateral displacement of the anterior structures was greater than the lateral displacement of the posterior structures. Similarly, inferior structures showed more lateral displacement than superior structures. In the Y-axis, structures close to the midline showed anterior displacement (frontonasal suture, ANS, apical region of incisors, apical region of canine), while structures in the lateral parts showed posterior displacement. In the vertical plane, structures close to the midline showed inferior displacement, while the lateral structures tended toward superior displacement.

von Mises Stress Distributions

The von Mises stress distributions following 0.2 mm of screw opening in different CP models are given in Table 3. In the unilateral cleft model, the maximum von Mises stress accumulation was observed on the internasal, frontomaxillary, zygomaticomaxillary suture landmarks, and the inferior orbital rim on the cleft side. The level of stress distributed at the cleft side was greater than that at the non-cleft side. In the BCP model, the highest stress was observed in the zygomaticomaxillary suture area. In the ICP model, the highest stress was observed in the internasal suture followed by nasomaxillary suture. The highest stress accumulation in the dentoalveolar area was observed in the molar regions (Figure 4A-C and Table 3).

DISCUSSION

The FEM proves to be an important instrument in the medical field and in orthodontic research, since it permits us to highlight the stress distribution areas and the displacement of anatomic units in a non-invasive and replicable manner. With FEM, it is possible to anticipate the tissue responses to mechanical forces by dividing complex structures into smaller sections with adjustable elastic properties. The control of the simplification degree represents the great advantages of this method. On the

Table 2. Displacement pattern of different cleft palate patients

	Unilateral cleft palate						Bilateral cleft palate			Isolated cleft palate		
	u_x (mm)		u_y (mm)		u_z (mm)		u_x (mm)	u_y (mm)	u_z (mm)	u_x (mm)	u_y (mm)	u_z (mm)
	Cleft side	Non-cleft side	Cleft side	Non-cleft side	Cleft side	Non-cleft side						
Sutura internasalis	0.12	0.12	0.12	0.12	-0.3	-0.3	0	0	0	0.14	0.17	-0.26
Sutura frontonasalis	0.19	0.18	0	0.12	-0.12	-0.34	0	0	0	0.01	-0.08	-0.17
Sutura frontomaxillaris	0.08	0	0	0.2	-0.12	-0.33	0.06	-0.03	-0.56	0	0.11	-0.37
Sutura nasomaxillaris	-0.12	0	0.05	0.22	-0.21	-0.36	0.16	-0.08	-0.54	0.11	0.16	-0.38
Sutura frontozygomatica	-0.03	0.01	0.23	0.06	0.34	0.12	-0.49	0	0	-0.06	0.05	0.06
Sutura temporozygomatica	-0.19	0.43	0.28	-0.03	0.39	0.19	-0.5	0	0	-0.18	0.18	0.22
Sutura zygomaticomaxillaris	-0.69	0.48	0.26	0.02	-0.86	0.01	-0.67	-0.06	-0.1	-0.34	0.14	0.06
Infraorbital margin	-0.33	0.27	0.19	0.09	0.32	-0.06	-0.67	-0.08	-0.08	-0.27	0.11	-0.02
Foramen infraorbitalis	-0.6	0.41	0.16	0.13	0.45	-0.08	-0.71	-0.17	-0.32	-0.35	0.09	-0.09
Zygomatic process	-1.06	0.66	0.19	0	0.63	-0.1	-0.9	-0.03	-0.23	-0.52	0.15	-0.02
Lateral nasal wall	-0.81	0.34	0.04	0.2	-0.04	-0.3	-0.82	-0.31	-0.49	-0.52	0.05	-0.37
ANS	-	0.43	-	0.26	-	-0.44	-	-	-	-1.16	-0.05	-0.8
Point A	-	0.52	-	0.25	-	-0.48	-	-	-	-0.95	0	-0.59
Apical region of incisors	-	0.56	-	0.17	-	-0.37	-	-	-	-1.05	-0.08	-0.61
Apical region of canine	-1.38	0.63	0	0.05	0.27	-0.21	-1.16	-0.23	-0.54	-1	-0.08	-0.33
Apical region of premolars	-1.19	0.68	0.14	0.01	0.54	-0.17	-1.14	-0.07	-0.38	-0.83	0.14	-0.14
Apical region of molars	-1.08	0.71	0.16	-0.01	0.56	-0.15	-1	0.01	-0.31	-0.65	0.17	-0.02
Retromolar region	-0.88	0.74	0.16	0	0.47	-0.18	-0.93	-0.08	-0.46	-0.4	0.14	-0.02
Tip of the upper central incisor	-	0.81	-	0.11	-	-0.38	-	-	-	-1.38	-0.1	-0.6
Tip of the upper canine	-1.79	0.82	-0.1	0.07	-0.11	-0.33	-1.51	-0.2	-0.53	-1.27	-0.07	-0.4
Tip of the upper premolar	-1.66	0.88	-0.02	0.05	0.07	-0.34	-1.46	-0.15	-0.55	-1.27	-0.05	-0.34
Tip of the upper molar	-1.66	0.97	0.01	-0.01	0.19	-0.27	-1.45	-0.11	-0.51	-1.17	-0.25	-0.3

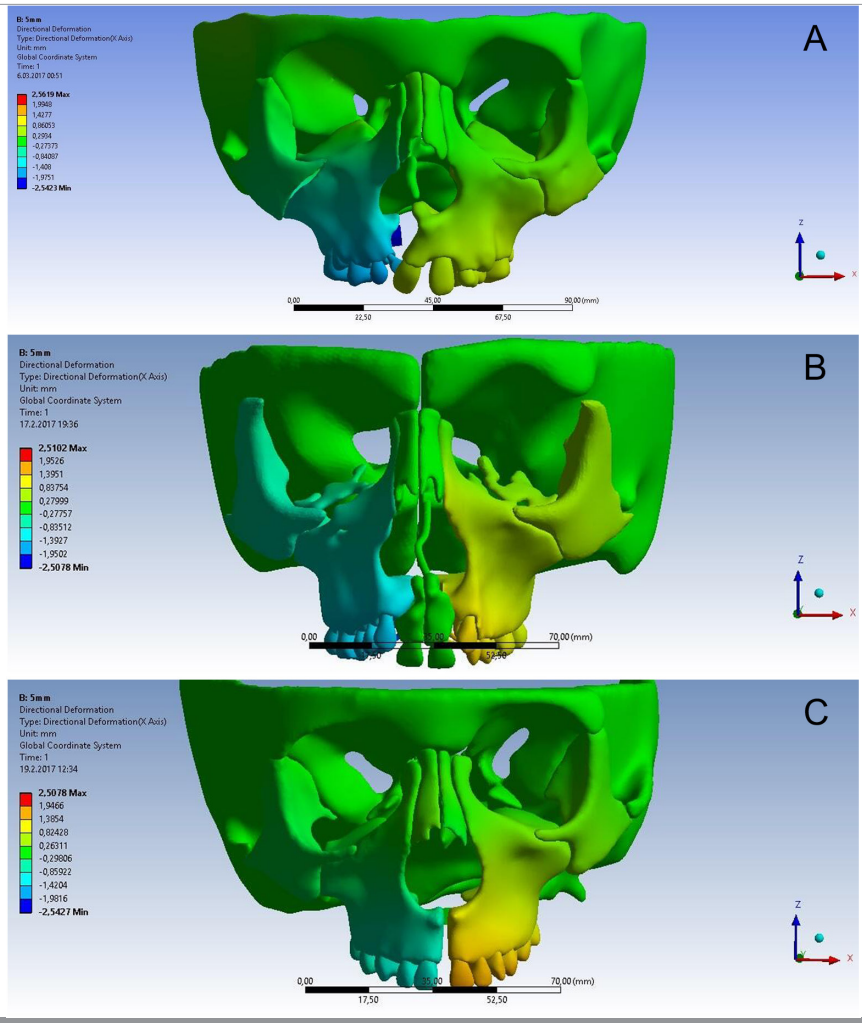

Figure 3. Displacement pattern in the unilateral (A), bilateral (B), and isolated (C) cleft palate patient in the x-axis.

other hand, the photoelastic models, which might be considered as an alternative experimental tool, have the disadvantage of exploring only the surface of the structures.[10] Moreover, FEM is an accurate method that provides quantitative and detailed data regarding the responses occurring in the modeled tissues.[11]

The reliability and accuracy of the FEM entirely depend on the validity of the model. The models developed in this study were based on DVT images. In our FEM studies, the material properties assigned to the elements were isotropic, homogeneous, and linearly elastic.[7,9,12] We referred the material properties based upon average values used in former studies.[7-9,13-15] Previous studies used shell elements for meshing the geometry.[4] In this study, tetrahedral elements with 10 nodes were used for mesh generation because this element had a quadratic displacement behavior and was well suited to modeling irregular meshes.

Over the past years, simulation models of the craniofacial complex have improved with geometric precision. In 1994, Miyasaka-Hiraga et al.[16] modeled the skull with 1776 single elements in an FEM study. Iseri et al.[4] performed a study with a model that consisted of 2349 single elements in 1998. An increase in the geometric precision was observed in a study by Jafari et al.[6] which introduced a model with 6951 elements. Finally, in 2007, Holberg et al.[17] used a simulation model that consisted of approximately 30 000 elements and 50 000 nodes. The finite element model of the craniofacial complex introduced here consisted of 2 785 413 elements and 1 799 565 nodes for the UCP model, 2 508 593 elements, and 1 609 498 nodes for the BCP model, 3 198 386 elements and 2 117 163 nodes for the ICP model.

According to the results of our study, the highest amount of transverse expansion was recorded for the BCP model. A similar amount of expansion has been observed in the cleft side of the UCP. Less expansion was recorded in the ICP model, followed by the non-cleft side of the UCP model. Mathew et al.[18] compared different types of upper jaw expansion appliances, including hyrax and bone-borne palatal expander, in a UCP patient model, and found higher amounts of displacement on the cleft side with both appliances. That might be explained by the fact that the missing bone tissue in the cleft area causes less resistance to the expansion forces. However, clinically, a significant relapse tendency in cleft patients is associated with the scar tissue or soft tissue tension. Modeling soft tissue is very difficult in FEM studies, since it exhibits hyperelastic behavior. For this reason, soft tissues such as mimic muscles, chewing muscles, gingiva, soft

Table 3. Von Mises stress distribution of different cleft palate patients (MPA)

	Unilateral		Bilateral	Isolated
	Cleft Side	Non-cleft Side		
Sutura internasalis	19 360	19 360	0	46 447
Sutura frontonasalis	0.49	0.51	0	0.25
Sutura frontomaxillaris	32 143	0.72	0	0.19
Sutura nasomaxillaris	0.57	33 970	0	45 352
Sutura frontozygomatica	0.53	0.14	0	0.06
Sutura temporozygomatica	0	0	20 821	0
Sutura zygomaticomaxillaris	16 650	19 725	33 635	1555
Infraorbital margin	23 833	0.56	0.42	1215
Foramen infraorbitalis	0.5	0.22	0.32	0.895
Zygomatic process	0.5	0.57	0.53	23 774
Lateral nasal wall	0.76	0.73	0.38	43 466
ANS	-	0	-	0
Point A	-	0	-	0.035
Apical region of incisors	-	0.01	-	0.03
Apical region of canine	0.11	0.01	0.12	0.53
Apical region of premolars	0.42	0.17	0.17	0.69
Apical region of molars	0.34	0.21	0.07	44 044
Retromolar region	0.25	0.06	0.14	43 831
Tip of the upper central incisor	-	0	-	0
Tip of the upper canine	0	0	0	0
Tip of the upper premolar	0.89	46 023	0.34	0.83
Tip of the upper molar	0.18	0.17	0.35	1075

palate, velopharyngeal region, scar tissue, and the skin were not included in modeling. This is a major limitation in this and other FEM studies. In light of these, it might be assumed that fewer expansion forces are effective in UCP or BCP patients; however, the soft tissue reaction should be taken into consideration.

In response to the maxillary expansion procedure, the asymmetrical changes were also observed in other regions such as the zygomatic bone and the 2 halves of the maxilla. Consistent with our study results, previous studies have also documented asymmetric changes in UCP patients.[2,19,20] Nicholson and Plint (1989),[21] in Capelozza Filho et al. (1994),[22] and later Pan et al.[2] mentioned a triangular opening with the base in the incisor teeth region and the apex in the nasal region, in accordance with our study.

Some authors concluded that the A point moves forward, others stated that it moves backward; contradictory to these 2 opposite findings, other researchers found that the A point's position remains stable following RME.[5,23-27] According to the results of our study, A point moves backward in the UCP patient and moves forward in the ICP patient.

In a study by Wang et al.[9] who evaluated the biomechanical outcomes of the RME in a UCP patient FEA model, most of the changes in the sagittal plane were found in the dental region, indicating that these values gradually decreased from the inferior to the superior region. Similarly, the highest displacement values were found in the dental regions in all 3 CP models in our study; most of the anatomic structures in the UCP model tended to displace posteriorly, but the amount of displacement was asymmetric on the cleft and non-cleft sides. This asymmetric distribution is an expected condition due to the structural and functional asymmetry existing in anatomical structures of UCP patients. On the other hand, in the BCP model, all the structures tended to displace anteriorly. Interestingly, in the ICP model, the structures close to the midline tended to displace anteriorly, while lateral structures had the tendency for posterior displacement. This type of displacement has been previously reported in a clinical study by Yilmaz et al.[28] In light of these results, it might be assumed that fewer expansion forces might be effective in UCP or BCP patients. However, these findings should be interpreted with caution since the major limitation in the FEM studies is the lack of effects of the soft tissue, especially that of the palatal scar tissue in cleft patients. Even though the expansion procedure might be completed successfully with lesser forces, it should be kept in mind that there would be a greater relapse tendency.

Previous clinical studies reported that the maxilla displaces downward by Rapid Palatal Expansion (RPE). The clockwise rotation of the mandible after RPE was also reported in CLP patients.[29,30] In our study, in the UCP and ICP models, the structures close to the

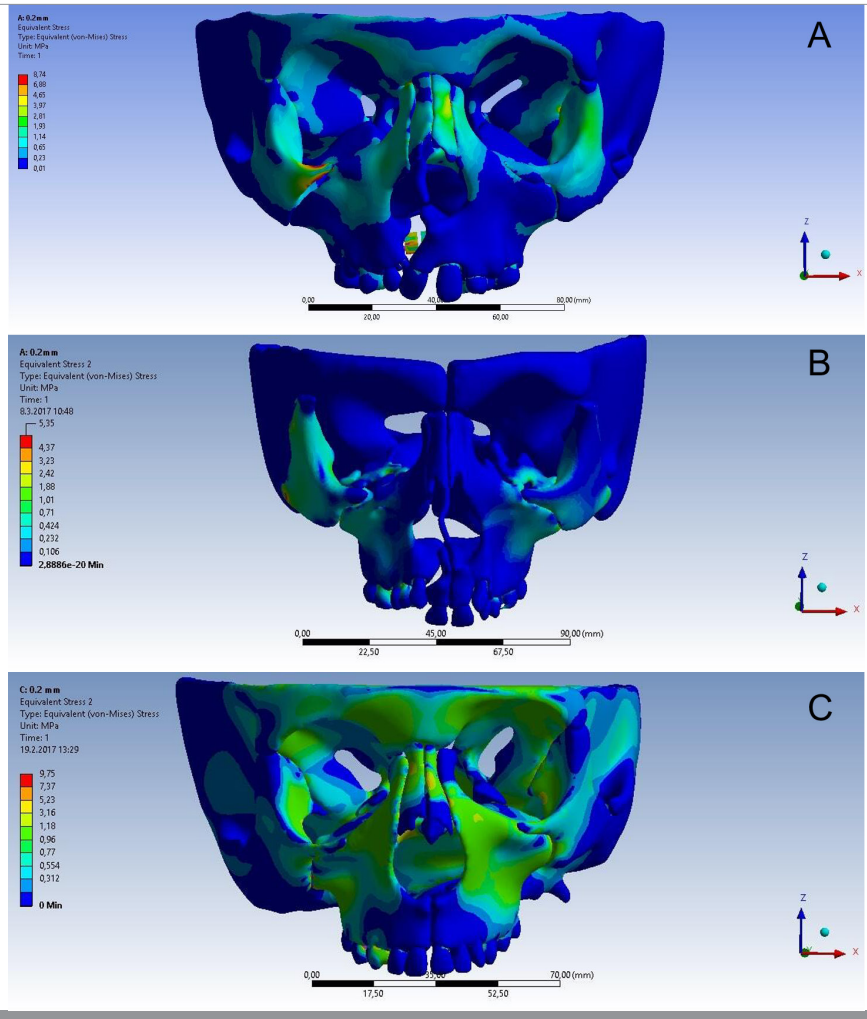

Figure 4. Von Mises stress distribution of the unilateral (A), bilateral (B), and isolated (C) cleft palate patient.

midline displaced downward, while the structures located more laterally showed upward displacement. In the BCP model, most of the anatomic structures showed a tendency toward inferior displacement. These findings are in harmony with those in the literature.[9,29,30]

It is important to know whether there is a change in the mechanism of interaction between the expansion forces and the resistance areas in CP patients to be able to predict the treatment outcomes. Pan et al.[2] observed significant differences in skull models with and without a cleft. They reported that the stresses accumulated in the lateral buccal margin of the maxilla was greater than those previously reported in non-cleft patients. In our study, in the patient model with a unilateral cleft, relatively higher stress values were observed on the cleft side compared to the non-cleft side. The maximum von Mises stresses were found on the cleft side in the internasal, frontomaxillary, and zygomaticomaxillary suture areas, in harmony with the studies by Lee et al.[31] and Gautam et al.[5] On the other hand, in the model with bilateral cleft, maximum von Mises stresses were found in the zygomaticomaxillary and zygomaticotemporal suture areas, and no stress was recorded in any of the nasal landmarks. This difference in stress distribution might be related to the fact that the stresses created by the expansive forces are directed to the lateral parts of the maxillary complex in BCP. In contrast, in UCP and ICP models, where the integrity of the alveolar bone is preserved, the stresses are also transferred to the internasal region.

In the present study, the greatest dental expansion among the 3 cleft models was observed in the BCP model, followed by the UCP model. In the UCP model, the amount of displacement and deformation was greater on the cleft side compared to that of the non-cleft side, indicating that asymmetric displacement and deformation occurs in UCP model following RPE. Based on these findings, it can be hypothesized that the RPE procedure should be customized to the patient's individual needs in cleft patients, depending the type of the cleft (primary or secondary palate), and the desired area of expansion (anterior or posterior).

CONCLUSION

- Different patterns of stress distribution occurred in response to expansion forces in all 3 different cleft type models. In the isolated cleft type, more stress accumulated especially in the nasal region. On the other hand, no stress was observed on landmarks in the nasal region for the bilateral cleft model.

- More intense stress accumulation was observed on the cleft side of the unilateral cleft model.
- The maximum dentoalveolar expansion in the cleft side of the unilateral, bilateral and isolated cleft patients occurred at the canine area, decreasing toward the posterior part. On the other hand, on the non-cleft side of the unilateral cleft model, the maximum dentoalveolar expansion occurred at the molar area, decreasing toward the anterior segment.
- In all 3 models, pyramidal opening occurred on the facial structures in the frontal plane.

Ethics Committee Approval: This study was approved by Ethics committee of Bezmialem Vakif University, Scientific Research Projects Commission. (Approval No:-6.2015/9).

Informed Consent: Written informed consent was obtained from the patients who agreed to take part in the study.

Peer Review: Externally peer-reviewed.

Author Contributions: Supervision – B.Y., S.I.R.; Design – E.B.; Concept – E.B., B.Y., S.I.R.; Resources – E.B.; Materials – E.B.; Data Collection and/or Processing – E.B., B.Y.; Analysis and/or Interpretation – E.B.; Literature Search – E.B., B.Y.; Writing Manuscript – E.B.; Critical Review – B.Y., S.I.R.

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Original Article

First Clinical Appointment after the COVID-19 Lockdown: Reflections from Orthodontic Patients and Their Anxiety Levels

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Main Points

- Patients receiving fixed orthodontic treatment are anxious during the clinical visit because of the Covid 19 pandemic, with women being more anxious than men.
- No significant relationship was found between the presence of chronic diseases and anxiety levels.
- A positive correlation was found between age and trait anxiety.

ABSTRACT

Objective: To evaluate the views and anxiety levels of orthodontic patients during the first clinical appointment after the coronavirus disease 2019 (COVID-19) lockdown.

Methods: Data were collected using a questionnaire that was administered to patients aged over 14 years who resumed their scheduled orthodontic treatment at Adıyaman University, Faculty of Dentistry, Department of Orthodontics during the normalization period after the COVID-19 lockdown. Anxiety levels of the participants were assessed using the State-Trait Anxiety Inventory (STAI).

Results: The study included 241 participants, comprising 177 (73.4%) women and 64 (26.5%) men with a mean age of 17.73 ± 3.27 years. Anxiety levels were significantly higher in women (State-trait index-State anxiety [STAI-S]: 39.26 ± 9.81, State-trait index-Trait anxiety [STAI-T]: 43.53 ± 9.16) than in men (STAI-S: 34.32 ± 10.12, STAI-T: 38.5 ± 7.87) ($P < .01$). No significant relationship was found between the presence of chronic diseases and anxiety levels ($P > .05$), while a positive correlation was found between age and trait anxiety ($P = .041$). Of all patients, 79.7% were positive about rescheduling their clinical appointment. Participants with higher anxiety levels indicated that they considered dental clinics as risky environments for the spread of COVID-19 infection ($P < .01$) and thus wanted to resume their treatment once the pandemic had ended ($P < .05$).

Conclusion: The results indicate that patients receiving fixed orthodontic treatment were anxious in the clinic.

Keywords: COVID-19, patient, anxiety, orthodontics

INTRODUCTION

On December 31, 2019, the Chinese health authorities reported a cluster of 27 cases of pneumonia of an unknown etiology in the city of Wuhan, Hubei Province, China.[1] The disease later became known as Coronavirus 2019 (COVID-19) caused by the severe acute respiratory syndrome coronavirus 2 (SARS-CoV-2) infection, and then rapidly spread throughout the world. On March 11, 2020, the World Health Organization (WHO) declared this outbreak as a global pandemic.[2,3]

Numerous health ministries around the world recommended postponement or cancelation of dental procedures that were not urgent due to the difficulty in maintaining social distancing and the potential for aerosol spread of the virus during these procedures.[4,5] Orthodontic treatment is a prolonged process requiring regular

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follow-up. However, orthodontic treatments had to be abruptly suspended for millions of people around the world during the pandemic.[6]

The COVID-19 pandemic brought not only the risk of death from the viral infection but also unbearable psychological pressure on people around the world.[7,8] The continuous spread of the pandemic, strict isolation measures, and the closure of schools and public places has led to a sharp increase in the anxiety and depression levels of general adult and pediatric populations.[9-11] Cotrin et al.[12] conducted an online survey to examine the effect of the COVID-19 pandemic and lockdown on the clinical appointments, concerns, and anxiety levels of orthodontic patients. The survey indicated that the pandemic and the lockdown had an impact on orthodontic appointments and anxiety levels of the patients.

Following the relaxation of lockdown measures in the new normalization period, dental services, along with orthodontic services, were reopened in accordance with the new measures designated by the national health committee of each country. The present study aimed to investigate state anxiety, trait anxiety, and treatment-related experiences and concerns of patients who resumed their orthodontic visits during the normalization period after the nationwide lockdown.

METHODS

The study protocol was approved by the Republic of Turkey, Ministry of Health (Approval No: 020-06-15T16_07_06), and ethical approval was obtained from Adıyaman University Clinical Research Ethics Committee (No: 2020/7-11). On March 17, 2020, the Health Ministry canceled all dental procedures that were not urgent; orthodontic appointments were postponed indefinitely. On June 1, 2020, dental services were resumed, and dental appointments were rescheduled in accordance with the new measures brought in during the new normalization period.

Data collection was achieved using a questionnaire that was administered to patients aged over 14 years who had resumed their fixed orthodontic treatment at Adıyaman University, Faculty of Dentistry Department of Orthodontics, and consented to participate in the study. A written informed consent form was obtained from each subject or guardian. To avoid the possibility of incorrect results or incomplete questionnaires if filled in before the treatment, each patient was given a disposable pen and asked to fill out the questionnaire after their visit to the clinic.

The questionnaire consisted of 2 sections. The first section involved questions probing patients' demographic profile, treatment-related experiences and concerns during the lockdown period, and their expectations from the orthodontics clinic. The second section included the State-Trait Anxiety Inventory (STAI), which is a self-report scale developed by Spielberger et al.[14] STAI is a self-report inventory comprising 2 separate self-report scales which measure state anxiety (STAI-S) (how one feels at a particular moment; e.g., dental visit) and trait anxiety (STAI-T) (how one usually feels). The STAI-S score is calculated based on 20 four-point Likert-type items designed to measure anxiety on a scale from 1 (not at all) to 4 (very much so). In contrast, the STAI-T score is calculated based on 20 four-point Likert-type items designed to measure anxiety on a scale from 1 (almost never) to 4 (almost always). STAI has been validated for many situations and populations.[15-17] In the present study, the Turkish version of STAI that was verified by Le Compte and Oner[18] was utilized.

Statistical Analysis

The universe of the study consisted of 496 patients who presented to the Orthodontics Department at Adıyaman University School of Dentistry. Based on the 95% CI (t = 1.96), with an estimated incidence of 0.05[19] and a sampling error of 0.05, the optimal sample size was calculated as 116 based on the Cohen's criteria.[20]

Statistical analyses were performed using Number Cruncher Statistical System 2007 (Kaysville, Utah, USA). Descriptive statistics were expressed as mean, standard deviation (SD), median, frequency (n), ratio, minimum, and maximum. Normal distribution of data was assessed using the Shapiro–Wilk test. When the number of possible answers given to the questions was 3 or more, the anxiety scores of the individuals who chose these options were compared using the one-way analysis of variance test for variables with normal distribution and the Kruskal–Wallis test for variables with the non-normal distribution. Post hoc analysis was performed using Tamhane correction for continuous variables with non-normal distribution and Bonferonni correction for continuous variables with normal distribution. When the number of possible answers given to the questions was 2, the anxiety scores of the individuals who chose these options were compared using Student's t-test for variables with normal distribution and the Mann–Whitney U-test for variables with non-normal distribution. Correlations between continuous variables were determined using Spearman's correlation coefficient. A P value of $< .05$ was considered significant as applicable.

RESULTS

Of the 496 patients, 281 (56.6%) of them were able to attend the first appointment when th study was conducted. Of these 281 patients, 241 (85.7%) of them consented to participate in the study. To increase the power of the study, a total of 241 patients were included in the analysis, comprising 177 (73.4%) women and 64 (26.5%) men. The participants were aged between 14 and 36 years, with a mean age of 17.73 $\pm$ 3.27 years. Of the 241 participants, 13 (5.4%) of them had a chronic disease.

The mean STAI-S score was 38.00 $\pm$ 10.08, and the mean STAI-T score was 42.25 $\pm$ 9.09. According to the Student's t-test and the Mann–Whitney U-test, these scores were significantly higher in women than in men ($P < .01$ for both). No significant relationship was found between the presence of chronic diseases and anxiety scores (Student's t-test and Mann–Whitney U tests) ($P > .05$). Table 1 presents the anxiety scores of the participants compared with their descriptive statistics.

Table 1. Distribution of variables and their comparison with STAI-S and STAI-T scores

Variables		STAI-S			STAI-T		
	n (%)	Mean ± SD	Min–Max (Median)	*P*	Mean ± SD	Min–Max (Median)	*P*
Q1. What is your gender?							
Female	177 (73.4%)	39.26 ± 9.81	21-66 (39)	.001**[a]	43.53 ± 9.16	20-68 (43)	.001**[b]
Male	64 (26.5%)	34.32 ± 10.12	20-71 (33.5)		38.5 ± 7.87	22-58 (38)	
Q2. Do you have a chronic disease?							
Yes	13 (5.4%)	33.15 ± 9.09	20-52 (34)	.78[a]	40.23 ± 6.88	32-52 (38)	.410[b]
No	228 (94.5%)	38.28 ± 10.09	21-71 (38)		42.37 ± 9.2	20-68 (42)	
Q3. Did you ever have an urgent orthodontic condition (e.g., cheek injury caused by the extension of the wire to the distal segment) during the lockdown?							
Yes	123 (51%)	38.06 ± 9.74	20-65 (37)	.852[a]	43.3 ± 9.05	20-62 (43)	.081[b]
No	118 (51%)	37.95 ± 10.45	21-71 (38.5)		41.25 ± 9.06	20-68 (41)	
Q4. If Yes, what did you do to solve the problem?							
I solved the problem myself	68 (55.2%)	39.03 ± 10.54	22-66 (39)	.478[c]	42.33 ± 9.12	22-63 (41)	.967[d]
I scheduled an appointment with the clinic after failing to solve it myself.	33 (26.8%)	36.55 ± 9.91	22-65 (36)		41.85 ± 9.58	20-59 (42)	
I immediately scheduled an appointment with the clinic.	22 (17.8%)	38.05 ± 9.21	22-56 (37)		42 ± 8.3	24-57 (40.5)	
Q5: What do you and your family members think about rescheduling your clinical appointment?							
We are both positive	192 (79.7%)	37.05 ± 9.52	20-66 (37)	.008**[c]	41.5 ± 8.81	20-68 (41)	.009*[d]
I am positive but my family is hesitant.	26 (10.8%)	39.12 ± 9.25	21-57 (40.5)		44.27 ± 9.38	28-62 (47)	
We are both hesitant.	17 (7.1%)	45 ± 9.17	33-60 (43)		47.94 ± 9.2	29-61 (49)	
Q6: What was your biggest concern regarding your orthodontic treatment during the lockdown?							
Delay in the completion of the treatment	115 (47.7%)	38.75 ± 10.34	21-65 (39)	.031*[c]	43.42 ± 9.27	20-65 (43)	.803[d]
Obtaining undesirable treatment outcomes	20 (8.3%)	35.91 ± 9.35	22-57 (35)		42.45 ± 8.7	28-56 (41)	
Breakage of the brackets and worsening of the problem	32 (13.2%)	39.71 ± 9.32	21-52 (42)		45.06 ± 8.21	31-59 (46)	
Being hurt by the wires and the broken brackets	10 (4.1%)	49.67 ± 7.79	40-59 (47.5)		47 ± 10	31-55 (52)	
I had no concerns at all.	64 (26.5%)	36.42 ± 8.01	23-59 (36)		43.55 ± 6.67	23-56 (44)	
Q7: Do you consider dental clinics as risky environments for the spread of COVID-19 infection?							
Yes	121 (50.2%)	40.74 ± 9.28	21-66 (41)	.001**[a]	44.63 ± 8.26	29-65 (45)	.001**[b]
No	120 (49.8)	35.54 ± 10.28	20-71 (35)		40.15 ± 9.41	20-68 (40)	
Q8: Do you perform additional procedures for cleaning your body and clothes after arriving home from the clinic?							
Yes	216 (89.6%)	38.3 ± 9.62	20-66 (38)	.402[a]	42.56 ± 9.05	20-68 (42)	.565[b]
No	25 (10.4%)	37.4 ± 12.94	22-71 (36.5)		41.53 ± 9.35	22-58 (41.5)	
Q9: How would you like to continue your treatment during the COVID-19 pandemic?							
Continue as before	126 (52.3%)	36.4 ± 9.89	20-71 (36)	.008*[c]	41.06 ± 9.49	20-68 (41)	.024*[d]
Resume after the pandemic	112 (46.4%)	39.55 ± 10.06	21-66 (40)		43.47 ± 8.49	20-65 (43)	
Complete it immediately	3 (1.2%)	51.5 ± 7.78	46-57 (51.5)		54 ± 4.24	51-57 (54)	

*$P < .05$, **$P < .01$. [a]Mann–Whitney *U*-test; [b]Student's *t*-test; [c]Kruskal–Wallis test; [d]One-way analysis of variance.
Q, question; SD, standard deviation; Min–Max, minimum–maximum, STAI-S, State-trait index-State anxiety; STAI-T, State-trait index-Trait anxiety.

According to the Spearman's correlation analysis, a positive correlation was found between age and STAI-T score ($P < .05$), while no significant correlation was found between age and STAI-S score ($P > .05$) (Table 3).

Of all participants, 123 (51%) indicated that they needed urgent orthodontic care during the quarantine period, while 118 (49%) indicated that they did not have such a need. Of the 123 patients, 68 (55.2%) of them solved the problem by themselves, 33 (26.8%)

Table 2. Distribution of responses provided for multiple-answer questions

Variables	*n* (%)
Q10. What could be the cause of the psychological pressure and concerns you experience during your clinical visits (if any)? Please indicate (you may choose multiple options).	
Having direct contact with COVID-19-positive cases	50 (12%)
Contracting COVID-19 infection during the appointment	71 (17.1%)
Inadequacy of the measures	35 (8.4%)
Violation of rules by other people	115 (27.7%)
Uncertainty about the end of the pandemic	80 (19.3%)
Fearing that the pandemic will never be controlled	49 (11.8%)
Fear of being stigmatized if tested positive for COVID-19	15 (3.6%)
Q11. What is the most important issue that requires utmost attention in a dental clinic during the pandemic? (You may choose multiple options)	
Admission of one patient at a time at the entrance	66 (17%)
Use of a protective facemask by the dentists	83 (21.3%)
Patients' keeping their facemask on throughout the clinic visit except for during the treatment	50 (12.9%)
Use of a face shield in addition to a protective facemask by the dentists	86 (22.1%)
Use of a disposable head cover by the dentists	56 (14.4%)
Use of a disposable laboratory coat by the dentists	48 (12.3%)

scheduled an appointment with the clinic after failing to solve the problem by themselves, and 22 (17.8%) of them immediately scheduled an appointment with the clinic.

About rescheduling their dental appointments, 192 (79.7%) participants indicated that they themselves, as well as their families, were both positive about this rescheduling, whereas 26 (10.8%) participants stated that they were happy, but their families were hesitant, and 17 (7.1%) participants revealed that they themselves, as well as their families, were both hesitant about the rescheduling.

When asked what their biggest concern was, 115 (47.7%) participants indicated that they were most concerned about a delay in completing their treatment, 20 (8.3%) of them were most concerned about an undesirable treatment outcome, 32 (13.2%) of them were most concerned about the breakage of their orthodontic appliances (wire and brackets), 10 (4.1%) of them were most concerned about being hurt/injured by breakage of the orthodontic appliances, whereas 64 (26.5%) of them indicated having no concerns during this period.

More than half of the participants (n = 121; 50.2%) indicated that they considered dental clinics as risky environments for the spread of COVID-19 infection, while the remaining 120 (49.8%) participants indicated that they did not.

Table 3. Correlation between age and STAI-S and STAI-T scores (Spearman's correlation coefficient)

Correlation	*r*	*P*
Age/STAI-S	0.100	.124
Age/STAI-T	0.133	.041*

STAI-S, State-trait index-State anxiety; STAI-T, State-trait index-Trait anxiety; *$P < .05$.

Most of the participants (n = 216; 89.6%) considered that they took extra measures to clean their body and clothes after arriving home from the clinic, while 25 (10.4%) of them indicated that they did not.

Of the 241 participants, 126 (52.3%) of them stated that they wanted to continue their treatment as they did before the pandemic, 112 (46.4%) of them declared that they wanted to continue their treatment after the pandemic had ended, and 3 (1.2%) of them indicated that they wanted to complete their treatment immediately.

About the causes of psychological pressure experienced in the clinic, "violation of rules by other people" was indicated as the most common cause by the participants (n = 115; 27.7%), followed by "uncertainty about the end of the pandemic" (n = 80; 19.3%), and "the risk of contracting COVID-19 during the appointment" (n = 71; 17.1%). On the other hand, about the issues that required utmost attention in a dental clinic during the pandemic, "use of a face shield in addition to a protective facemask by the dentists" was found to be the most popular response (22.1%), followed by "use of a protective facemask by the dentists" (21.3%), and "admission of one patient at a time at the entrance" (17%) (Table 2).

DISCUSSION

The present study hypothesized that orthodontic patients have high anxiety levels, there is a positive correlation between age and the presence of chronic diseases, and the anxiety levels are higher in women than in men among these patients during the pandemic. STAI is an anxiety scale commonly used for assessing anxiety among dental patients.[21,22] The scale consists of 2 components, of which STAI-S assesses how one feels at a particular moment and STAI-T assesses how one usually feels.[14] In the

present study, we preferred STAI for assessing participants' general and occasional anxiety levels, considering the prolonged nature of the pandemic.

On the very first day of the survey (June 8, 2020), the accumulative number of COVID-19 cases reported in Turkey was 171 121 (ranking 17th in the world), the curfew imposed for children under 18 years of age, and the ban on intercity travel had been lifted, and public places had been reopened. Moreover, on the same day, the numbers of newly diagnosed COVID-19 cases and of the deaths caused by COVID-19 were continuously decreasing, and various normalization steps were being taken—both by Turkey and by many other countries around the world.

In line with the normalization processes, the clinical services in our institution were reopened, taking several protective measures for clinical staff such as avoiding the use of aerosol during the procedures, wearing personal protective equipment (laboratory coat, pants, shirt, facemask, face shield), working at half capacity, and limiting clinical care to one patient at a time. Additionally, some measures were determined for patients as well, such as applying hand sanitizer before entering the clinic and keeping their facemask on throughout the clinic visit except for the duration of the treatment. With the implementation of these rules, the clinical appointments for patients were rescheduled after a 3-month lockdown. Irregular attendance to the dental clinic may play an important role in increased dental anxiety.[21] Accordingly, the present study aimed to assess anxiety levels and concerns and expectations about treatment in patients who resumed their fixed orthodontic treatment at a time when the COVID-19 pandemic was still ongoing.

The mean STAI-S (38.00 ± 10.08) and STAI-T (42.25 ± 9.09) scores in our study were remarkably higher than those measured by Yildirim and Karacay[21] before the pandemic in orthodontic patients whose demographic profiles were similar to those of our patients. However, our findings were consistent with the increased anxiety and depression levels measured in the general adult and pediatric populations within the first months of the pandemic.[11,19,23] In our study, "violation of rules by other people" was indicated as the most common cause of psychological pressure in the clinic (n = 115; 27.7%), followed by "uncertainty about the end of the pandemic" (n = 80; 19.3%). These findings implicate that the patients' fear of contracting COVID-19 during dental procedures was replaced—probably as a result of their observations of the measures taken in the clinic—by other concerns such as the violation of rules (e.g., maintaining social distancing and continuous use of facemask) by other people and uncertainty about the future of the pandemic.

In our study, the STAI-S and STAI-T scores were higher in women than in men. This difference reflects the already known gender-based difference in anxiety and depression levels.[24,25] Moreover, numerous studies conducted during the COVID-19 pandemic also indicated that women have higher anxiety scores than men.[9,19,23]

Advanced age and underlying chronic diseases have been shown to be the most critical risk factors for mortality from SARS-CoV-2 infection.[26] Studies conducted during the COVID-19 pandemic have also indicated a relationship between the presence of chronic diseases and increased anxiety and stress levels.[9,19,23] On the contrary, our study found no significant relationship between the presence of chronic diseases and anxiety scores, which could be associated with the fact that our patients had a low mean age (17.13 ± 3.45 years), young individuals have a lower mortality rate than older individuals, and that this phenomenon is frequently mentioned in the mass media.[27] In our study, the mean age of the patients ranged between 14 and 36 years, and although a positive correlation was found between age and STAI-T score, no significant correlation was found between age and STAI-S score. These lower STAI-T scores in our participants could be associated with the fact that the curfew imposed for individuals under 18 years of age in Turkey had been lifted at the time of our survey. Wang et al.[23] found no significant relationship between age, anxiety, and stress scores. In contrast, Shevlin et al.[9] and Wang et al.[28] found higher anxiety scores in younger individuals, unlike in our study. Unlike our study, these studies divided the individuals into various age groups (young, middle, and old) and investigated anxiety levels for each group.

Most of our patients indicated that they solved their problems by themselves when they had an urgent dental condition during the lockdown. Moreover, no significant relationship was found between patients' reaction to such problems and their anxiety scores. It was also revealed that participants who had significantly higher STAI-S scores indicated that their biggest concern during the lockdown was being hurt by the distal extension of the wires and broken brackets. These findings implicate that it is highly important for orthodontists to inform their patients about how to manage urgent conditions during the lockdown. Moreover, orthodontists can use mobile applications such as WhatsApp Web (Facebook Inc., Mountain View, California) to remotely monitor their patients and also to guide and comfort them during urgent situations.[29]

Patients with high anxiety levels may avoid receiving medical care during the pandemic due to their concern that hospitals are a source of infection.[30] This phenomenon was confirmed by our findings indicating that some of our patients considered dental clinics to be risky environments for the spread of COVID-19 infection, some other patients and their families were hesitant about rescheduling their appointments, and some patients wanted to continue or complete their treatment after the pandemic ended.

Dental patients are likely to have increased STAI-S and STAI-T levels due to various reasons such as difficulty in maintaining social distancing during dental procedures, patients' keeping their mouth open throughout the procedure, and the news stories broadcasted on televisions and social media about the risk of infection conveyed by dentists. To avoid these concerns, patients should be informed via mass media or face-to-face interactions about the fact that they could minimize the risk of infection by following the instructions dictated by WHO and local authorities,

such as maintaining personal hygiene, keeping social distance, and wearing a facemask.

A significant portion of our patients indicated that "use of a face shield in addition to a protective facemask by the dentists" was the most important issue that required utmost attention in a dental clinic during the pandemic. This finding is highly compatible with the notion that face shields are highly useful when compared to surgical masks, in that they can be used multiple times after being disinfected with water, soap, or sanitizers, can reduce the risk of autoinoculation by preventing contact with the face, and remind the patients about social distancing. A previous simulation study revealed that wearing a face shield decreased the inhalational exposure of the worker to an immediate cough within a diameter of 3 m by 96%.[31]

Most of our patients (89.6%) stated that they performed additional procedures for cleaning their body and clothes after arriving home from the clinic. This finding indicates that most patients paid attention to the hygiene rules dictated by the authorities via mass media for COVID-19 during the lockdown.

Our study was limited in several ways. First, the findings of our study, as in other cross-sectional studies, cover a certain period of the pandemic. Second, as the study was conducted with patients who were continuing fixed orthodontic treatment at a School of Dentistry, the results of the study may not be generalized to other faculties/schools, private clinics, and/or other countries. Accordingly, further studies with larger numbers of participants that cover different periods of the pandemic and utilize different orthodontic appliances are needed to substantiate our findings.

CONCLUSION

Patients receiving fixed orthodontic treatment are anxious, with women being more anxious than men. It was also revealed that most of the patients solved their problems by themselves when they had an urgent dental condition during the lockdown and were positive about the rescheduling of their appointments. Moreover, participants with higher anxiety levels indicated that they considered dental clinics as risky environments for the spread of COVID-19 infection and thus wanted to resume their treatment once the pandemic has ended.

Ethics Committee Approval: This study was approved by Ethics committee of Adıyaman University, (Approval No: 2020/7-11).

Informed Consent: Written informed consent was obtained from the patients who agreed to take part in the study.

Peer-review: Externally peer-reviewed.

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Original Article

Oral Health Literacy and COVID-19 Pandemic Anxiety and Concerns Among Iranian Orthodontic Patients

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Main Points

- Most of the participants in this study respected the quarantine recommendations.
- There was no significant difference between women and men except for the level to which they respect the quarantine measures.
- Most of the respondents had an adequate level of oral health literacy (OHL).
- Most of the respondents indicated that they were calm regarding the COVID-19 pandemic.
- There was a significant association between the level of OHL and willingness to attend orthodontic treatment, concerns regarding the impact of the pandemic situation on orthodontic treatment, and the frequency of daily brushing.
- The greatest concern for most patients regarding the impact of the COVID-19 outbreak on their orthodontic treatment was the possibility of a delay in the completion of treatment.

ABSTRACT

Objective: This study aims to evaluate the impact of the COVID-19 pandemic on orthodontic appointments, and the concerns and anxiety levels of orthodontic patients in Iran.

Methods: An anonymous 40-question questionnaire was sent online to the patients of private orthodontic clinics in 2 cities of Birjand, and Mashhad, capitals of Eastern provinces of Iran. Orthodontic patients of Mashhad dental school received the questionnaire as well. Descriptive statistics were reported, and the association between gender, oral health literacy (OHL), and adherence to orthodontic appointments and attendance, along with data on feeling, concern, and level of anxiety regarding quarantine/coronavirus pandemic were evaluated using the chi-square analysis.

Results: Three hundred twenty-four patients, with a mean age of 32.43 years, answered the questionnaire. Fifty-seven percent of participants said that they only left home for their daily requirements. Seventy-two percent of the participants reported feeling calm about the COVID-19 pandemic and its consequences. Most of the patients (74%) said that they would attend their orthodontic appointment in case of urgency, and 41% of patients declared that their greatest concern was the probability of a delay in completion of treatment. Forty-five percent of patients had adequate OHL. There was a significant association between OHL and willingness to attend orthodontic treatment, concerns regarding the impact of the pandemic on orthodontic treatment, and the frequency of daily teeth brushing.

Conclusion: Women respected the quarantine more than men. Patients with higher OHL were more willing to attend their appointments, but only in case of an emergency, due to the outbreak of COVID-19. Women were more concerned and had better oral hygiene behaviors.

Keywords: COVID-19, orthodontics, questionnaire

INTRODUCTION

The new coronavirus disease (COVID-19) arose beginning late December 2019, with severe pneumonia first in Wuhan, China, and then rapidly spreading to 200 countries, including Iran, by March 31, 2020.[1] In late January,

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the state of the COVID-19 pandemic was confirmed by the WHO, and the disease was defined as a public health emergency, raising global concern.[2] It was declared that more than 80% of patients are asymptomatic, and that fever, fatigue, dry cough, and acute respiratory distress syndrome are among the most common symptoms of disease.[3] By March 31, 2020, Iran was among the top 10 countries with the highest number of COVID-19 cases.[4]

The COVID-19 pandemic caused the closure and cancellation of many public places and social activities, and in many countries, people were asked to stay home and respect home quarantine instructions. Coronavirus was primarily transmitted from bats and pangolins to humans, and then became widespread by interpersonal transmission through direct contact or indirectly from respiratory droplets, aerosols, or fecal–oral routes.[5-9] The easy transmission of the virus through respiratory droplets, aerosols, and close contact places dentists and dental hygienists among the groups with a high risk of COVID-19 infection.[10] Many dental offices were closed, and many are still closed due to the COVID-19 outbreak, limiting their activities to managing emergencies. Many orthodontic treatments are pending in line with this decision, and patients have not had an appointment for months. This unexpected break in dental treatments can potentially cause some problems and discomfort, especially for orthodontic patients. The results of a study conducted to evaluate the anxiety level of the general Iranian population during the COVID-19 outbreak showed that people who were more involved in following the corona-related news and people in the age range of 21-40 had a higher level of anxiety.[11] It was found that there is a significant association between the feelings about the COVID-19 pandemic and dental appointment attendance among Brazilian dental patients.[12] Females were found to be more concerned about the pandemic situation, quarantine, and consequences.[13] Considering the lack of information about the impact of the pandemic on orthodontic treatment in Iran, this study aimed to evaluate orthodontic patients' stress and anxiety level regarding the COVID-19 pandemic, and the impact of this situation on their orthodontic treatment. We also assessed oral health literacy (OHL), oral health behaviors, and the relationship between these parameters in a population of orthodontic patients in 2 eastern cities in Iran.

METHODS

An anonymous online questionnaire comprising 40 questions was used for data collection, including 6 questions asking about general information (age, gender, city/state, educational level, occupational status, family size), 8 questions evaluating the perceived anxiety and concerns regarding the COVID-19 pandemic (the levels of anxiety about the coronavirus pandemic and the impact of quarantine on orthodontic treatment were evaluated by a numerical rating scale (NRS)), the impact of this pandemic on the participants' orthodontic treatment and how they observe quarantine and protective measures, 16 questions to assess OHL, 4 questions regarding oral health behaviors, and finally, 6 self-assessment questions regarding the state of their oral health and attendance to orthodontic appointments.[13,18] The ethics committee approved the study protocol of Birjand University of Medical Sciences (IR.BUMS.REC.1399.138). We did not obtain informed consent from the participants because our questionnaire was anonymous and did not disturb their treatment process. The online questionnaire surveyed patients above 12 years old who were actively undergoing orthodontic treatment. The questionnaire was sent to patients of private orthodontic clinics in 2 cities, Birjand, and Mashhad, capitals of Eastern provinces of Iran. Orthodontic patients of Mashhad dental school received the questionnaire as well. The questionnaire was active for data gathering for 1 week.[13]

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Health literacy is defined as follows: "the degree to which individuals can obtain, process, and understand basic health information and services needed to make appropriate health decisions".[15] In oral health context, literacy can be considered as the skills necessary for people to understand the causes of poor oral health, to learn and adopt fundamental aspects of positive oral self-care behaviors, to communicate with oral health care providers, to place their names on dental treatment waiting lists or organize appointments, to find their way to dental clinic, to fill out the necessary forms and to comply with any required regimes, including follow-up appointments and compliance with prescribed medication.[16] This definition addresses functional oral health literacy, encompassing knowledge, as well as the ability to use that knowledge in making appropriate oral health-related decisions. Oral health literacy, in this definition, encompasses far more than reading; it involves writing, numeracy, speaking, listening, and "understanding the system".[17]

The ethics committee approved the study protocol of Birjand University of Medical Sciences (IR.BUMS.REC.1399.138). We did not obtain informed consent from the participants because our questionnaire was anonymous and did not disturb their treatment process. The online questionnaire surveyed patients bove 12 years old who were actively undergoing orthodontic treatment. The questionnaire was sent to patients of private orthodontic clinics in 2 cities Mashhad and Birjand, capitals of Eastern provinces of Iran. Orthodontic patients of Mashhad University Of Medical Sciences received the questionnaire as well. The questionnaire was active for data gathering for 1 week (13).

Statistical Analysis

Using Cochran's Formula, and considering the total of 1800 patients of private orthodontic clinics in the 2 cities of Birjand, and Mashhad, capitals of Eastern provinces of Iran. Orthodontic patients of Mashhad dental school received the questionnaire as well, the standard error of 5% and 95% for confidence interval, the sample size was calculated to be at least 317. Results were obtained and analyzed using descriptive statistics. A chi-square test was used to compare and analyze the results. The chi-square test was used to evaluate the association between gender, the feeling and concern, level of anxiety regarding the quarantine/coronavirus pandemic, and adherence and attendance to regular appointments. Similarly, to evaluate the association between OHL and the variables mentioned above, the chi-square test was used. The Statistical Package for Social Sciences version 21.0 software (IBM Corp.; Armonk, NY, USA). The level of significance was set at 0.05.

RESULTS

Six hundred twenty-one patients viewed the questionnaire, 52% of them (324 people) completed it. The average response time was 187 seconds. Most of the respondents (97%) answered utilizing mobile devices, and the rest of them used a computer to complete the questionnaire.

In total, 324 patients who were in the course of their fixed orthodontic treatments (75 males, 249 females) participated in the study. The mean age of participants was 32.43 years (minimum 12 years, maximum 53 years).

Considering observance of the suggested quarantine, 57% of participants said that they only left home for their daily requirements, 40% stayed home completely, and 3% said that they lived their usual life and did not respect the quarantine at all.

Sixty-three percent of patients said that they worked/studied at home during the quarantine. Regarding the COVID-19 pandemic and its consequences, 72% were calm, and 20% reported being anxious. We asked the patients to report their anxiety level regarding the impact of pandemic on their orthodontic treatment on a scale of 0-10. We classified the scores into 3 levels: low (0-3), moderate (4-6), and high (7-10). The reported anxiety level of 55% of patients was moderate, and only 14% reported feeling highly anxious. Most of the patients (74%) said that they would attend their orthodontic appointment if urgent, and 26% said they would attend their appointment regardless of the emergency.

Forty-one percent of the patients declared that their greatest concern regarding the impact of the COVID-19 pandemic on their orthodontic treatment was the probability of a delay in their treatment. The detailed results can be seen in the tables.

We used the oral health literacy-adult questionnaire (OHL-AQ). This questionnaire's validity and reliability for the Iranian population have been previously confirmed.[14,18] This questionnaire has 16 questions in 5 sections, and the scores are in the range of 0 to 16. The scores are categorized and interpreted as inadequate (0-9), borderline (11-12), and adequate (13-16) OHL. Forty-five percent of the participants in our study had adequate OHL, 27% were borderline, and the OHL of 28% of the patients was inadequate. The descriptive statistics and chi-square test results comparing different variables are presented in Tables 1-4 and Figures 1-3.

DISCUSSION

The questionnaire for orthodontic patients was available online for 1 week from June 21 to 27, 2020. It was answered by 52% of the patients who received the questionnaire.

Totally, 324 patients who were in the course of their fixed orthodontic treatments (75 males, 249 females) participated in the study. As mentioned earlier, the minimum sample size for this study was calculated to be 317 responses. The sample size in this study was comparable to that of Cotrin et al.,[13] in which 354 patients were included. However, it was smaller in comparison with the sample size of Peloso's study[12] with 595 participants. It seems that differences of this magnitude would not have a considerable impact on the results. The questionnaire was available for patients of private orthodontic clinics in 2 cities, Birjand and Mashhad, capitals of Eastern provinces of Iran. Orthodontic patients of Mashhad received the questionnaire as well, and it was active for about 1 week.

Seventy-seven percent of the participants were females, and 23% were males. The results showed that 63% of the respondents were studying/working at home during the outbreak of the COVID-19 pandemic, 40% stayed home completely during the suggested quarantine, and 57% left home only for emergencies. The results of a study conducted on Brazilian dental patients by Peloso et al.[12] revealed similar results. They found that 54.5% were working from home, and 78% left home only for emergencies such as buying food or medicine.

It is well understood that for many reasons, the COVID-19 outbreak can cause anxiety and stress.[11] In a study conducted to assess the general Iranian population's anxiety level, and it was found that women, people who were more involved in following COVID-19 related news, and people in the age range of 21-40 were more anxious. It was suggested to design and plan some psychosocial interventions to control the anxiety level of the aforementioned groups of people.[11] There was no significant difference between males and females regarding the items except for the level of respect for the quarantine. Considering the nature of health services provided in a dental clinic, the transmission of the infection to dentists and patients is possible. Although there are guidelines recommended by the Centers for Disease Control and Prevention (CDC), the American Dental Association, and WHO for working safely in a dental clinic, there may be concerns in presenting at a dental clinic during the pandemic. Considering these concerns, many dental clinics were closed or provided only emergency services for the patients when newly diagnosed cases of the COVID-19 infection were rapidly increasing. However, it could

Table 1. Descriptive statistics of study variables including frequency and percentage

Variable	Answer	Frequency	(Percentage)
Gender	Male	75	(23%)
	Female	249	(77%)
How are you observing the quarantine?	Stay home during the entire quarantine period	128	(40%)
	Stay home as much as possible (leave home for emergencies)	186	(57%)
	Going out as before the outbreak	10	(3%)
Are you working or studying?	Yes, and I leave home for work/study	94	(29%)
	Yes, I work/study at home	163	(50%)
	No	67	(21%)
How can you describe yourself regarding the anxiety and stress you are experiencing because of COVID-19 pandemic?	Calm	232	(72%)
	Anxious	65	(20%)
	Scared	9	(2%)
	Panic	4	(1%)
	Indifferent	14	(5%)
How can you describe your anxiety level regarding the COVID-19 pandemic?	Low	97	(30%)
	Moderate	171	(53%)
	High	56	(17%)
Would you attend your orthodontic appointments in this period?	Yes	84	(26%)
	Only in the case of emergency	240	(74%)
	No	0	0
What is your greatest concern regarding your orthodontic treatment in this situation?	The treatment would become prolonged	134	(41%)
	The final result would be less than ideal	74	(23%)
	The problem with my teeth would get worse	15	(5%)
	The probability of injuries to lips and cheeks	34	(10%)
	I am not concerned	67	(21%)
How do you describe the level of your anxiety regarding the impact of the COVID-19 pandemic and quarantine on your treatment?	Low	102	(31.5%)
	Moderate	133	(41%)
	High	89	(27.5%)
How many times a day you brush your teeth?	2-3 times a day	184	(57%)
	Once a day	124	(38%)
	2-3 times a week	9	(3%)
	Once a week	7	(2%)
How many times a day you eat sugary snacks?	3 times or more	42	(13%)
	Twice a day	74	(23%)
	Once a day	55	(17%)
	Occasionally	104	(32%)
	Rarely	49	(15%)
Have you ever smoked?	No, never	301	(93%)
	I quit smoking	5	(1.5%)
	I smoke 1 cigarette a month	4	(1%)
	I smoke 2-3 cigarettes a month	3	(1%)
	I smoke 2-3 cigarettes a week	3	(1%)
	I smoke 1 cigarette a day	3	(1%)
	I smoke 2-3 cigarettes a day	5	(1.5%)
How did you attend your orthodontic appointment before the COVID-19 outbreak?	Regularly on monthly basis	269	(83%)
	Often on monthly basis	41	(13%)
	Occasionally	14	(4%)

Table 2. Association between gender, feeling and concern, and level of anxiety regarding quarantine/coronavirus pandemic (Chi-square test)

Variables	Answer	Males	Females	*P*
How are you observing the quarantine?	Stay home during the entire quarantine period	15	113	$X^2 = 24.727$
	Stay home as much as possible (leave home for emergencies)	53	133	*df* = 2
	Going out as before the outbreak	7	3	*P* = .000*
How can you describe yourself regarding the anxiety and stress you are experiencing because of the COVID-19 pandemic?	Calm	58	174	$X^2 = 2.482$
	Anxious	12	53	*df* = 4
	Scared	2	7	*P* = .647
	Panic	0	4	
	Indifferent	3	11	
How can you describe your anxiety level regarding the COVID-19 pandemic?	Low	28	69	$X^2 = 3.388$
	Moderate	36	135	*df* = 3
	High	11	45	*P* = .336
Would you attend your orthodontic appointments in this period?	Yes	51	189	$X^2 = 1.875$
	Only in the case of emergency	24	60	*df* = 1
	No	0	0	*P* = .171
What is your greatest concern regarding your orthodontic treatment in this situation?	The treatment would become prolonged	27	107	$X^2 = 5.220$
	The final result would be less than ideal	19	55	*df* = 4
	The problem with my teeth would get worse	6	9	*P* = .265
	The probability of injuries to lips and cheeks	5	29	
	I am not concerned	18	49	
How do you describe the level of your anxiety regarding the impact of COVID-19 pandemic and quarantine on your treatment?	Low	27	75	$X^2 = 2.822$
	Moderate	33	100	*df* = 2
	High	15	74	*P* = .224
Oral health literacy	Inadequate	27	64	$X^2 = 3.491$
	Borderline	16	72	*df* = 2
	Adequate	32	113	*P* = .175

Table 3. Association bBetween adherence to regular appointment and the concern and level of anxiety regarding quarantine/coronavirus pandemic (Chi-square test)

Variables	Answer	Patients who attend their orthodontic appointment regularly	Patients who fail to attend on a regular basis	*P*
How can you describe your anxiety level regarding the COVID-19 pandemic?	Low	31	66	$X^2 = 3.680$
	Moderate	37	134	*df* = 2
	High	16	40	*P* = .159
What is your greatest concern regarding your orthodontic treatment in this situation?	The treatment would become prolonged	42	92	$X^2 = 12.557$
	The final result would be less than ideal	11	63	*df* = 4
	The problem with my teeth would get worse	7	8	*P* = .014*
	The probability of injuries to lips and cheeks	5	29	
	I am not concerned	19	48	
How do you describe the level of your anxiety regarding the impact of COVID-19 pandemic and quarantine on your treatment?	Low	32	70	$X^2 = 3.984$
	Moderate	27	106	*df* = 2
	High	25	64	*P* = .136

Table 4. Association between oral health literacy, gender, feeling, concern, and level of anxiety regarding quarantine/coronavirus pandemic (Chi-square test)

Variable		Oral Health Literacy			*P*
		Inadequate	Borderline	Adequate	
Gender	Male	27	16	32	$X^2 = 3.491$ $df = 2$ $P = .175$
	Female	64	72	113	
How are you observing the quarantine?	Stay home for the entire quarantine period	32	30	66	$X^2 = 6.082$ $df = 4$ $P = .193$
	Stay home as much as possible (leave home for emergencies)	54	56	76	
	Going out as before the outbreak	5	2	3	
Are you working or studying?	Yes, and I leave home for work/study	25	23	46	$X^2 = 2.334$ $df = 4$ $P = .674$
	Yes, I work/study at home	44	45	74	
	No	22	20	25	
How can you describe yourself regarding the anxiety and stress you are experiencing because of the COVID-19 pandemic?	Calm	63	64	105	$X^2 = 10.736$ $df = 8$ $P = .217$
	Anxious	16	16	33	
	Scared	2	4	3	
	Panic	3	1	0	
	Indifferent	7	3	4	
How can you describe your anxiety level regarding the COVID-19 pandemic?	Low	31	30	36	$X^2 = 4.346$ $df = 4$ $P = .361$
	Moderate	45	41	85	
	High	15	17	24	
Would you attend your orthodontic appointments in this period?	Yes	34	25	25	$X^2 = 12.175$ $df = 2$ $P = .002^*$
	Only in the case of emergency	57	63	120	
	No	0	0	0	
What is your greatest concern regarding your orthodontic treatment in this situation?	The treatment would become prolonged	43	32	59	$X^2 = 17.606$ $df = 8$ $P = .024^*$
	The final result would be less than ideal	16	19	39	
	The problem with my teeth would get worse	6	6	3	
	The probability of injuries to lips and cheeks	10	4	20	
	I am not concerned	16	27	24	
How do you describe the level of your anxiety regarding the impact of the COVID-19 pandemic and quarantine on your treatment?	Low	30	26	46	$X^2 = 6.530$ $df = 4$ $P = .163$
	Moderate	29	37	67	
	High	32	25	32	
How many times a day you brush your teeth?	2-3 times a day	50	51	83	$X^2 = 22.408$ $df = 8$ $P = .004^*$
	Once a day	31	35	58	
	2-3 times a week	8	1	0	
	Once a week	2	1	4	
How many times a day you eat sugary snacks?	3 times or more	9	12	21	$X^2 = 11.269$ $df = 8$ $P = .187$
	Twice a day	15	21	38	
	Once a day	20	10	25	
	Occasionally	32	35	37	
	Rarely	15	10	24	
Have you ever smoked?	No, never	84	81	136	$X^2 = 11.068$ $df = 12$ $P = .523$
	I quit smoking	0	3	2	
	I smoke 1 cigarette a month	1	1	2	
	I smoke 2-3 cigarettes a month	2	1	0	
	I smoke 2-3 cigarettes a week	1	0	2	
	I smoke 1 cigarette a day	2	1	0	
	I smoke 2-3 cigarettes a day	1	1	3	
How did you attend your orthodontic appointment before the COVID-19 outbreak?	Regularly on monthly basis	78	69	122	$X^2 = 3.195$ $df = 6$ $P = .784$
	Often on monthly basis	10	14	17	
	Occasionally	3	5	6	

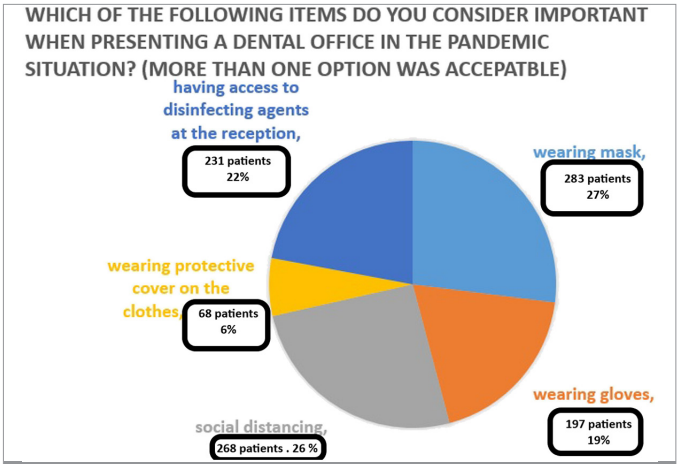

Figure 1. Descriptive statistics, including the percentage of patient's answers to "which of the following items do you consider important when presenting at a dental clinic in the pandemic situation?"

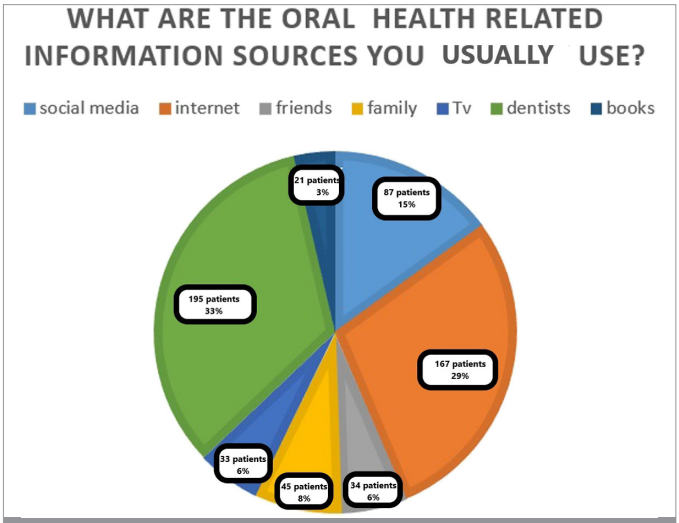

Figure 2. Descriptive statistics including the source percentage of patients' oral health-related information.

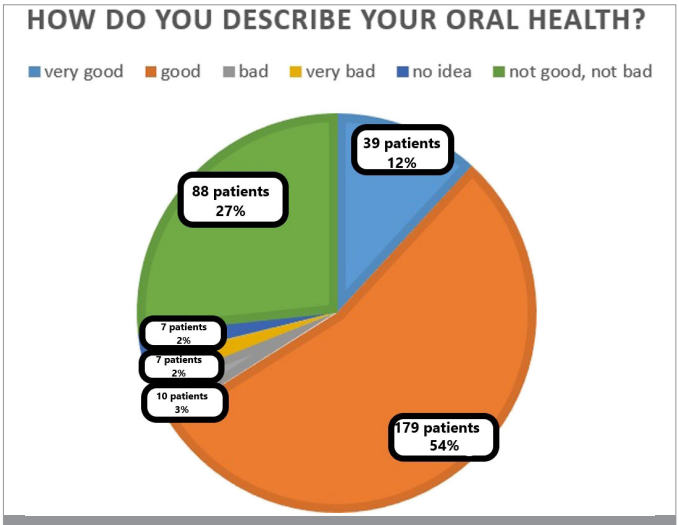

Figure 3. Descriptive statistics including patient's descriptions of their oral health.

not be the case for ongoing active treatments such as orthodontic treatment. The orthodontic patient might have some extra concerns due to the unpredicted pause in their treatment and its possible consequences. Therefore, we asked them to describe their anxiety level in general and express how they felt that the pandemic would affect their orthodontic treatment. Most (72%) of orthodontic patients who participated in our study said that they were calm, 55% assessed their anxiety level as moderate, and 74% said that they would go for an orthodontic appointment if it was needed. The greatest concern among 52% of our patients was the probability of a delay in completing their treatment, and 41% were moderately concerned about the pandemic's impact on their orthodontic treatment. There was no significant difference between males and females regarding the items except for the level they respect the quarantine. Xin Xiong et al., in a study conducted to assess mental distress in orthodontic patients during the COVID-19 pandemic, also found that disruption of routine appointments led to higher odds of mental distress and anxiety about treatment duration and outcome among orthodontic patients.

In Peloso et al.[12] study, most patients were not calm regarding the situation, 28.6% were anxious, and 23.2% were scared. However, that study was conducted at an early stage of the pandemic in Brazil; the high level of anxiety among Brazilian dental patients was attributed to the reports circulated worldwide regarding the seriousness of the situation.[12] Our study was conducted in late June 2020 when the pandemic had become a kind of chronic health problem, which can explain a lower anxiety level among our patients. Cotrin et al.,[13] in a study conducted to evaluate the impact of coronavirus pandemic on appointments and the anxiety/concerns of Brazilian orthodontic patients, revealed that 44.7% of respondents were calm regarding the coronavirus outbreak, and 46.3% were afraid or anxious. In that study, men were significantly calmer compared to women, which is contrary to our findings since we fail to find any significant difference between males and females in this regard. A nationwide survey of Chinese people to evaluate psychological stress caused by the COVID-19 pandemic further confirms what Cotrin et al.[13] found. That survey showed that females were significantly more distressed than males. As previously mentioned, in a study aimed at evaluating the general Iranian population's anxiety level during the COVID-19 outbreak, the level of anxiety was higher among the women.[11] Also, Xin Xiong et al. showed that female patients were more likely to experience mental distress during the pandemic, which might be attributed to the biological nature of their responses to stressors and risk factors, as well as their lower quality of life due to their orthodontic condition and treatment.

An interesting finding of the present study was the significant association between adherence to regular orthodontic appointment attendance and concerns regarding treatment. Those patients who attended their appointments regularly every month were significantly less concerned about the impact of pandemic on their treatment. Most of the respondents (74%) said that they would go to the orthodontic appointment if it was needed. In the Cotrin et al.[13] study, 60.2% of the participants answered positively to the question. The greatest concern

of patients in both studies was a delay in completing the orthodontic treatment. A delay in treatment is probable since missed appointments increase the duration of orthodontic treatment.

We assessed the OHL of respondents as well. OHL has been defined by the American Dental Association as the ability to obtain, process, and understand basic health information. It was found that people with lower levels of OHL had poorer oral health status. Improving patients' OHL was found to be linked to better adherence to medical instructions, self-management skills, and overall treatment outcomes. Inadequate OHL of parents was associated with a high rate of dental caries and fewer fillings in their children. The findings of our study showed that 45% of patients had adequate OHL, and only 28% of respondents had inadequate OHL. OHL was significantly associated with the willingness of patients to attend their appointments in the pandemic situation. Patients with higher OHL levels were more likely to attend the orthodontic appointment only in the case of an emergency. Those with adequate OHL were more concerned about the impact of the COVID-19 outbreak on their orthodontic treatment and also significantly increased the frequency and duration of daily tooth brushing. These findings correlate with better adherence to medical and health instructions by people with higher OHL.

Observing the social distancing instructions and wearing a mask were 2 of the measures which our respondents considered most important when visiting a dental clinic. Most of them used the internet as the main source to gather health information.

The nature of orthodontic treatment needs regular monthly appointments, which might be a challenge in situations like the present due to the COVID-19 pandemic. Improving patients OHL, following the responsible authorities' instructions, and making some modifications in orthodontic treatment plan to reduce the treatment time may help in this regard.

CONCLUSION

The results of this study showed that women respect the quarantine more than men. Most of the respondents indicated that they were calm regarding the COVID-19 pandemic. Patients who had more adherence to orthodontic appointment attendance (before the COVID-19 outbreak) were less concerned about their impact on their treatment. The greatest concern of our patients was the probability of a delay in completing their treatment. Most of the respondents had adequate OHL. Patients with higher OHL were more willing to attend the appointments only in the case of an emergency during the COVID-19 outbreak; they were more concerned about the impact of the COVID-19 outbreak on their orthodontic treatment and had better oral hygiene behaviors.

Ethics Committee Approval: This study was approved by Ethics committee of Birjand University of Medical Sciences (IR.BUMS.REC.1399.138).

Informed Consent: Verbal informed consent was obtained from the patients who agreed to take part in the study.

Peer Review: Externally peer-reviewed.

Author Contributions: Supervision – M.G.M., M.O.; Design – M.G.M.; Concept – M.G.M.; Resources – M.G.M., H.K.; Materials – M.G.M., M.O., H.K.; Data Collection and/or Processing – M.G.M., M.O., H.K.; Analysis and/or Interpretation – M.G.M., H.K.; Literature Search – M.G.M., H.K.; Writing Manuscript – M.G.M., H.K.; Critical Review – H.K.

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Original Article

Cone-Beam Computed Tomographic Assessment of Bone Thickness in the Mandibular Anterior Region for Application of Orthodontic Mini-Screws

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Main Points

- The best choice for the placement of mini-screws in the anterior region of the mandible is the interdental area of the lateral incisor and canine teeth.
- At the level of 8 mm from the CEJ, mini-screws could be applied more successfully due to proper mesiodistal and labiolingual bone dimensions.
- Mini-screws of 1.3-1.7 mm diameter and 5-7 mm length provides the best fit in the mandibular anterior region for orthodontic anchorage procedures.

ABSTRACT

Objective: To determine the proper zones for placement of orthodontic mini-screws, based on cone-beam computed tomography (CBCT) measurements in the anterior mandibular region.

Methods: The current cross-sectional study was performed on CBCT images of 77 individuals in the age range of 18-60 years. Axial slices at the levels of 2, 5, and 8 mm from the cementoenamel junction (CEJ) of the mandibular anterior teeth were selected. Interdental distances were measured in the mesiodistal direction, parallel to the midline of the mandibular arch. Areas with more suitable width were investigated for measuring the minimum interdental space. On the reconstructed cross-sectional images, labiolingual thickness of the bone was measured at the levels of 2, 5, 8, and 11 mm from the CEJ. The Kruskal–Wallis test, Mann–Whitney test with Bonferroni correction, Welch test, and Tukey's multiple analogy test were used to analyze the data.

Results: Mesiodistal and labiolingual distances between the roots in every measured region had the highest values at the levels of 8 and 11 mm from the CEJ. The highest measured values were related to the interdental region between the lateral incisor and canine teeth on both sides of the arch. There were no statistically significant differences between these values ($P < .001$).

Conclusion: The lateral incisor–canine areas at the level of 8 mm from the CEJ are introduced as the optimal sites for placement of orthodontic mini-screws. In addition, the results recommend the application of mini-screws with 1.3-1.7 mm diameter and 5-7 mm length.

INTRODUCTION

One of the most challenging issues in orthodontics is obtaining sufficient anchorage to make intended tooth movements.[1] Introduction of mini-screws that help to obtain anchorage redefined the concept of infinite anchorage. Mini-screws are easily placed and removed without the need for muco-periosteal flaps, and can be easily exposed to external forces after placement.[2]

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Achieving primary stability is the key to successful mini-screw anchorage. To achieve stability, the mechanical interlocking between the mini-screw and the bone should be administered carefully; 3 factors are more important in that regard: (a) bone quality (host factor); (b) mini-screw design (i.e., material factor); and (c) placement technique (i.e., operator factor). For bone quality, the cortical bone thickness is the most important determinant of primary stability.[3] Many parameters should be considered before placing an orthodontic mini-screw, such as biomechanics employed (i.e., direct or indirect anchorage) and the placement site anatomy. The placement site anatomy depends on the individual characteristics, which means it differs from person to person. However, some outcomes are relatively predictable.[4-6]

When planning for the design and placement of orthodontic mini-screws, the cortical bone thickness and bone width are 2 important micro-and macro-anatomical factors that should be considered.[7] Evaluation of distances at the mid-root level is also important in the treatment planning since it affects both the safety and stability of mini-screws.

Root proximity is of crucial importance in the final outcome of the mini-screws. According to the literature, there is a significant correlation between stability and safety margins around mini-screws. This not only confirms the usefulness of using relatively smaller diameter screws but also shows that adequate distance from the roots is a vital factor in ensuring the stability of mini-screws.[8,9] To achieve adequate anchorage and to prevent damage to the roots or adjacent teeth, and it is necessary to measure the buccolingual and mesiodistal inter-radicular dimensions of the recipient bone.[10]

The application of cone-beam computed tomography (CBCT) is now a popular method for measuring bone thickness.[11] The main feature of CBCT is that it uses multiple planar projections acquired by a single rotational scan to construct a volumetric dataset. It results in adequate tissue contrast and minimized image distortion and adjacent tooth overlapping. Moreover, it provides diverse views from the anatomical structures. Thus, CBCT overcomes many limitations of conventional radiographic techniques. Another advantage is the significant dose reduction compared to conventional CT.[12]

The current study aimed to evaluate the labiolingual bone thickness and mesiodistal root distances of the anterior mandibular teeth at different levels using CBCT images. The main purpose was to determine which areas have sufficient and appropriate thickness and could be considered safe for placement of mini-screws to achieve maximum anchorage during orthodontic treatments.

METHODS

The current cross-sectional study was performed on CBCT images of 77 patients who were referred to the Faculty of Dentistry, Guilan University of Medical Sciences. The scans had been prescribed for various purposes, including implant surgery, evaluation of impacted posterior teeth, supernumerary teeth, and endodontic management of the posterior teeth during orthodontic treatments from 2016 to 2019. Sample size was calculated based on a pilot study on 30 subjects by assuming α = 0.05, 95% CI, standard deviation = 1.19, and study power = 80%.

CBCT images were acquired by a VATECH Pax-i3D device (Gyeonggi-do, Korea), and measurements were performed using Ez3D-i software Version 4.1 (Gyeonggi-do, Korea). The study was approved by the Research Ethics Committee of Guilan University of Medical Sciences (Approval ID: IR.GUMS.REC.96.268.). Informed consent was taken from the patients with regard to the use of their CBCT data. The patients were assured that their personal information would not be published in the research.

Inclusion criteria were the age range of 18-60 years, presence of mandibular anterior teeth, absence of horizontal and vertical bone loss around the anterior teeth, and absence of retained primary teeth in the mandibular anterior region. Cases with crowding or spacing more than 3 mm, craniofacial syndromes and deformities, pathologies of the maxillofacial region, old or new fracture in the anterior mandible, and significant distance (>1 mm) between the CEJs of adjacent teeth were excluded from the study.

Axial mandibular sections at the levels of 2, 5, and 8 mm from the CEJs of the mandibular anterior teeth were used to measure the mesiodistal distances of the teeth roots. These measurements were made in the midline of the arch and parallel to a curved line connecting the midpoints of proximal portions of the adjacent roots (Figure 1). Subsequently, cross-sectional slices perpendicular to this curved line were reconstructed with 2 mm thickness and 1 mm distance. Maximum Sharpness was applied to the images to determine the distal border of the available bone. The CEJ was identified as a reference line in the acquired sections. Consequently, parallel lines were drawn and measured at the levels of 2, 5, 8, and 11 mm from the CEJ (Figure 2).

The results of the first part of the research were analyzed by the Kruskal–Wallis test. In the second step, after obtaining the results

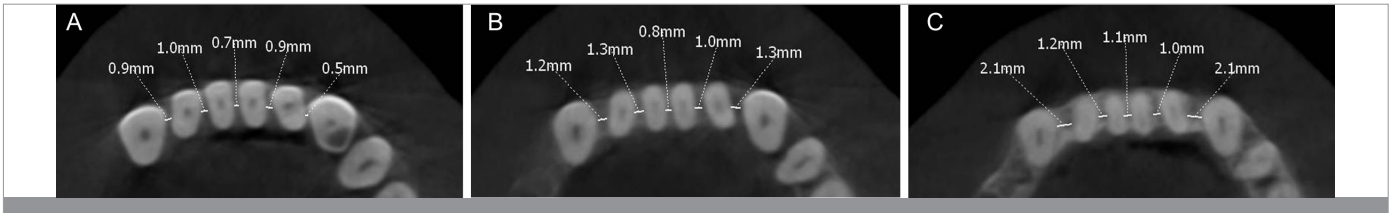

Figure 1. Mesiodistal distances between roots of the anterior mandibular teeth on axial views at the levels of 2 (A), 5 (B) and 8 mm (C) from the CEJ.

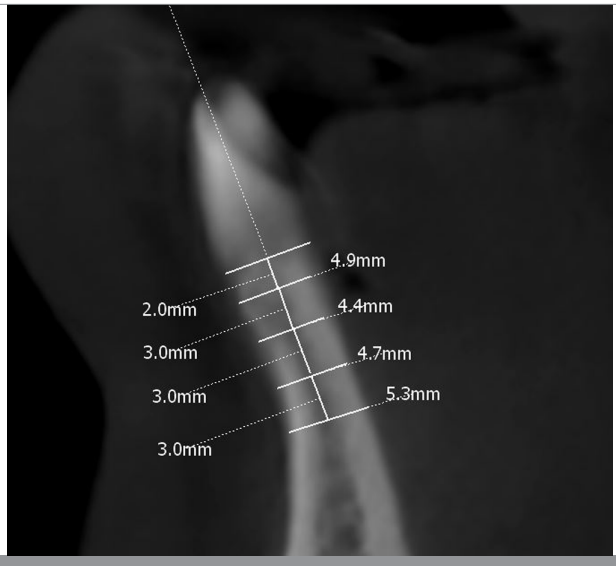

Figure 2. Cross-sectional view from the alveolar bone between the right mandibular canine and lateral incisor teeth showing the labiolingual bone thickness at the level of 2, 5, 8 and 11 mm from the CEJ.

and statistical analysis, the areas between the mandibular lateral incisors and the canines on both sides were identified as areas with proper mesiodistal width for the placement of mini-screws. The roots of these teeth on both sides were measured at the levels of 2, 5, and 8 mm from the CEJ to determine the proper diameter for the mini-screws (Figure 3).

Statistical Analysis

To check the normality of quantitative variables (i.e., mesiodistal and labiolingual measurements of the available bones between roots of the anterior teeth), kurtosis and skewness values, histograms, Q–Q plots, and Shapiro–Wilk tests were used. As the data were normally distributed and variances were homogeneous, non-parametric Kruskal–Wallis test (for asymmetrically distributed data), Mann–Whitney test with Bonferroni correction, Welch test (for normally distributed data with non-homogenous variances), and Tukey's multiple comparison test (to examine if the differences between mean values are significant in 2 or more groups) were used for further analysis. Statistical significance was set at a .05 probability level. All analyses were conducted using SPSS software Version 18 (Chicago, IL, USA).

RESULTS

Median and interquartile ranges of the mesiodistal distances between roots of the anterior teeth at the levels of 2, 5, and 8 mm from the CEJ are provided in Table 1. The highest median amount was at the level of 8 mm from CEJ, and the findings showed a statistically significant difference between the levels.

Median and interquartile ranges of the mesiodistal distances between roots of the anterior teeth at the levels of 2, 5, and 8 mm from the CEJ are provided in Table 1. The highest median amount was at the level of 8 mm from CEJ, and the findings showed a statistically significant difference between the levels.

Median and interquartile ranges of the mesiodistal distances between roots of the anterior mandibular teeth, regardless of the distance from CEJ, are shown in Table 2. The highest median amount was related to the right, followed by the left lateral incisor–canine regions. There was a statistically significant difference between the regions ($P < .001$).

Median and interquartile ranges of the minimum mesiodistal distances between roots of the lateral incisor and canine teeth at the levels of 2, 5, and 8 mm from the CEJ on both sides are presented in Table 3. On both sides, the highest median amount was obtained at the level of 8 mm. Statistically significant differences were found between the different levels in the canine–lateral incisor region ($P < .001$).

Using the Mann–Whitney test, a pairwise comparison of the least mesiodistal distances among the different levels from the CEJ (2, 5, and 8 mm) indicated statistically significant differences between each of the 2 groups ($P < .001$).

Mean labiolingual bone thickness values at the levels of 2, 5, 8, and 11 mm from the CEJ are given in Table 4. The highest mean value was at the level of 11 mm from the CEJ. Overall, there were statistically significant differences between the mean labiolingual values at the different levels in each region.

Median and interquartile ranges of the labiolingual distances between roots of the anterior mandibular teeth, regardless of the distance from CEJ are shown in Table 5. The highest median value was related to the right, followed by the left lateral incisor–canine regions. There was a statistically significant difference between the median labiolingual distances between the roots in the different regions ($P < .001$).

According to the findings, mesiodistal width of the available bone between the anterior mandibular teeth at the level of 8 mm from the CEJ was the greatest. The highest mesiodistal distance was observed between the lateral incisor and canine teeth on both sides.

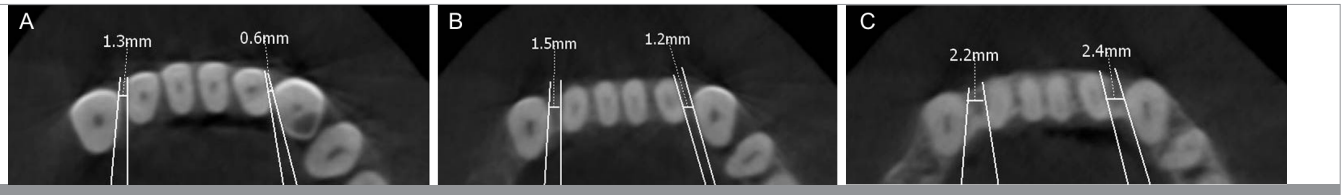

Figure 3. Axial views of the mandible at the levels of 2 (A), 5 (B) and 8 (C) mm from the CEJ of the anterior teeth showing the minimum mesiodistal distance between the roots of canine and lateral incisor teeth.

Table 1. Comparison of the mesiodistal distances between roots of the anterior mandibular teeth at different levels of 2, 5, and 8 mm from the CEJ

Region	Level from the CEJ	Number	Median (Interquartile range)	Minimum	Maximum	*P**
Right lateral and canine	2 mm	77	2.60[a] (2.15-3.00)	1.10	4.00	<.001
	5 mm	77	2.80[b] (2.50-3.30)	1.50	4.60	
	8 mm	77	3.40[c] (2.90-3.80)	1.50	6.20	
Right central and lateral	2 mm	77	2.50[a] (1.80-2.75)	1.10	4.90	.003
	5 mm	77	2.30[b] (1.90-2.80)	1.10	4.50	
	8 mm	77	2.60[c] (2.25-3.20)	1.00	5.30	
Left and right centrals	2 mm	77	2.50[a] (1.85-3.00)	1.10	4.50	.002
	5 mm	77	2.40[b] (2.20-3.00)	1.20	4.60	
	8 mm	77	2.80[c] (2.30-3.50)	1.00	5.50	
Left central and lateral	2 mm	77	1.20[a] (1.80-2.70)	1.00	4.60	.007
	5 mm	77	2.30[b] (1.90-2.75)	1.20	4.80	
	8 mm	77	2.60[c] (2.20-3.20)	1.30	5.20	
Left lateral and canine	2 mm	77	2.4 0[a] (2.10-2.90)	1.20	4.30	<.001
	5 mm	77	2.70[b] (2.40-3.30)	1.70	4.50	
	8 mm	77	3.10[c] (2.70-3.80)	1.60	6.00	
All mandibular anterior teeth	2 mm	385	2.40[a] (1.90-2.90)	1.00	4.90	<.001
	5 mm	385	2.60[b] (2.10-3.10)	1.10	4.80	
	8 mm	385	2.90[c] (2.40-3.50)	1.00	6.20	

*Kruskal Wallis test ($P < .05$); Identical uppercase letters indicate no statistically significant difference in Mann-Whitney comparative test with Bonferroni correction ($P < .017$).

After identifying the regions with greater mesiodistal widths in the anterior portion of the mandible, the minimum mesiodistal distances between the roots in these regions were measured at 2, 5, and 8 mm from the CEJ. Based on the measurements, in the regions between the left lateral incisor and canine teeth at the level of 2 mm from the CEJ, only 19.5% of the subjects indicated a minimum mesiodistal width of about 2.3 mm for insertion of the thinnest mini-screws. At levels of 5 and 8 mm from the CEJ, this frequency was 37.7 and 76.6%, respectively.

In the right lateral incisor–canine region, 6.28, 48.1, and 81.8% of the subjects had available bone with a mesiodistal width of 2.3 mm or more, at the levels of 2, 5, and 8 mm from the CEJ, respectively. Considering the minimum standard of 60% as the least mesiodistal bone width to indicate a suitable location for mini-screw insertion, the width is not appropriate at distances of 2 and 5 mm from the CEJ, while at a distance of 8 mm from the CEJ, there is sufficient width on both sides to secure mini-screw placement.

The greatest labiolingual thickness of the bone among the mandibular anterior teeth was at the level of 11 mm from the CEJ. Also, the highest labiolingual bone thickness was observed in the lateral incisor–canine regions. There was no significant difference between the right and left sides. Considering both mesiodistal and labiolingual thicknesses, at the level of 8 mm from the CEJ, the lateral incisor–canine region is an optimal area for insertion of mini-screws. Furthermore, if adequate attached gingiva exists, the level of 11 mm from the CEJ is also suitable for the insertion of mini-screws. Additionally, this level (11 mm) has the highest available labiolingual alveolar

Table 2. Comparison of mesiodistal distances between the roots in different regions

Region	Number	Median (Interquartile range)	Minimum	Maximum	*P**
Right lateral and canine	231	2.90[a] (2.50-3.50)	1.10	6.20	<.001*
Right lateral and central	231	2.40[b] (1.90-2.90)	1.00	5.30	
Right central and Left central	231	2.60[b] (2.10-3.20)	1.00	5.50	
Left central and lateral	231	2.40[b] (1.90-2.80)	1.00	5.20	
Left lateral and canine	231	2.80[a] (2.40-3.30)	1.20	6.00	

*Kruskal Wallis test ($P < .05$); Identical uppercase letters indicate no statistically significant difference in Mann-Whitney comparative test with Bonferroni correction ($P < .05$).

Table 3. Comparison of the minimum mesiodistal distances between the roots of the canine and lateral incisor teeth at the levels of 2, 5, and 8 mm from the CEJ on both sides

Region	Level from the CEJ	Number	Median (Interquartile range)	Minimum	Maximum	*P**
Right lateral and canine	2 mm	77	2.00[a] (1.65-2.60)	1.00	3.80	<.001
	5 mm	77	2.30[b] (2.10-2.90)	1.30	4.50	
	8 mm	77	2.90[c] (2.50-3.45)	1.60	6.20	
Left lateral and canine	2 mm	77	2.00[a] (1.60-2.20)	0.40	3.70	<.001
	5 mm	77	2.30[b] (2.00-2.70)	0.90	4.00	
	8 mm	77	2.70[c] (2.40-3.10)	1.50	5.40	

*Kruskal Wallis test ($P < .05$); Identical uppercase letters indicate no statistically significant difference in Mann-Whitney comparative test with Bonferroni correction ($P < .017$).

bone thickness. The mesiodistal distances between the mandibular anterior teeth at the level of 11 mm were not measured since roots of the anterior teeth, except for the canines, do not extend to this level. Therefore, there is less concern about root damage at the level of 11 mm from the CEJ. However, individual alveolar bone and soft tissue examinations are essential prior to treatment planning.

Another important point is the diameter and length of the mini-screws that can be inserted in the anterior mandibular region. Mini-screws generally have a diameter ranging from 1.3-2 mm and a length of 5-12 mm (more commonly 6-8 mm).[13] The minimum suggested distance between a mini-screw and the adjacent tooth root is 0.5 mm.[14] The recommended length for the mini-screws inserted at the level of 8 mm from the CEJ in the

Table 4. Comparison of the mean labiolingual bone thickness between the anterior mandibular teeth at the levels of 2, 5, 8 and 11 mm from the CEJ

Region	Level from the CEJ	Number	Mean ± Standard deviation	Confidence interval 95%	Minimum	Maximum	*P**
Right lateral and canine	2 mm	77	6.98[a] ± 1.06	(6.74,7.22)	4.10	9.00	.002
	5 mm	77	7.07[a] ± 1.06	(6.83,7.32)	4.40	9.70	
	8 mm	77	7.14[a] ± 1.26	(6.86,7.43)	3.50	9.70	
	11 mm	77	7.78[b] ± 1.51	(7.44,8.12)	4.20	11.10	
Right central and lateral	2 mm	77	6.13[a] ± 0.81	(5.95,6.32)	4.30	8.00	<.001
	5 mm	77	6.27[a] ± 0.90	(6.07,6.48)	3.90	8.80	
	8 mm	77	6.49[a] ± 1.15	(6.23,6.75)	3.50	9.00	
	11 mm	77	7.32[b] ± 1.55	(6.96,7.67)	3.20	11.40	
Left and right central	2 mm	77	5.35[a] ± 0.79	(5.18,5.54)	4.00	7.30	<.001
	5 mm	77	5.77[a] ± 0.96	(5.55,5.98)	3.60	8.70	
	8 mm	77	6.51[b] ± 1.31	(6.21,6.80)	3.60	8.90	
	11 mm	77	7.69[c] ± 1.75	(7.29,8.09)	4.10	11.40	
Left central and lateral	2 mm	77	6.26[a] ± 0.78	(6.08,6.43)	5.00	8.80	<.001
	5 mm	77	6.26[a] ± 0.95	(6.05,6.48)	4.50	9.10	
	8 mm	77	6.57[a] ± 1.20	(6.30,6.85)	3.70	9.50	
	11 mm	77	7.45[b] ± 1.60	(7.09,7.82)	3.90	11.00	
Left lateral and canine	2 mm	77	7.04[a] ± 0.83	(6.86,7.23)	5.00	8.80	.001
	5 mm	77	7.01[a] ± 0.89	(6.81,7.22)	4.50	9.10	
	8 mm	77	7.13[a] ± 1.22	(6.58,7.41)	3.70	9.50	
	11 mm	77	7.83[b] ± 1.53	(7.48,8.17)	3.90	11.00	
Total	2 mm	385	6.35[a] ± 1.06	(6.25,6.46)	4.00	9.00	<.001
	5 mm	385	6.48[a] ± 1.07	(6.37,6.59)	3.60	9.70	
	8 mm	385	6.77[b] ± 1.26	(6.64,6.90)	3.30	9.90	
	11 mm	385	7.78[c] ± 1.51	(7.45,7.77)	3.20	12.80	

* Welch test ($P < .05$); Identical uppercase letters indicate no statistically significant difference in Tukey's multiple comparison test.

Table 5. Comparison of the labiolingual distances between the roots in different regions

Region	Number	Median (Interquartile range)	Minimum	Maximum	*P**
Right lateral and canine	308	7.30 [a] (6.40-8.00)	3.50	11.10	<.001
Right central and lateral	308	6.40 [b] (5.70-7.30)	3.20	11.40	
Left and right centrals	308	6.10 [c] (5.30-7.30)	3.60	11.40	
Left central and lateral	308	6.60 [b] (5.80-7.40)	3.30	12.80	
Left lateral and canine	308	7.20 [a] (6.50-8.00)	3.70	11.00	

*Kruskal Wallis test ($P < .05$); Identical uppercase letters indicate no statistically significant difference in Mann-Whitney comparative test with Bonferroni correction ($P < .05$).

lateral incisor–canine regions is 5-7 mm. Long mini-screws, which pass through the medullary bone and reach the cortical layer on the opposite side, can provide more stability; however, they are rarely applied.[15]

To the best of our knowledge, this is the first study to focus on the mandibular anterior region for the application of orthodontic mini-screws using CBCT images. In situations where proper anchorage could not be achieved solely from the posterior regions due to factors such as lack of sufficient bone or the need for applying arbitrary forces to a tooth or a group of teeth, the need for anterior anchorage is more highlighted.

Previous studies which have examined both the anterior and posterior regions of the mandible to determine the appropriate location for insertion of mini-screws have confirmed the superiority of posterior areas owing to the greater bone volume.

Lee et al.[16] evaluated the tooth-bearing alveolar bone for orthodontic mini-screw placement by using CBCT images. They examined the tooth-bearing alveolar bone of the maxilla and the mandible in 30 patients with an average age of 27.8 years, with normal occlusion, and without a history of orthodontic treatments. Linear measurements at the levels of 2, 4, 6, and 8 mm from the CEJ were performed in the mesiodistal and buccolingual dimensions. Accordingly, the maximum mesiodistal and buccolingual bone thickness were 2.02 $\pm$ 0.66 mm and 3.06 $\pm$ 0.87 mm, respectively, which were recorded in the lateral incisor–canine region at the level of 8 mm from the CEJ.

Fayed et al.[17] investigated appropriate locations for mini-screw placement using CBCT images. A total of 100 patients were included and divided into 2 age groups (13-18 and 19-27 years). Buccolingual bone thickness, mesiodistal space on the buccal and lingual/palatal sides, and cortical bone thickness were measured in different areas of the jaws at the levels of 2, 3, and 5 mm from the CEJ. The maximum mesiodistal spaces on the buccal and lingual sides of the mandible on the right side were 3.28 $\pm$ 0.88 and 2.78 $\pm$ 1.13 mm, respectively. On the left side, these values were 3.89 $\pm$ 1.33 and 3.12 $\pm$ 1.51 mm, respectively. They also reported that the maximum buccolingual thickness was 7.83 $\pm$ 1.36 mm on the right side and 7.75 $\pm$ 1.43 mm on the left side, being related to the lateral incisor–canine region at the level of 6 mm from the CEJ.

Purmal et al.[18] conducted a study to determine the safe zones in the maxilla and mandible for placement of inter-maxillary fixation screws. They evaluated 98 maxillary and 95 mandibular CBCT images. Linear measurements were performed at distances of 2, 5, 8, and 11 mm from the alveolar crest. The mesiodistal distances were measured parallel to the midline of the arch and the buccolingual/palatal distances were measured on reconstructed sagittal cross-sectional images. According to the results, the maximum mesiodistal distance and buccolingual bone thickness on the right side of the mandible were 3.99 $\pm$ 0.32 and 8.25 $\pm$ 1.41 mm, respectively. On the left side, these values were 3.91 $\pm$ 0.31 mm and 10.1 $\pm$ 1.56 mm, respectively. Statistical analysis of the results indicated significant differences between the right and left sides ($P < .05$). As a result, the mesiodistal dimension in the interdental area between the lateral incisor and canine teeth at the level of 11 mm from the CEJ on the right side was proved to be the most appropriate. The same region on the left side was shown to be the most proper location with regard to the buccolingual dimension. The authors also reported that the interdental area of the lateral incisor–canine teeth, at the level of 11 mm from the CEJ, is more suitable for placement of mini-screws for inter-maxillary fixation.

Sadeghian et al.[19] conducted an anthropometric analysis of the buccal and lingual bone thickness of the anterior mandibular teeth by CBCT. They examined the buccal and lingual bone thickness of the mandibular anterior teeth of 20 patients aged 18-40 years by considering 4 reference lines. The alveolar bone thickness of the canine teeth on both lingual and buccal sides was greater than the rest of the anterior teeth. In all of the anterior teeth, the thickness of the lingual plate was larger than that of the buccal plate. The distance between the root apex of the canine tooth to the deepest buccal curvature was also higher than the same distance for the other teeth. No statistically significant differences were observed between males and females.

By comparing the above-mentioned studies[6,17,18,19] with the present study, there is an agreement with regard to the appropriateness of the lateral incisor–canine region for insertion of orthodontic mini-screws. Results of the current study are consistent with the previous findings[6,17,18,19] and can be justified in 2 ways: First, the presence of a nearly uniform conical root in the mandibular anterior teeth may contribute to the increased amount of available bone from the CEJ toward the apex, both in the mesiodistal and the labiolingual dimensions. Nevertheless, there may be exceptions due to various skeletal malocclusions,

root morphology, and tooth alignment in the mandibular arch. Second, the distinct position of the canine tooth at the curvature of the mandibular arch, in addition to its position in relation to the lateral incisor root, results in a sufficient amount of bone in the mesiodistal and labiolingual dimensions at this location.

One of the limitations of our study was that the facial height and malocclusion type were not considered; however, it should be noted that Gracco et al.[20] assessed morphology of the mandibular symphysis in various facial heights (short, long, and normal heights) and found that despite the greater total thickness of the symphysis in the short-face group, no statistically significant difference exists in the total and cancellous areas of the symphysis among the 3 facial types.

CONCLUSION

The interdental area of the lateral incisor–canine teeth at the level of 8 mm from the CEJ is suitable for the application of orthodontic mini-screws in the mandible owing to sufficient mesiodistal and labiolingual dimensions. Mini-screws with a diameter range of 1.3-1.7 mm and length of 5-7 mm is recommended for anterior anchorage in orthodontic treatments.

Ethics committee approval: This study was approved by Ethics committee of Guilan University, (Approval No: IR. GUMS .REC.96.268).

Informed consent: Written informed consent was obtained from the patients who agreed to take part in the study.

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Original Article

Evaluation of the Effect of Different Bracket Systems on External Apical Root Resorption Using Cone-Beam Computed Tomography

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Main Points

- The incidence of EARR was higher in the 18-30 age group.
- The rate of EARR in male patients was found to be higher than in female patients.
- The duration of orthodontic treatment influences EARR.
- The bracket system does not affect external apical root resorption.

ABSTRACT

Objective: The aim of this study was to evaluate the external apical root resorption (EARR) developed in the maxillary and mandibular teeth of patients undergoing orthodontic treatment with conventional and self-ligating bracket systems.

Methods: Cone-beam computed tomography images of patients treated with self-ligating and conventional bracket systems, which were taken at the beginning and end of treatment, were evaluated. The teeth where EARR developed during the treatment period were identified. EARR was evaluated as yes or no. A *P* value of $< .05$ was considered statistically significant.

Results: Of a total of 300 patients (68.7% female, 31.3% male), 20% were treated with the self-ligating bracket system, while 80% were treated with the conventional bracket system. EARR occurred in 8.3% ($n = 25$) of the patients after treatment. A statistically significant difference was found when the effect of age, gender, and treatment duration on the incidence of EARR was evaluated. The incidence of EARR was higher in the age group of 18-30 years than in the age group of 12-17 years. Similarly, it was found to be higher in men than in women and higher in the group with a treatment duration of 33-49 months than in the group with a treatment duration of 8-32 months.

Conclusion: Treatment duration has been observed to affect the incidence of EARR in patients undergoing fixed orthodontic treatment, and the incidence of EARR increases with increased treatment duration. Furthermore, it has been concluded that EARR during orthodontic treatment is influenced by age and gender. There is no difference between self-ligating and conventional bracket systems in terms of EARR.

Keywords: Orthodontics, bracket systems, external apical root resorption

INTRODUCTION

External apical root resorption (EARR) is one of the most common complications seen during the orthodontic treatment.[1] It is manifested as the loss of substance in the root apex in permanent teeth and shortening of the root apex.[2] A sterile necrotic area is formed when the intensity of the orthodontic force required for the correction of malocclusions during orthodontic treatment is above the capillary blood pressure within the periodontal ligament. Destructive cells, macrophages, and multinucleated cells migrate to this area in response to signals released from necrotic tissues, causing a local inflammatory response. This inflammation is reported to be the

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main factor in the development of EARR.[3,4] In the literature, there are many studies evaluating the relationship between EARR and orthodontic treatment. These studies report that there are many factors associated with EARR, including age, gender, nutrition, treatment with and without tooth extraction, treatment duration, amount of tooth movement, and genetic factors.[5,6] Furthermore, the mechanics used during orthodontic treatment and the type of forces applied have been found to be associated with EARR.[5] In conclusion, the etiology of EARR is complex and multifactorial. Therefore, it has been reported that patients at risk of developing EARR should be recognized early and patients should be offered radiographic controls 6 months after the initiation of orthodontic treatment.[7]

The incidence of EARR, the identification of patients who are more likely to develop EARR, its predictability, and preventability are still being studied.[8] Although EARR rarely reaches dimensions that may affect the functions of a tooth, EARR developed during orthodontic treatment negatively affects the opinion of orthodontists and patients about treatment success.[8] Currently, studies on this subject have regained intensity with the contribution of genetic science and the development of new imaging techniques.[8] Although there have been many studies on EARR, its risk factors are still discussed in many studies.[7] There are no comprehensive research studies on the effects of genetic structure on root resorption. However, the current studies agree on the important role of genetics, although no information has been provided about which genes are active. Adult patients have been reported to be in the high-risk group for the orthodontic treatment-induced EARR.[7] Predictability, prevention, and early diagnosis of EARR are of great importance for the course of orthodontic treatment and the patient's dental health. Therefore, it is important to determine the severity and prevalence of EARR in various populations and its associated risk factors.[9]

Research studies aimed at improving the effectiveness of orthodontic treatment have focused on new bracket designs. One of them is the self-ligating bracket—the Damon system in particular—which has become popular in recent years.[10] The Damon system (Ormco, Glendora, CA) is based on the use of a passive self-ligating brackets and super-elastic nickel-titanium wires.[11] This system, which particularly has low friction forces, has been promoted to apply only light forces to move the teeth.[12] In the initial leveling and alignment phase, the amount of EARR in this system is similar to that in the conventional bracket systems.[4] Studies in the literature have shown that the bracket system or technique used for orthodontic treatment may be related to the EARR severity.[9] On the other hand, lighter forces have been shown to often lead to less resorption.[10] There are a limited number of studies investigating EARR after orthodontic treatment with the Damon system.[11] Although the effectiveness of orthodontic treatment with self-ligating and conventional bracket systems has been extensively studied in the literature, the number of studies on EARR during orthodontic treatment is limited.[5,7,9] Therefore, the aim of this retrospective study was to compare EARR developed in maxillary and mandibular teeth in patients treated with self-ligating and conventional brackets.

METHODS

The study population consisted of a total of 300 patients aged 12-30 who were admitted to the Orthodontic Clinic between 2014 and 2016. The sample size was calculated based on an alpha significance level of 0.05 to achieve 80% of power (0.1 sampling error (d), $P = .8$, $q = 0.2$) to detect the frequency of EARR with G*Power software Version 3.0.10. The sample size calculation showed that 60 patients were needed in a group. Patients undergoing fixed orthodontic treatment without tooth extraction, in which the Damon system and Roth 3M bracket system were used, were included in the study. After the study was planned, the Clinical Research Ethics Committee approval was obtained (Decision Number: 2020/02-20). Written informed consent was obtained from the patients who participated in this study. The study was conducted in accordance with the ethical principles of the Helsinki Declaration. Cone-beam computed tomography (CBCT), KaVo 3D eXam (Biberach, Germany) images were obtained with a 4-second exposure time and a 0.3 mm-voxel size using a FOV of 130 at 120 kV and 5 mA. The EARR was evaluated by examining the CBCT images obtained at the beginning and end of treatment in patients treated with passive self-ligating/0.022-inch slot bracket (Damon Q, Ormco, Glendora, CA) and conventional bracket systems/0.022 inch slot (Roth, 3M Unitec, Gemini, Monrovia, Calif). Pre- and post-treatment changes in tooth sizes were evaluated according to Levander and Malmgren index .[8] 0 = no root resorption; 1= irregular root resorption; 2 = apical root resorption less than 2 mm (minor resorption); 3 = apical root resorption from 2 mm to one-third of the original root length (severe resorption); 4 = apical root resorption exceeding one-third of original root length (excessive resorption) (Figure 1). All evaluations were made by the same researcher (E.Ö). Individuals with skeletal Class I malocclusion, no skeletal asymmetry, no severe deep bite and open bite, no incisor or molar intrusion, permanent dentition, mild or moderate crowding according to Little's irregularity index, and non-extraction treatment were included. Patients who had EARR prior to treatment, those who had previously received orthodontic treatment, individuals with dental anomalies such as agenesis, dental invagination, taurodontism, and dilatation, patients with missing orthodontic records or having low-quality radiographs, were excluded from the study. Non-extraction treatment with

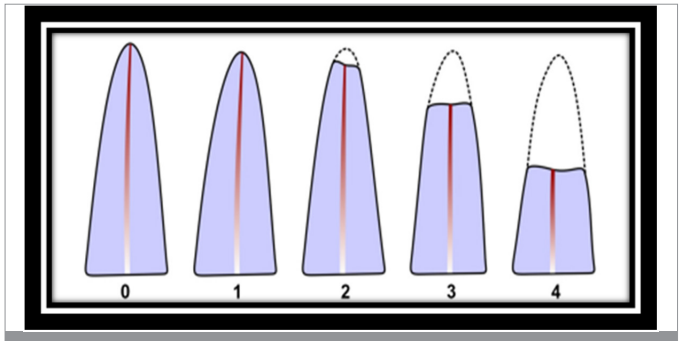

Figure 1. Levels of the external apical root resorption by Levander and Malmgren.[8] Grade 0, absence of root resorption; Grade 1, mild resorption; Grade 2, moderate resorption; Grade 3, accentuated resorption; and Grade 4, extreme resorption.[28]

the passive self-ligating Damon Q system is characterized by beginning leveling and alignment with round 0.013 in or 0.014 in Nitinol, followed by round 0.016, 0.018 in Nitinol, rectangular 0.014 × 0.025, 0.016 × 0.025, 0.018 × 0.025, and 0.019 × 0.025 in Nitinol archwires. Roth brackets (3M Unitek Gemini) of 0.022-inch slot were used on all arches in the conventional bracket system. In the leveling and alignment stage, orthodontic mechanics involved a wire sequence characterized by an initial round 0.012 in or a 0.014 in Nitinol, followed by round 0.016, 0.018 in Nitinol, and rectangular 017 × 0.025, 0.019 × 0.025 in Nitinol archwires. After the leveling and alignment of the maxillary and mandibular dental arches were completed with Nitinol archwires, rectangular stainless steel archwires were used.

Statistical Analyses

Fifteen days after the initial evaluation, 50 of the CBCT images were randomly selected, and the EARR scores of the teeth were re-measured by another investigator to determine the inter-investigator error with the Kappa test. (SCC). Scores were calculated for each of the patients with EARR in the self-ligating and conventional bracket system groups. Scores 0 and 1 were considered as insignificant EARR (no) and scores 2, 3, and 4 were considered as EARR (yes) (Figure 2). Statistical analyses were performed using Number Cruncher Statistical System (NCSS) 2007 (Kaysville, Utah, USA). Descriptive statistical methods (mean, standard deviation, median, frequency, percentage, minimum, maximum) were used to evaluate the study data. The suitability of the quantitative data for normal distribution was examined using Shapiro–Wilk test and graphical analyses. Independent-samples *t*-test was used to compare the quantitative variables with normal distribution between the 2 groups. Qualitative data were compared using Pearson's chi-squared test and Fisher's exact test. A *P* value of .05 was considered statistically significant.

RESULTS

There was a high agreement between the researchers confirming the reliability of the measurements. The Kappa coefficient between researchers was 0.86 for maxillary teeth and 0.82 for mandibular teeth. The study included a total of 300 patients (68.7% (*n* = 206) female; and 31.3% (*n* = 94) male). The age of the patients ranged from 12 to 30 years, with a mean age of 16.13 ± 4.08 years. Of the patients, 74% (*n* = 222) were in the 12-17 age group and 26% (*n* = 78) were in the 18-30 age group (Table 1, Figure 3).

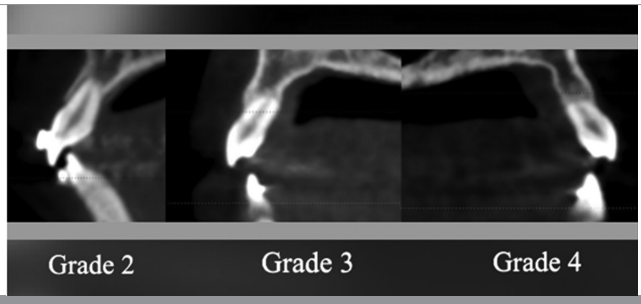

Figure 2. Grades 2, 3, and 4 showing external apical root resorption.

Table 1. Descriptive statistics of the study sample

Variable	Categories	
Age (years)	Min–max	12-30
	Mean ± SD	16.13 ± 4.08
	12-17 years [n (%)]	222 (74.0)
	18-30 years [n (%)]	78 (26.0)
Gender	Female [n (%)]	206 (68.7)
	Male [n (%)]	94 (31.3)
EARR after treatment	No [n (%)]	275 (91.7)
	Yes [n (%)]	25 (8.3)
Number of EARR per patient (*n* = 25)	Min–max	1-10
	Mean ± SD	4.00 ± 2.06
Bracket system	Self-ligating system [n (%)]	60 (20.0)
	Conventional system [n (%)]	240 (80.0)
Duration of treatment (months)	Min–max	8-49
	Mean ± SD	31.99 ± 9.26

Min, minimum; Max, maximum; SD, standard deviation; n, number of patients

EARR occurred in 8.3% (*n* = 25) of the patients after treatment. Two of these 25 patients were in the self-ligating bracket system group, whereas 23 were in the conventional bracket system group—the total number of teeth with EARR was100 among 25 patients. The number of teeth with EARR ranged from 1 to 10 for each patient, with a mean number of 4.00 ± 2.06 (Table 1).

The treatments were classified according to the bracket systems used. Orthodontic treatment was performed using a self-ligating bracket system in 20% (*n* = 60) of the patients and a conventional bracket system in 80% (*n* = 240) (Figure 4). The mean treatment duration was 31.99 ± 9.26 months, ranging from 8 to 49 months (Table 1).

The difference between the age and gender distributions of the patients treated with self-ligating and conventional bracket systems were not statistically significant (*P* > .05) (Table 2).

There was not a statistically significant difference between the patients treated with self-ligating and conventional bracket systems in terms of post-treatment EARR (*P* > .05) (Table 2).

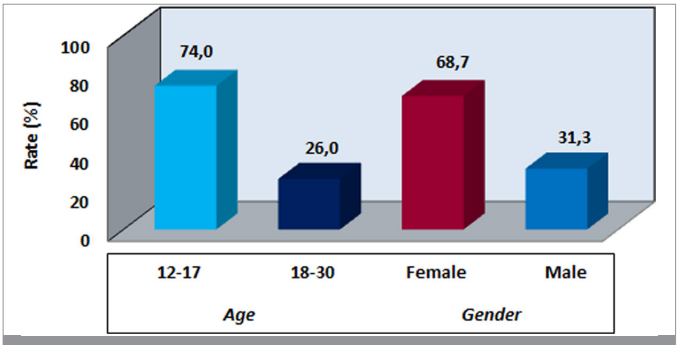

Figure 3. Age and gender distributions.

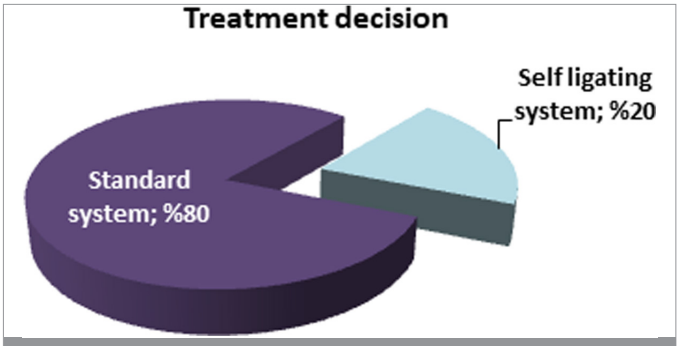

Figure 4. Distributions of bracket system.

No statistically significant difference was observed between the patients treated with self-ligating and standard bracket systems in terms of orthodontic treatment duration ($P > .05$) (Table 2).

There was a statistically significant difference between the rates of post-treatment EARR according to age ($P < .01$). The incidence of EARR in the 18-30 age group was found to be higher than in the 12-17 age group (Table 3).

There was a statistically significant difference between the rates of post-treatment EARR according to gender ($P = .020$; $P < .05$). The rate of EARR in male patients was found to be higher than in female patients (Table 4).

There was a statistically significant difference between the rates of post-treatment EARR according to treatment duration ($P = .043$; $P < .05$). The incidence of root resorption in patients receiving treatment for 33-49 months was found to be higher than in patients receiving treatment for 8-32 months (Table 5).

Table 3. Age evaluations

Root Resorption After Treatment	Age Groups (years) 12-17 (*n*=222), *n* (%)	18-30 (*n*=78), *n* (%)	*P*[a]
No	210 (94.6)	65 (83.3)	.002**
Yes	12 (5.4)	13 (16.7)	

[a]Pearson chi-square test; **$P < .01$.

Table 4. Gender evaluations

Root Resorption After Treatment	Gender Female (*n*=206), *n* (%)	Male (*n*=94), *n* (%)	*P*[a]
No	194 (94.2)	81 (86.2)	.020*
Yes	12 (5.8)	13 (13.8)	

[a]Pearson chi-square test; *$P < .05$.

Table 5. Evaluation of duration of treatment

Root Resorption After Treatment	Duration of Treatment (Months) 8-32 months (*n*=154), *n* (%)	33-49 months (*n*=146), *n* (%)	*P*[a]
No	146 (94.8)	129 (88.4)	.043*
Yes	8 (5.2)	17 (11.6)	

[a]Pearson chi-square test; *$P < .05$.

DISCUSSION

This study aimed to compare the rates of EARR in the maxillary and mandibular teeth of patients treated with Damon and Roth bracket systems. In patients who developed EARR during orthodontic treatment, EARR was observed not only in incisor teeth but also in premolar and molar teeth. Therefore, unlike other studies, the examination was performed on all maxillary and mandibular teeth in the present study.[8] Post-treatment EARR occurred in 8.3% ($n = 25$) of the patients. There was a statistically significant difference between the patients treated with Damon and Roth bracket systems in terms of post-treatment EARR. A statistically significant difference was observed between the post-treatment EARR rates according to age; EARR incidence in the 18-30 age group was found to be higher than in the 12-17 age group. When the EARR incidence was evaluated according to gender, it was found to be higher in males than in females.

Table 2. Comparison of the bracket systems in terms of age and gender distribution, presence of EARR and treatment duration with Pearson Chi-Square test and Student's t-test

Variable	Categories	Bracket System Self-ligating System (*n*=60)	Conventional System (*n*=240)	*P*
Age (years)	12-17 [n (%)]	48 (80.0)	174 (72.5)	.236[a]
	18-30 [n (%)]	12 (20.0)	66 (27.5)	
Gender	Female [n (%)]	38 (63.3)	168 (70.0)	.319[a]
	Male [n (%)]	22 (36.7)	72 (30.0)	
EARR after treatment	No [n (%)]	58 (96.7)	217 (90.4)	.117[a]
	Yes [n (%)]	2 (3.3)	23 (9.6)	
Duration of treatment (months)	Min–max	14-48	8-49	.775[b]
	Mean ± SD	31.68 ± 8.31	32.07 ± 9.50	

[a]Pearson chi-square test; [b]Student's *t*-test.
Min, minimum; Max, maximum; SD, standard deviation; n, number of patients.

There was a statistically significant difference between the post-treatment EARR rates according to treatment duration. The EARR rates in patients receiving treatment for 33-49 months were found to be higher than in the patients receiving treatment for 8-32 months.

In almost all studies on tooth movement, EARR, torque, and tipping are defined as the total horizontal movement of the root apex, considered the riskiest movement regarding EARR.[12,13] In a study by Baumrind et al.,[14] a 1 mm posterior movement of the root apex has been reported to cause EARR of 0.49 ± 0.14 mm. Regardless of the mechanics of treatment, intrusive forces are reported to increase the risk of EARR.[15] The methods used in studies investigating the relationship between malocclusion type and EARR are quite different. Therefore, inconsistent and sometimes contradictory results are reported.[12,16] Therefore, no malocclusion is considered to be immune to EARR. The common results are as follows: increased overjet and open bite closure are risk factors for maxillary incisors. Angle classification is not effective, and the effect of overbite is controversial.[12-16] In this study, EARR was not evaluated according to orthodontic malocclusions. Therefore, we could not compare the present study with other studies.

Prolonged use of the edgewise bracket applying active torque has been reported to increase the risk of resorption.[17] Sameshima and Sinclair[18] have reported that the type or elastic use of the archwire is not correlated with the EARR. In a histologic study by Maltha et al.,[19] the effects of forces of 10, 25, 50, 100, and 200 g on EARR were evaluated, and the amount of force was reported to have no effect on resorption. This conclusion is quite different from other studies. Darendeliler et al.[20] studied the resorption craters in human premolar teeth subjected to heavy and light forces through a 3D evaluation and reported an increase in the volume of resorption craters as a result of heavy forces. There are a limited number of studies in which the mechanics used for treatment are evaluated for EARR. In one study, the standard edgewise, Roth straight-wire, and Begg techniques were compared for EARR and reported no difference between the 3 techniques in terms of root resorption.[21] In this study, patients treated with Roth and Damon bracket systems were compared, and no difference was found in terms of EARR incidence.

Some studies have reported that the duration of force is a more critical factor than the magnitude of the force in the etiology of EARR, particularly in relation to long treatment duration.[5] Therefore, it has been reported that patients at risk for EARR should be recognized early, and patients should be offered radiographic controls 6 months after the initiation of orthodontic treatment.[5] In the literature, CBCT imaging has been accepted as the most reliable technique for the measurement of EARR.[22] Therefore, CBCT guide orthodontists to continue or change the treatment plan as needed.[22] In our study, CBCT images were used to evaluate EARR as it is the most accurate and reliable technique. No additional CBCT was taken for the study since the patients included in the study were selected from patients who had CBCT image recordings, and the patients were not further exposed to radiation for this retrospective study. In this study, EARR was evaluated on CBCT. Patients had the first CBCT for evaluation of impacted teeth before orthodontic treatment. They had a second CBCT after orthodontic treatment to evaluate the risk of complications due to impacted tooth extraction.

It is noteworthy that studies conducted over the last 2 decades evaluating the relationship between orthodontic treatment-induced EARR and gender have reported no correlation. On the other hand, Kjaer,[22] who examined the morphological characteristics of the dentitions of patients with excessive EARR during orthodontic treatment, and Horiuchi et al.,[16] who evaluated the effect of the relationship between tooth roots and cortical plaque on EARR, have concluded that the risk of EARR was higher in female patients. In contrast, Baumrind et al.,[14] who examined the factors affecting EARR in adults and examined the relationship between endodontic treatment and EARR, have concluded that the risk was higher in male patients. Lee and Lee[23] have reported that both treatment duration and patient's age have shown a statistically significant correlation with EARR in patients receiving orthodontic treatment and that there is no significant correlation between gender and EARR. In this study, it was concluded that the incidence of EARR varied according to gender and was higher in male patients.

Many studies have reported that prolonged orthodontic treatment is an important cause of EARR. In a study by Levander and Malmgren,[8] resorption has been reported in 34% of the teeth after a 6-9 months, and this rate has been reported to increase to 56% after treatment of 19 months. In a study by Goldin,[24] 0.9 mm EARR has been reported to develop per year. Unlike these studies, there are also researchers who argue that large amounts of tooth movements occur in the first phase of treatment and that treatment duration is, therefore, not correlated with resorption. In the present study, it has been concluded that EARR increased with the increasing orthodontic treatment duration.

In the majority of studies on the type of force and EARR, intermittent or interrupted forces that provide a resting period for tissues have been reported to cause less EARR.[25] Faster correction of orthodontic malocclusion has been reported to have the potential to cause undesirable side effects, such as root resorption, which is a great concern for orthodontists.[26] Studies have shown that the bracket system or technique used for orthodontic treatment may be related to the EARR severity.[3] There are also studies showing that lighter forces generally lead to less resorption.[27] In recent years, there has been a significant increase in the use of self-ligating bracket systems by orthodontists. The Damon system is based on the use of a passive self-ligating bracket and super-elastic nickel-titanium wires.[11] This system, which particularly has low friction forces, has been emphasized to apply only light forces to move the teeth.[27] In the initial leveling and alignment phase, the amount of EARR in this system has been reported to be similar to that in the conventional bracket systems.[27] In this study, patients treated with Roth and Damon bracket systems were compared, and no difference was found in terms of EARR incidence.

In their study, Leite et al.[4] have compared the EARR in incisors in patients treated with self-ligating (EasyClip, SP, Brazil) and conventional (3M Unitec, Monrovia, Calif) brackets and found that EARR developed at significant rates in both groups 6 months after orthodontic treatment. In a study by Handem et al.[27] involving patients aged between 16 and 19, who were treated with self-ligating (Damon Q) and conventional bracket systems, EARR has been evaluated with Levander and Malmgren scores through periapical radiographs of maxillary and mandibular incisors at the end of orthodontic treatment; the authors have reported no significant difference between the 2 groups in terms of EARR severity. In a study by Aras et al.,[28] where Damon Q and conventional brackets (Titanium Orthos [TO]) used, it has been reported that there is no difference between the 2 bracket systems in terms of EARR. In the present study, no statistical difference has been found between the patients treated with Damon Q and conventional bracket systems in terms of EARR, compatible with the literature. Although there are many studies in the literature evaluating the effectiveness of orthodontic treatment with Damon and conventional brackets, the number of studies evaluating the effect of these systems on EARR during orthodontic treatment is limited. We believe that there is a need for further clinical trials.

Technological innovations have made it possible to evaluate the degree of EARR in 3D because of its accuracy in measuring EARR. It is recommended to use nickel-titanium archwires that apply less and optimum force instead of using stainless steel archwires that are thought to cause more resorption.[29] Although some amount of EARR (0.25 mm) occurs in all teeth during leveling and alignment phases, this degree of EARR is considered small and clinically irrelevant.[29] Self-ligating brackets provide faster tooth movement but are also suggested to pose a high risk for EARR. However, studies have reported that the degree of EARR is similar in orthodontic treatments with conventional or self-ligating bracket systems. In the present study, the effect of self-ligating and conventional bracket systems on the incidence of EARR after orthodontic treatment did not show any statistically significant difference. However, the amount of EARR was higher in the conventional bracket system compared to the self-ligating bracket system. The limitations of this study are that, since the number of patients who had CBCT taken at the beginning and end of treatment was limited, the number of patients could not be increased further and the standardization could not be fully achieved among patients due to the effect of many local and systemic factors on EARR. EARR should be evaluated at least by taking periapical radiographs from incisors, which are considered to be the most affected teeth, in the sixth month of orthodontic treatment; if there are any changes in the root form, treatment at the affected arch should be stopped for a while.

CONCLUSION

In this study, it was observed that the effect of bracket systems on external root resorption was similar. Age and gender were found to influence root resorption.

Ethics Committee Approval: This study was approved by Ethics committee of Van Yuzuncu Yil University, (Approval No:2020/02-20).

Informed Consent: Written informed consent was obtained from the patients who participated in this study.

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Original Article

Quality of Information on YouTube™ about Rapid Maxillary Expansion

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Main points:

- YouTube™ is a social platform that patients use to share information and experiences related to orthodontics.
- This study evaluated the content and quality of YouTube™ videos on rapid maxillary expansion (RME).
- YouTube™ videos are generally inadequate regarding containing information about RME.

ABSTRACT

Objective: This study aimed to evaluate the content and quality of YouTube™ videos about rapid maxillary expansion (RME).

Methods: Videos on YouTube™ were searched using the term "palatal expansion." After sorting by relevance, the final 100 videos were analyzed for video demographics, primary purpose, information reliability, audiovisual quality, and Global Quality Scale (GQS). Also, viewers' interaction index and viewing rate formulas were calculated for each YouTube™ video. Mann–Whitney U test, Spearman's correlation coefficient and Intra-class Correlation Coefficient were used for statistical analyses.

Results: YouTube™ videos about palatal expansion were mostly uploaded by patients and their relatives (51%). The reliability of the information in the videos with a GQS value >3 was significantly higher than those with a GQS value ≤3 (4.33 vs. 1.69) ($P < .001$). There was an excellent correlation between information reliability and GQS in videos uploaded by orthodontists and dentistry professionals (r=0.878, $P < .01$).

Conclusion: YouTube™ is currently not an appropriate source of information about RME for patients. Orthodontists should refer patients to reliable sources of information on social media platforms.

Keywords: Internet, rapid maxillary expansion, social media, YouTube

INTRODUCTION

Most of the world's population has access to many websites that provide information regarding modern healthcare. Recent studies have found that 8 of 10 internet users have access to online healthcare information.[1,2] It has been demonstrated that patients believe that the internet is a valuable source of healthcare information, and it plays a role in the patients' relationship with healthcare professionals.[3]. Not only healthcare professionals but also any internet user can produce health-related information and upload it on the related websites. Therefore, the validity and reliability of this information are controversial.

People have quick and easy access to information on social media regarding orthodontic treatment for themselves or their children. Therefore, YouTube™ is the first source of information about treatment, especially orthodontic treatment, more than other social media platforms because YouTube™ provides visual and auditory information.[4,5] Since 2005, YouTube™ has become a phenomenon for commercial and personal content distribution, that is, it has become the second most growing video platform on the internet. Over 1.9 billion logged-in users visit YouTube™ each month. In addition, over a billion hours of videos are watched every day, and billions of pieces of content are created.[6] However, YouTube™ videos about dentistry are mostly underdeveloped and

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underestimated.[7] The quality and integrity of dental information on YouTube™ are controversial because of the minimal filtering of uploaded videos.[8]

Rapid maxillary expansion (RME) is a routine clinical procedure in orthodontics that is used to expand the maxilla transversally. The main purpose of the procedure is to expand the maxilla in young adolescents who have transversal maxillary narrowness, deep palatal vault, and associated maxillary cross-bite. Although this treatment is intended to correct the dental and skeletal maxillary transverse malocclusions, some authors have shown that treatment outcomes may increase nasopharyngeal airway size and improve nasal breathing.[9] The literature includes reports on potential positive effects of RME in the treatment of nasal airways, septal deformity, recurrent ear or nose infections, allergic rhinitis, asthma, and their combinations.[10] However, RME may involve complex and difficult procedures from the patient's perspective despite such positive outcomes. Not understanding the RME screw activation protocol causes the RME screw to get stuck and causes the appliance to fail to function. Moreover, patients may have other complaints, including pain, formation of median diastema between the maxillary incisors, periodontal and oral mucosa injury, and difficulty in speech. The risk of swallowing and aspiration of the RME screw key during screw activation is critical as it may lead to serious complications. YouTube™ is also a social media platform that patients use to share information and experiences about such issues in dentistry. Therefore, the content quality of RME videos is important to guarantee the accuracy of information on YouTube™.

The number of studies on the relationship between social media and orthodontics are limited[11,12], and there are no studies that have investigated the information on RME treatment on social media. Therefore, the purpose of this study was to evaluate the content and quality of YouTube™ videos about RME and to analyze the effectiveness and usefulness of the videos for patients. The null hypothesis was that videos about RME on YouTube™ are of low quality.

METHODS

YouTube™ Search Strategy

Using the term "rapid maxillary expansion" as a starting point, this study evaluated the search frequency of similar terms in the Google Trends application. Among similar terms, "palatal expansion" was returned as the most used search term on YouTube™. The search parameters were set to "Worldwide"/ "All Categories" for the last 5 years to expand the search results.

A search was performed on YouTube™ (https://www.youtube.com) on June 30, 2019, with the term "palatal expansion" to evaluate the videos shared about "rapid maxillary expansion." A new YouTube™ account was created for this study. To avoid any bias when searching for results, the computer history and cookies were deleted. The uniform resource locators of all videos were saved. Videos that were in a language other than English, videos that had no audio, and videos that lasted longer than 15 minutes were not included, and in total, 30 videos were excluded from the study (11 videos with no audio, 7 videos not related to the subject, 4 duplicate videos, and 8 videos longer than 15 minutes). Our research was classified using default search filters. The only search filter applied was "relevance"[13], and other filters were not changed or replaced. Two researchers (MTA and SKB) evaluated all the videos for all parameters. Because this study comprised only the data available in the public domain, it did not require approval from an ethics committee. Furthermore, this study was approved by Clinic Research Committee of Ordu University (2020/154).

The remaining 100 videos were evaluated in this study. Thus, the relevant search term was returned as a representative of audience behavior.[14]

Video Assessment

All the videos were watched in full, and the following general parameters were recorded for each video: (1) number of views, (2) time (seconds), (3) total number of "likes and dislikes," and (4) number of comments.

The videos were also divided into 2 main groups according to their sources as follows: (1) orthodontists and dentistry professionals and (2) patients and relatives.

The purpose of the video was categorized under 3 main groups as follows: (1) patient information, (2) patient experiences, and (3) education. The main reason for creating the videos this way was to ensure that the videos fulfilled these purposes. While creating groups, the researchers combined the related sub-groups with each other to achieve more successful results.

The reliability of information was scored between 1 and 5 (reliability score) based on 5 questions (Table 1).[14] Furthermore, all videos were rated using the Global Quality Scale (GQS) (Table 2), according to the quality of information and reviewer's comments on the usefulness of the video for patients.[14] Videos with a GQS score of ≤3 were considered low to poor in quality, and those with a score >3 were classified as good to excellent.

The interaction of viewers was calculated using the interaction index and viewing rate formulas. Video interaction was calculated through the difference of the total number of "likes" and "dislikes" divided by the total number of views.[14] The video viewing rate was calculated by dividing the total number of views by the number of days of the video on YouTube™. A total of 20 videos were evaluated again by the same researchers (MTA and SKB). The agreement coefficients of reliability of information and GQS scores between the 2 evaluation times (intra-observer correlation: MTA) were 0.769 and 0.772, respectively, according to the Cohens' kappa (κ) statistics.

Statistical Analysis

The Statistical Package for Social Sciences, version 20.0 software (SPSS Inc.; Chicago, IL, USA) was used for the statistical analyses. The normality of data distribution was assessed by Shapiro-Wilk test. Mann–Whitney U test was performed for comparison of the

video characteristics. Spearman's correlation coefficients were also calculated to assess the possible correlations between the GQS, content, and reliability scores. Intra-class correlation coefficients were calculated to define intra-rater reliability. Statistical significance was evaluated on the $P < .05$ level.

RESULTS

The inter-observer (MTA versus SKB) agreement coefficients for GQS and reliability of information evaluation of randomly selected videos were statistically significant (κ: 0.781 and κ: 0.741, respectively).

Table 1. Evaluation of the reliability of videos useful for maxillary expansion on YouTube™

Serial number	Questions
1	Were the aims clear and achieved?
2	Were the sources of information reliable? (Examples include valid studies cited to support claims, information presented by an orthodontist specialist)
3	Is the information balanced and unbiased?
4	Are additional resources for learning provided?
5	Does the video address areas of controversy/ uncertainty?

Table 2. Global Quality Scale criteria used to rate videos containing information about rapid maxillary expansion on YouTube™

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

Table 3 shows the descriptive statistics of the video characteristics. The mean length of the YouTube™ videos about palatal expansion was 4.86 (± 3.95) minutes. The mean total number of views was 50,014.51 (± 173,455.92). The mean view-through rate was 3,826.10 (± 10,000.67). The mean interaction index value was .70 (± 0.76). The mean GQS score was 2.07 (± 1.09).

YouTube™ videos about palatal expansion were mostly uploaded by patients and their relatives (51%, n = 51), followed by orthodontists and dentistry professionals (49%, n = 49).

Patient experiences (n = 49) took prominence in terms of the purpose of sharing, followed by patient information (n = 45) and education (n = 6).

The videos were divided into 2 groups based on the source as follows: orthodontists and dentistry professionals (n = 49) and patients and patient relatives (n = 51).

There was a significant difference between the mean number of views of videos created by orthodontists/dentistry professionals and those uploaded by patients and their relatives ($P = .027$). When the reliability of the information in the videos was examined, it was found that the information reliability of the videos uploaded by orthodontists/dentistry professionals was significantly higher than that of the videos uploaded by patients and their relatives (2.81 vs. 1.23) ($P < .001$). The GQS scores of the videos uploaded by orthodontists/dentistry professionals were significantly higher than those uploaded by the patients and their relatives ($P < .001$). The mean interaction index of the videos by patients and their relatives was significantly higher than that of the videos created by orthodontists ($P = .008$) (Table 4).

The reliability of the information in the videos with a good to excellent GQS score was significantly higher than that in videos with a low to poor GQS score (4.33 vs. 1.69) ($P < .001$) (Table 5).

Table 6 shows the Spearman's correlation coefficients between the scores of reliabilities of information and GQS and YouTube™ parameters. There was a high correlation between the information reliability and GQS (r = 0.878, $P < .01$) in the videos uploaded by orthodontists/dental professionals, whereas the correlation between the interaction index (r = 0.337, $P < .05$) and the view-

Table 3. Descriptive statistics of the YouTube™ videos

	N	Minimum	Maximum	Mean	SD
No. of views	100	89.00	1,440,723.00	50,014.51	173,455.92
Duration in minutes	100	.20	14.59	4.86	3.95
No. of likes	100	.00	7,847.00	301.14	950.10
No. of dislikes	100	.00	267.00	13.71	39.68
No. of comments	100	.00	1,015.00	60.96	155.45
Reliability of information	100	.00	5.00	2.01	1.23
Global Quality Scale (GQS)	100	1.00	5.00	2.07	1.09
Interaction Index	100	.00	3.77	0.71	0.77
Viewing Rate	100	25.89	77,944.15	3,826.11	10,000.67

SD: Standard deviation.

ing rate (r = 0.392, $P < .01$) was moderate. Moreover, there was a moderate correlation between the GQS and interaction index (r = 0.318, $P < .05$) and viewing rate (r = 0.434, $P < .01$) in the videos uploaded by orthodontists/dentistry professionals. In contrast, there was an high correlation between the information reliability and GQS (r = 0.642, $P < .01$); however, the correlation between information reliability and viewing rate (r = 0.305, $P < .05$) was on a moderate level in the videos uploaded by patients. There was moderate correlation between the GQS and viewing rate (r = 0.514, $P < .01$) for the videos uploaded by patients, whereas the correlation between GQS and interaction index (r = 0.351, $P < .05$) was moderate.

Table 4. Quality of useful videos (n=100) on rapid maxillary expansion to source of information

	Orthodontist/ Dental Professionals (n=49) Mean (SD)	Patient/ Relative (n=51) Mean (SD)	*P**
Number of views	64137.98 (226964.25)	36444.90 (98674.28)	.027
Duration in minutes	2.44 (1.95)	7.19 (4)	<.001
Number of likes	195.39 (501.65)	402.74 (1234.59)	<.001
Number of dislikes	13.65 (45.12)	13.76 (34.11)	.015
Number of comments	66.75 (188.53)	55.39 (116.88)	.012
Reliability of information	2.81 (1.15)	1.23 (0.71)	<.001
Global Quality Scale	2.65 (1.11)	1.51 (0.73)	<.001
Interaction index	0.64 (0.84)	0.77 (0.69)	.008
Viewing rate	2945.84 (7575.36)	4671.85 (11893.15)	<.001

*Result of the Mann-Whitney U Test, SD: Standard deviation.

Table 5. Comparison of RME videos according to GQS information

	Orthodontist/ Dental Professionals (n=49) Mean (SD)	Patient/ Relative (n=51) Mean (SD)	*P**
Number of views	253131.08 (454698.93)	22316.79 (40366.13)	.051
Duration in minutes	4.42 (3.08)	4.92 (4.06)	.783
Number of likes	1102.83 (2256.67)	191.81 (531.56)	.137
Number of dislikes	59.41 (99.61)	7.47 (14.48)	.217
Number of comments	175.66 (329.82)	45.31 (108.08)	.190
Reliability of information	4.33 (0.65)	1.69 (0.91)	<.001
Interaction index	1.16 (1.25)	0.64 (0.66)	.211
Viewing Rate	14861.95 (24041.43)	2321.21 (4651.86)	.304

*Results of the Mann-Whitney U test
RME: Rapid maxillary expansion, GQS: Global Quality Scale, SD: Standard deviation.

DISCUSSION

Many patients research about their orthodontic treatment for detailed information. They mostly use YouTube™ that provides rich visual content and easy access instead of scientific platforms that provide more academic and accurate information.[15] However, the validity of information on YouTube™ is questionable because anyone can share videos, and there is no standardization of content for the uploaded videos. Therefore, this study evaluated the content quality of YouTube™ videos on RME and evaluated the primary purposes of sharing these videos.

The concept of opening the midpalatal suture was first described by Angell in 1860.[16] However, opening of the midpalatal suture with RME appliances could be radiographically proven only in the early 1900s because X-rays were not discovered before those years. RME became a popular method in recent years for eliminating transversal disorders between the dental arches because of maxillary narrowing.[17] Some potential positive effects of RME are reported for the treatment of a combination of poor nasal airway, septal deformity, recurrent ear or nose infection, allergic rhinitis, and asthma.[18] RME produces great forces to overcome the limitations of orthodontic tooth movement and achieve a minimum dental and maximum orthopedic effect, thus enabling expansion and gradual opening of the middle palatal suture.[19] The expansion force depends on the activation protocol. For example, the screw may be activated once or twice a day for approximately 2–4 weeks, and a single activation creates a force of 3–10 pounds.[20] However, RME may involve complex and challenging procedures from the patient's perspective despite such positive outcomes. Failure to understand the screw activation protocol causes the RME screw to jam and the device to malfunction. Moreover, patients may have other complaints such as pain, median diastema formation between the maxillary incisors, bad breath, periodontal and oral mucosa injury, and dif-

Table 6. Spearman correlation coefficients between scores reliability information, GQS, and YouTube™ parameters

		Number of Views	Duration (minute)	Number of Likes	Number of Dislikes	Number of Comments	Information Reliability	GQS	Interaction Index	Viewing rate
Patient/Relative	Information Reliability	0.100	0.132	0.160	0.129	0.254	1.000	0.642**	0.164	0.305*
	GQS	0.272	0.374**	0.417**	0.367**	0.527**	0.642**	1.000	0.351*	0.514**
Orthodontist/ Dental Professionals	Information Reliability	0.285*	0.624**	0.532**	0.379**	0.585**	1.000	0.878**	0.337*	0.392**
	GQS	0.327*	0.615**	0.542**	0.447**	0.623**	0.878**	1.000	0.318*	0.434**

Significance levels, *$P < .05$; **$P < .01$
GQS: Global Quality Scale.

ficulty in speaking. The risk of swallowing and aspiration of the key during screw installation is critical as this may lead to severe complications. YouTube™ is also a platform that patients use to share information and experiences about orthodontics. Therefore, the content quality of RME videos is crucial to guarantee the accuracy of information.

There are no standards for the videos shared on medical issues on YouTube™ because not only orthodontists but also lay people can upload and share videos, and this may affect human health. However, the information reliability of high-quality videos scored higher than the information reliability of low-quality videos in our study. This result showed a positive correlation between information reliability and video quality. The mean duration of the videos shared by patients or their relatives was longer than that of the videos shared by orthodontists or dentistry professionals. This could be because patients or their relatives do not share videos with an educational purpose but would like to share their experiences about the treatments. The mean GQS score of the videos shared by orthodontists or dentistry professionals and the reliability score of information in these videos were higher than those of the videos shared by patients or their relatives. This finding showed that the videos shared by orthodontists on RME were more beneficial than those shared by patients or their relatives in terms of content, streaming quality, and reliability. This finding also showed that the content of videos shared by orthodontists or dentistry professionals was educational because orthodontists or dentistry professionals are educated in this field.

The increasing use of social media in all fields of life has led to a need for studies investigating the quality, accuracy, and precision of the content of videos, especially those related to the field of health.[12-14] Numerous studies have analyzed websites in different areas in health-related fields. Several studies have also evaluated the content of videos related to orthodontics on YouTube™ and other social media platforms.[4, 11–13, 21, 22, 23] Canigur-Bavbek and Balos-Tuncer[22] evaluated the quality of website information related to orthognathic surgery in Turkey, they concluded that web-based information was of low quality. Olkun et al.[23], in their study on the quality and reliability of websites providing information about lingual orthodontics in Turkey, reached the conclusion that there was insufficient information on these websites regarding lingual orthodontics. In our study, similar results were obtained with the conclusion that the quality of Internet-based information was low.

A systematic review by Papadimitriou et al.[24] on the use of social media in providing information and its effects on orthodontic patients has shown that information exchange on several social networks developed as a significant source of information on orthodontics. The study showed that social media was a common platform for information exchange, especially among young people. In addition, these young people shared their experiences on various social media platforms. One of the possible reasons was that young people were more comfortable communicating through social media than communicating with orthodontist face to face. As a result of the increasing use of the Internet and social media both by professionals and employees in the field of medicine and dentistry, studies regarding the quality of video content and other shared visual information become more crucial. There are many studies evaluating online information on medicine and dentistry. Knösel and Jung[7] conducted a study to measure the level of knowledge in orthodontic posts on YouTube™. They concluded that although YouTube™ was a platform for sharing patient experiences, related videos remain inadequate in terms of content. Singh et al.[14] have investigated the quality of information shared on YouTube™ about rheumatoid arthritis, and they analyzed viewer interactions. They concluded that there was no standard of quality of relevant information on YouTube™, and there was no difference between the popularity and viewing of useful and misleading videos. Lena and Dindaroglu[13] conducted a study examining the content and quality of YouTube™ videos on lingual orthodontics and concluded that the content and quality of the videos were inadequate. Hatipoglu and Gas[25] investigated the quality of YouTube™ videos regarding surgically supported rapid palatal expansion. The results of the study showed that only 25.76% of all uploaded videos were of moderate content quality. The remaining videos had low-quality content. There were no high-quality content videos. The results of these studies show that the quality of video content is essential because the feedback on these videos affect the patients' decision-making process regarding the orthodontic treatment.

Patients and their relatives mostly shared their experiences in the videos, but healthcare professionals created and shared videos mostly for education and information. Therefore, these videos were more crucial and valuable. In our study, the ratios of the videos uploaded by patients/patients' relatives and dentistry professionals were 51% and 49%, respectively. Among the shared videos, only 3 obtained 5 full ratings in terms of information reliability and GQS, and they were all shared by orthodontists. This finding suggested that orthodontists should share high-quality videos, and there should be a control system to upload such videos.

For the videos shared by orthodontists and patients in terms of information reliability and GQS as well as other YouTube™ parameters, the correlation between the GQS score of the videos shared by orthodontists and information reliability was more significant than the correlation between the GQS score and information reliability of the videos shared by patients. In the videos shared by orthodontists, the scores on information reliability and GQS showed a positive correlation with duration in minutes, number of likes and dislikes, and number of comments. This finding suggested that patients prefer interacting through videos rather than directly with orthodontists.

YouTube™ content is dynamic, and search results are constantly changing. Comments, likes, dislikes, view rates, and various other parameters can be changed and manipulated. It should also be noted that although we had selected keywords for search using the Google Trends application, different videos might appear by using different keywords.

CONCLUSION

YouTube™ videos were generally inadequate in their content of information on RME. Therefore, patients who want to learn about RME on YouTube™ may have difficulty finding videos with high-quality content. Orthodontists should refer their patients to the right sources for up-to-date information on YouTube™.

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Original Article

Treatment Time of Class II Malocclusion, with and without Mandibular Crowding, Treated with Four Premolar Extractions: A Retrospective Study

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Main Points

- We compared the treatment times of complete Class II malocclusion, with and without crowding, treated with the 4 premolar extraction protocol.
- Treatment times were similar.
- No significant correlation between crowding and treatment time was found.

ABSTRACT

Objective: This study aimed to compare the treatment times in patients with complete bilateral Class II malocclusion, with and without mandibular crowding, treated with 4 premolar extractions.

Methods: The sample comprised 57 retrospectively and consecutively selected patients (30 male, 27 female) treated for initial Class II malocclusion, divided as follows: Group 1 consisted of 23 patients (11 males, 12 females; mean age 13.13 years) presenting no crowding or 3 mm at most. Group 2 consisted of 34 patients (19 males, 15 females; mean age13.06 years) presenting more than 4 mm of crowding. Crowding was manually measured in the initial dental casts. The Objective Grading System (OGS) index was manually measured in the final dental casts and radiographic images. The groups were comparable regarding initial age, gender distribution, and final occlusal statuses. The treatment times between the groups were compared using the *t*-test. Correlation between crowding and treatment time was evaluated with Pearson correlation coefficient.

Results: Treatment times between the 2 groups were similar ($P = .890$) and there was no significant correlation between the amount of crowding and treatment time ($r = 0.04$, $P = .760$).

Conclusion: Treatment times for complete Class II malocclusion with and without mandibular crowding, treated with 4 premolar extractions, are similar.

Keywords: Angle Class II; tooth extractions; orthodontics; time-to-treatment.

INTRODUCTION

Treatment time is one of the main complaints of orthodontic patients.[1] There are many factors that can affect this variable, such as age, sex, anteroposterior severity of the malocclusion, operator, bracket prescription, appliance breakage, and missing appointments, and 1- or 2-phase protocols.[1,2]

The need for molar anteroposterior discrepancy correction seems to be the strongest influencer of treatment efficiency and time, specifically in Class II malocclusion.[3-7] It has been demonstrated that in bilateral complete Class II malocclusion, the 2 maxillary premolar extraction protocol involves a shorter treatment time than the 4 premolar extraction and non-extraction approaches. This would be due to the high patient compliance required when

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using external devices— such as extraoral headgear or sagittal elastics—to aid in molar relationship correction when none or 4 premolars are extracted.[5,6] Nonetheless, 4 premolar extractions are still indicated if a significant amount of mandibular crowding and/or dental/labial protrusion are initially present.[8]

It has been speculated that the initial amount of anterior crowding or protrusion and its severity would significantly increase treatment time.[9,10] Andrews stated that treatment time for an anteriorly crowded case would be similar to that of a non-crowded case, with a corresponding dental protrusion.[11,12] From this second statement, one can assume that different groups, matched according to anteroposterior discrepancies and treatment protocol, would present similar treatment times as long as one had an amount of anterior crowding that was equivalent to the amount of protrusion in the other non-crowded group. On the other hand, it has also been suggested that more crowded cases would have a shorter treatment time because most of the extraction spaces would be utilized for crowding correction.[13] There would be only small spaces for anterior or en masse retraction, and therefore, treatment duration would be shorter.[13]

Although previous studies have evaluated the influence of crowding in orthodontic treatment,[1,10,14,15] their results cannot be safely extrapolated because these studies did not specifically evaluate Class II malocclusion treatment.

Thus, this study aimed to compare treatment times of Class II malocclusions treated with 4 premolar extractions, with and without mandibular crowding. The tested null hypothesis was that treatment times are similar in Class II malocclusions treated with 4 premolar extractions, with and without mandibular crowding.

METHODS

The Ethics in Research Committee of Bauru Dental School, University of São Paulo approved this study (Protocol Number 127/2011). All patients involved in this investigation provided written informed consent. Sample size calculation showed that 23 cases would be necessary in each group to detect a minimum difference of 7 months, with a standard deviation of 8.3 months, and a test power of 80%, at a significance level of 5%, in treatment time.[10]

The retrospective samples were consecutively selected from the files of the Orthodontic Department, at Bauru Dental School, University of São Paulo. The 23 patients of Group 1 (11 male, 12 female; initial mean age of 13.13 years) presented, initially, complete bilateral Class II malocclusions,[12,16] and a maximum of 3 mm of mandibular crowding. The 34 patients of Group 2 (19 male, 15 female; initial mean age of 13.06 years) presented, initially, complete bilateral Class II malocclusions, and mandibular crowding greater than 4 mm. Both groups were treated with 4 first premolar extractions. Presence of all other permanent teeth up to the first molars, absence of dental anomalies (shape, size, or number), complete orthodontic records, and treatment with Edgewise fixed appliances comprised the additional inclusion criteria. Initial anteroposterior molar discrepancy determined the groups' selection, regardless of other characteristics. Molar anteroposterior discrepancy severity of all patients was checked in the dental casts by the same calibrated operator (L.N.B.C.S.). Orthodontic treatments were performed by graduate students at the Orthodontic Program under the supervision of the clinical instructors.

Edgewise appliances with 0.022 × 0.028 inch conventional brackets were used. A usual wire sequence of an initial 0.015 inch twist-flex or a 0.016 inch nitinol, followed by 0.016, 0.018, 0.020 and 0.021 × 0.025 or 0.018 × 0.025 inch stainless steel archwires (Unitek, Monrovia, California, USA) was applied. Accentuated and reversed curves of Spee, in the maxillary and mandibular arches, respectively, were used for deep-bite correction. In both groups, anterior teeth were retracted "en masse", with elastic chains combined with rectangular wires. Extraoral headgears were used in both groups to distalize the posterior segment to obtain Class I molar relationship, and to reinforce anchorage. No absolute skeletal anchorage was used. Whenever necessary, intermaxillary Class II elastics were used to aid in obtaining Class I molar relationship. After debonding, the retention protocol consisted of a Hawley plate in the maxillary arch for a mean period of 1 year, and a mandibular fixed retainer bonded on mandibular canines, with a 3-year use recommendation.

Details on sex, initial age, bonding and debonding dates, and full comprehensive data on treatment time were obtained from the orthodontic files.

Mandibular crowding measurement was manually performed in the initial dental casts. It was calculated as the difference, in millimeters, between the arch length (circumference, from left to right first molars), measured with the aid of a brass wire segment, and the sum of crown widths from first molar to its homologous, measured with a dry-point compass.[17] The sum of the tooth widths should be equal to arch length, in well-aligned cases.[18] Crowding was considered when negative values were obtained.

The occlusal statuses of the final dental casts were evaluated by the Objective Grading System (OGS).[19]

Statistical Analyses

Kolmogorov–Smirnov tests were used to assess data normality, and showed that all variables had normal distribution. Therefore, the chi-square test was used for intergroup comparison regarding sex distribution, and the *t*-tests for intergroup comparability regarding initial age, crowding, and final occlusal statuses.

Intergroup treatment time was compared using *t*-tests. To evaluate the correlation between initial mandibular anterior crowding and treatment time, Pearson correlation test was performed. Results were considered significant at $P < .05$. All statistical analyses were performed with Statistica software (Statistica for Windows 7.0; Statsoft, Tulsa, Okla.).

Table 1. Intergroup comparability regarding sex distribution, initial age, crowding and OGS (Chi-square and t tests)

Sample	Group 1 (n=23)	Group 2 (n=34)	*P*
Sex	n (%)	n (%)	
Males	11 (47.83%)	19 (55.88%)	.55¥
Females	12 (52.17%)	15 (44.12%)	
	Mean ± SD	Mean ± SD	
Initial Age (years)	13.13 ± 1.64	13.07 ± 1.70	.90†
Crowding (mm)	1.13 ± 1.45	6.17 ± 2.77	.000†*
OGS scores	19.43 ± 14.67	18.29 ± 10.74	.33†

Group 1: without mandibular crowding, Group 2: with mandibular crowding
¥ - Chi-square test
† - t tests
* - Statistically significant at $P < .05$

Table 2. Intergroup treatment time comparison (t tests)

Variable	Group 1 (n=23) (Without mandibular crowding)	Group 2 (n=34) (With mandibular crowding)	*P*
	Mean ± SD	Mean ± SD	
Treatment Time (years)	2.51 ± 0.62	2.49 ± 0.83	.89
Treatment Time (months)	30.12 ± 7.45	29.88 ± 9.96	.89

RESULTS

Initial age, final occlusal statuses, and sex distribution were similar between the groups. Evidently, Group 1 had significantly smaller mandibular crowding than Group 2 (Table 1).

Treatment time was similar in the groups. No significant correlation was found between mandibular crowding and treatment time (Tables 2 and 3).

DISCUSSION

Because there were 34 patients who fit the selection criteria in Group 2 composition, they were all included to increase the test power even more. Thus, the final test power was 86%.[20]

Patients were selected based only on the initial anteroposterior molar relationship, because it has been shown that the cephalometric characteristics do not influence the occlusal success rate and consequently the treatment time.[21,22] Therefore, the cephalometric variables would not influence the aspects under consideration.

Table 3. Pearson correlation between initial anterior crowding and treatment time

n=57	R	*P*
Treatment Time X Initial Anterior Crowding	0.04	.76

Matching patients regarding the initial and final occlusal status is necessary because the intergroup comparison should be performed between patients who were treated from a similar initial condition to a similar final result.

Additionally, all patients in both groups should present complete bilateral Class II malocclusion because the 4 premolar extraction protocol for the correction of this malocclusion increases treatment difficulty, since it requires more patient compliance to correct the molar anteroposterior discrepancy.[23,24] If one intends to investigate treatment issues in a specific malocclusion, it has to be well defined. Milder severities could blur slight differences that could exist.[25]

There were similarities in initial age, sex distribution and post-treatment occlusal statuses between the groups. Therefore, these variables did not interfere with the comparison.[26-28] It can be argued that craniofacial residual growth may have aided in Class II malocclusion correction of the young patients included in the groups. However, since there was similarity in initial age, the residual growth amount would also be similar in the groups. The amount of initial mandibular crowding was significantly greater in Group 2 than in Group 1. This is evident because the amount of initial anterior crowding was used to divide the groups. It is important to emphasize that the intergroup difference in mandibular crowding was large and very significant, which exactly fit the purpose of the investigation.

Evidently, the use of anchorage reinforcement with extraoral headgear or Class II elastics is influenced by patient compliance, and it is not possible to access the mean compliance performance of each patient.[1] However, since no effort was taken to select patients with higher or lower compliance tendencies for a specific group, it can be assumed that patients with different compliance tendencies were homogeneously distributed in the groups.[29] Thus, this factor probably played no role in the intergroup comparisons.

The groups presented similar treatment times, contrary to other studies which stated that increased crowding would increase treatment time.[1,10] However, these studies were not conducted with a specific malocclusion, but included several types of malocclusions. As stated before, if a study sample is not restricted to a specific malocclusion, the results can be influenced by the heterogeneity of its elements.[25]

This result is in accordance with a previous study,[15] which performed a similar comparison on Class I malocclusion treatment in cases with mild and severe initial anterior crowding. No intergroup difference would be expected because equivalent amounts of anterior crowding or dental/labial protrusion will require similar anchorage reinforcement needs to be corrected, and therefore, would involve similar treatment time.[11,12]

It is speculated that more crowded dental arches would need less time for extraction-space closure because the teeth would quickly occupy the extraction spaces with minor movement, either with or without little need for anterior/en masse retraction,

which may take longer.[13] However, the results of this study reinforce the idea that, in a complete bilateral Class II malocclusion treatment with the 4 premolar extraction protocol, whether the intra-arch extraction space closures will take a little longer or not, is not the main issue. This is not the aspect that will prolong treatment time.[6] The issue that will prolong treatment time is the Class II anteroposterior discrepancy correction which is patient-compliance dependent.[6,23] For this, it is necessary for the patient to use extraoral appliances, such as headgears, or Class II intermaxillary elastics. This is what really prolongs treatment time when 4 premolar extractions are performed in complete bilateral Class II malocclusion treatment, as has been previously demonstrated.[5,7,30] The initial molar anteroposterior discrepancy and treatment times of both groups were also similar. Besides, there was no significant correlation between the amount of mandibular crowding and treatment time (Table 3).

Therefore, the current results also support the fact that correction of complete Class II anteroposterior discrepancy is the major problem to be addressed, when this malocclusion is treated with 4 premolar extractions. The orthodontist should not be influenced by secondary features of malocclusion at the moment of planning or deciding treatment, when estimating treatment time. Further comparisons between groups with similar amounts of initial anterior crowding and different molar anteroposterior relationships should also be performed to confirm the conclusions of this study.

CONCLUSION

The null hypothesis was accepted because:

- Treatment times of Class II malocclusions, with and without crowding, treated with a 4 premolar extraction protocol, were similar.
- Additionally, the amount of initial mandibular crowding was not correlated to treatment time in complete bilateral Class II malocclusion treatment with 4 first premolar extractions.

Ethics Committee Approval: The Ethics in Research Committee of the Bauru Dental School, University of São Paulo, approved this study (Protocol Number 127/2011).

Informed Consent: Written informed consent was obtained from the patients who agreed to take part in the study.

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Original Article

Alleviation of Lower Anterior Crowding with Super-Elastic and Heat-Activated NiTi Wires: A Prospective Clinical Trial

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Main Points

- Both heat-activated and super-elastic archwires showed similar alleviation of lower anterior crowding in initial leveling and aligning stages.
- Heat-activated archwires can be used to engage grossly malpositioned teeth to obtain greater control at the initial stages of treatment.
- Intercanine width, intermolar width, and arch depth were increased with use of heat-activated archwires.

ABSTRACT

Objective: To compare the amount of alleviation of lower anterior crowding and changes in intercanine width (ICW), intermolar width (IMW), and arch depth (AD) dimensions using 2 different types of nickel-titanium (NiTi) archwires.

Methods: Thirty participants were randomly allocated to 2 treatment groups, using heat-activated NiTi (HANT) or super-elastic (SE-NiTi) round (0.014″) archwires. The inclusion criteria were a Little's Irregularity Index (LII) greater than 4, malocclusion requiring non-extraction therapy, all teeth erupted to the second molars in the lower arch, and Angle's Class I malocclusion. The primary aim was to measure alleviation in mandibular crowding over 12 weeks; the secondary aim was to measure changes in ICW, IMW, and AD during those 12 weeks. Simple randomization was performed. The measurements were made on dental stone casts using a coordinate measuring machine at 4-week intervals.

Results: LII at 0, 4, 8, and 12 weeks was 8.59 ± 1.44, 6.17 ± 1.65, 4.65 ± 1.63, and 3.28 ± 1.57 mm in the HANT; 8.87 ± 1.29, 6.92 ± 1.49, 5.25 ± 1.32, and 3.63 ± 1.32 mm in the SE-NiTi group, respectively. ICW increased from 25.43 ± 1.39 to 27.41 ± 1.29 mm in the HANT and from 25.81 ± 1.78 to 27.27 ± 1.83 mm in the SE-NiTi groups over a period of 12 weeks, at $P < .05$. There was a statistically significant increase in IMW, CAD (canine arch depth), and MAD (molar arch depth), favoring the HANT group ($P < .05$). No significant differences in LII between the 2 groups were noted ($P > .05$).

Conclusions: The amount of alleviation of lower anterior crowding was similar with both archwires. ICW, IMW, and AD increased with HANT archwires.

Keywords: Orthodontic wire, nitinol, crowding, arch dimensions, coordinate measuring machine, tooth movement

INTRODUCTION

Fixed appliance therapy is a pillar of contemporary orthodontic treatment, in which archwires are used for force application. The aim of using aligning archwires at treatment initiation is primarily to alleviate crowding. Aligning archwires use light forces to move teeth, thereby reducing root resorption.[1] The dimensional and physical–chemical properties of an archwire determine the amount of force delivered clinically. Ideal properties of aligning archwires include a large range of activation, flexibility, low modulus of elasticity with reduced friction, low cost, and ease of manufacture.[2]

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Stainless steel (SS) archwires were the clinicians' first choice before the introduction of nickel-titanium (NiTi) archwires.[3] Subsequent developments led to the production of stabilized NiTi alloys by "Unitek Corporation" under the trade name Nitinol (Nickel Titanium Naval Ordinance Laboratory), for clinical use. This archwire soon replaced SS wires. Further searches for a better archwire for orthodontic use led to the development of super-elastic NiTi (SE-NiTi) alloys in 1978. Many modifications in archwire properties were made to obtain an ideal archwire with definite clinical advantages. One was the addition of copper (Cu) to NiTi wires, called Copper-NiTi (CuNiTi) wire or heat-activated archwires. These archwires demonstrated true shape-memory effects above the transition temperature range.

Adding Cu to the NiTi alloy improves shape-memory properties, thermal stability, and fatigue endurance; mitigates hysteresis and loading stress; and helps regulate transition temperature range.[4,5] These effects help in accelerating tooth movement.[6] Different compositions of NiTi alloy archwires with varied mechanical properties have shown various advantages in the literature.[6,7] However, most studies have been in vitro and require validation by in vivo studies. The findings obtained from in vitro[6,7] conditions are ambiguous compared to in vivo studies.[8-10] Two studies[11,12] showed contrasting results of alignment efficiency, where no significant difference was noted between Cu-NiTi and NiTi archwires. Conversely, another study[13] found that heat-activated NiTi (HANT) was more efficient in aligning teeth. Weiland et al.[14] demonstrated greater efficiency with SE-NiTi wires but with higher root resorption. These conflicting findings from multiple investigators make it difficult to gauge which archwire is better in terms of performance or alignment.[15]

The purpose of the present study was to investigate differences in the degree of alleviation of lower anterior crowding using SE-NiTi and HANT round archwires for alignment. It also aimed to assess intermandibular arch dimensional changes over 12 weeks using a coordinate measuring machine (CMM). The authors hypothesized that no difference would be observed between SE-NiTi and HANT archwires in the alleviation of lower anterior crowding over 12 weeks. The second hypothesis was that no difference would exist between SE-NiTi and HANT archwires in intermandibular arch dimensional changes in the same period.

METHODS

This study was a single-center prospective trial conducted in the Department of Orthodontics and Dentofacial Orthopaedics. Before recruitment, the research protocol was accepted by the ethical committee of the Institute (ACDS/IEC/32/Oct 2018). All participants were given a research participant information sheet, which detailed why the research was being conducted, what it would involve, and what was expected of them as participants. The participants completed a questionnaire about past dental and medical history and were subsequently evaluated intraorally to assess Angle's classification of molar relation and Little's Irregularity Index (LII).

The inclusion criteria were (a) requiring fixed orthodontic treatment, (b) lower anterior crowding with LII greater than 4, (c) all teeth erupted to the second molars in the lower arch, (d) malocclusion requiring only non-extraction therapy, (e) Angle's Class I malocclusion, and (f) maximum contact point displacement of 2.5 mm. Patients using medication, or with spacing in the lower anterior segment, or a blocked-out tooth that would not permit bonding in initial alignment, missing lower incisors and/or canines, periodontally compromised dentition, or previous history of orthodontic treatment were excluded. Those eligible to participate in the study signed a consent form.

The 30 included participants were allocated randomly in a 1 : 1 ratio to either of the 2 archwire groups, namely group 1: 0.014" HANT (3M Unitek, Monrovia, USA) or group 2: 0.014" Super-Elastic NiTi (3M Unitek, Monrovia, USA). A CMM was used to measure mandibular anterior irregularity (LII), intercanine width (ICW), intermolar widths (IMW), and arch depth (AD) on the lower cast, at 0, 4, 8, and 12 weeks. A monitoring committee was established to evaluate participant criteria and protocols. No changes were made to established protocols. Simple randomization using a computer-generated table at the beginning of the study allocated the archwires to participants. The allocated archwires were concealed in opaque envelopes, ensuring that both the investigator and participants were blind to the intervention. One author was responsible for the randomization. Both participants and investigators were blinded to the allocation of the archwire group, because the wires were provided in an opaque envelope to the clinician at the time of archwire placement. The investigators were also blinded to outcome measurements because each retrieved dental cast was assigned a number to innominate the data. A single operator treated all enrolled participants using 0.022" × 0.028" slot MBT prescription brackets (Mini-Twin™, Ormco Corp, Orange, CA, USA). The archwires used in the study were (a) 0.014" HANT (3M Unitek, Monrovia, USA) and (b) 0.014" Super-Elastic NiTi (3M Unitek, Monrovia, USA) with ovoid arch form. Teeth were etched with etching gel for 15 seconds. Ortho Solo™ (Ormco Corp, Orange, CA, USA) universal sealant and bond enhancer and Enlight light cure adhesive (Ormco Corp, Orange, CA, USA) were used for bracket bonding. After placement of brackets, an impression of the lower arch was made with alginate for each participant. The assigned archwire was then removed from the sealed envelope and ligated using elastomeric modules. The wire was removed at the next appointment and an impression with alginate was made again. This impression was poured in dental stone Type III. The same archwires were placed again using fresh elastomeric modules. Digital photographs of the lower arch were also obtained at each 4-week interval (Figure 1). At 8 and 12 weeks, the same process was replicated. The dental stone models were adjusted to be precisely positioned in the CMM (Figure 2). Specific points for each tooth were noted in 3 dimensions for all 6 lower anteriors. The central fossa of first molars, cusp tips of canines, and incisal edges of incisors were considered. Measurements of LII, ICW, IMW, and AD were made in the lower arch. ICW was assessed from cusp tips of bilateral lower

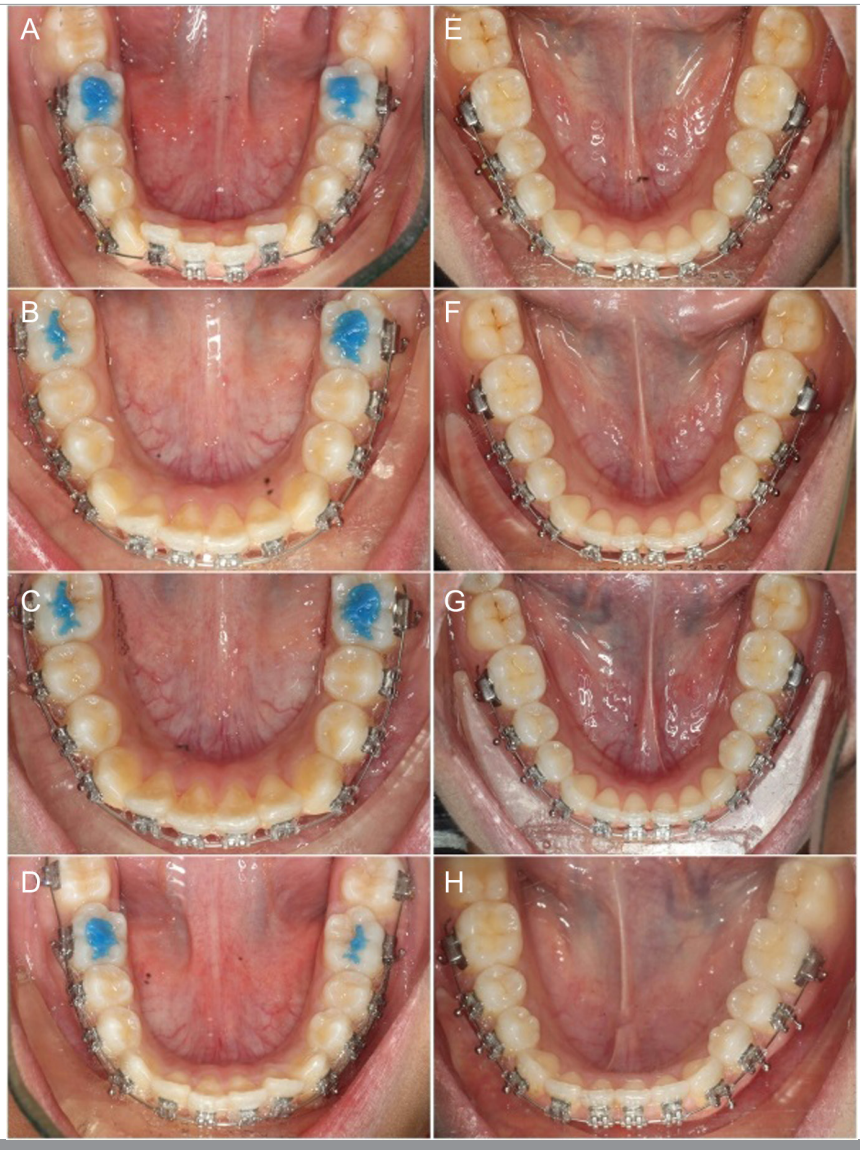

Figure 1. (A-D) Alignment at every 4-week interval using heat-activated NiTi; (E-H) Alignment at every 4-week interval using super-elastic NiTi.

canines and IMW was measured from central fossae of bilateral first molars. AD was assessed at 2 sites: intermolar depth and intercanine depth as the perpendicular distance from the most prominent lower central incisor to the respective IMW and ICW lines (Figure 3). All measurements were made using a CMM (Explorer Performance, Hexagon Manufacturing Intelligence, Stockholm, Sweden) by one author, who was unaware of the archwire being tested (Figure 4). The measurements were then repeated by another author to assess the reproducibility of measurements. LII, ICW, IMW and AD were noted at all stages. To reflect overall tooth movement, data recorded for intertooth distances (3-2, 2-1, 1-1, 1-2, 2-3) at all 4-week intervals were summed. Thus, the mean alignment value for the lower anterior segment at each phase was attained. The primary outcome was to assess the amount of alleviation of lower anterior crowding with 0.014" SE-NiTi and 0.014" HANT archwires over 12 weeks in non-extraction therapy. A secondary outcome was to assess changes in ICW, IMW, and AD using these archwires for the same duration. No modifications in result assessments were made after the start of the trial.

Statistical Analysis

Sample size estimation was performed according to the study by Sebastian.[16] The sample size was estimated using G Power software 3.1 using analysis of variance (ANOVA): repeated measures within-between interaction design. Effect size (partial eta squared) (n^2) [effect size measure for interaction between the within and between-subject variables, i.e., between wire and time] was calculated assuming medium (n^2 = 0.06) partial eta squared conversion, and thus effect size determined was 0.2526. Keeping alpha error at 5% or 0.05, statistical power at 90%, assuming correlation among repeated measures 0.5 and non sphericity correction (ε=1), the sample size estimated was 15 per group.

The Statistical Package for Social Sciences version 22.0 software (IBM Corp.; Armonk, NY, USA) was used to perform statistical analyses. Descriptive analysis of all the explanatory and outcome parameters was performed using mean and standard deviation for quantitative variables and frequency and proportions for categorical variables. Independent Student's *t*-test was used to compare LII values, ICW, IMW, CAD, and MAD between the 2 groups at

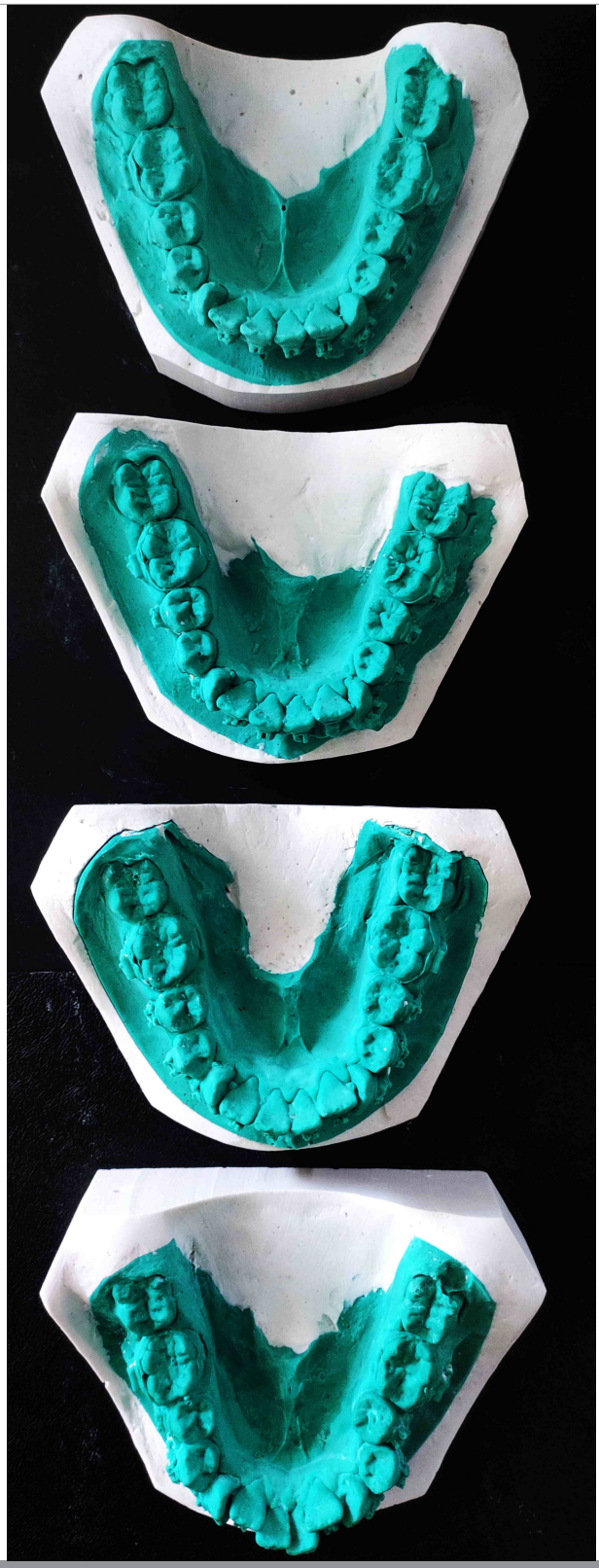

Figure 2. Dental stone models obtained at every 4-week interval.

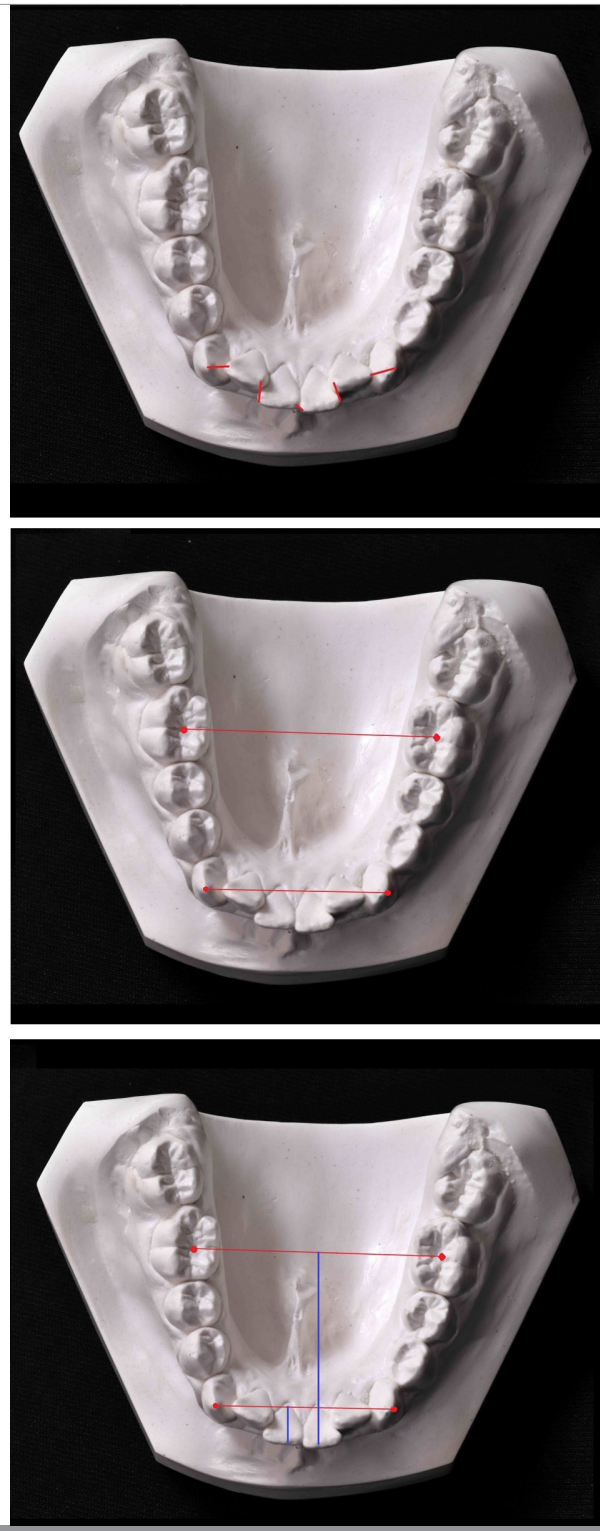

Figure 3. Mandibular measurements: Little's irregularity index, intercanine width, and intermolar width and arch depth.

different time intervals. Repeated Measures of ANOVA followed by Bonferroni's post hoc analysis was used to compare the mean values of different study parameters between time intervals in each study group. Intra-class correlation (ICC) statistics were used to assess the reproducibility of study measurements between 2 observers at baseline and 12 weeks. The level of significance was set at $P < .05$.

RESULTS

Participants were recruited over 1 year (July 2018 to July 2019). Sixty-three prospective participants were reviewed for enrolment;

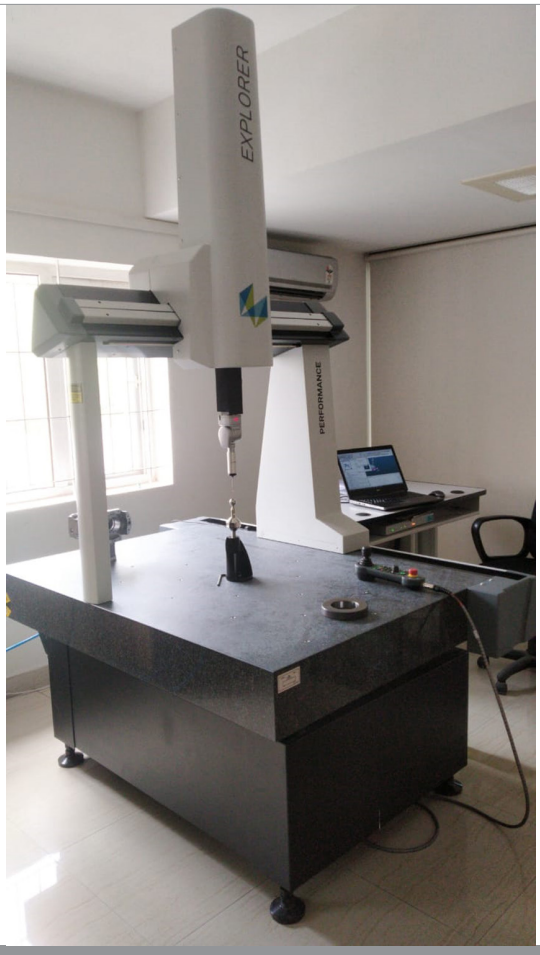

Figure 4. Coordinate measuring machine (Explorer Performance, Hexagon Manufacturing Intelligence, Stockholm, Sweden).

30 were disqualified because they did not meet the inclusion criteria. Three refused to take part. Thirty participants were randomly assigned to either group 1: HANT (n = 15) with a mean age of 17.4 ± 1.12 or group 2: SE-NiTi (*n* = 15) with a mean age of 17.13 ± 0.92 at the start. A CONSORT diagram (Figure 5) illustrates participant flow throughout the analysis. Table 1 and Table 2 display no significant disparities in statistical or preliminary information between the groups in terms of age, gender or initial amount of crowding.

Participants were examined at every follow-up for any bracket breakages, though none were reported. The LII, ICW, IMW, and AD of all 120 casts retrieved during this 12-week study were determined using a CMM, and values were rounded off to the nearest 0.1 mm.

A mean reduction in LII was noted from 8.59 to 3.28 mm for Group 1, and from 8.87 mm to 3.63 mm for Group 2, over a period of 12 weeks. The Student's *t*-test comparing the means between both the HANT (mean reduction of 5.31 mm) and SE-NiTi groups (mean reduction of 5.24 mm) indicated that LII was not statistically significant at the 5% level (Table 1) over a period of 12 weeks.

However, Table 3 shows that the amount of ICW, IMW, CAD, and MAD increased over a period of 12 weeks, favoring the HANT group. Table 3 portrays the pattern of decline in crowding as assessed with repeated measures ANOVA. LII at 0, 4, 8, and 12 weeks was 8.59 ± 1.44, 6.17 ± 1.65, 4.65 ± 1.63, and 3.28 ± 1.57 in HANT, and 8.87 ± 1.29, 6.92 ± 1.49, 5.25 ± 1.32, and 3.63 ± 1.32 in SE-NiTi group, respectively. ICW increased from 25.43 ± 1.39 to 27.41 ± 1.29 in the HANT and from 25.81 ± 1.78 to 27.27 ± 1.83 in the SE-NiTi groups over a period of 12 weeks. IMW increased from 37.13-38.54 to 40.18-41.32, respectively, in the HANT and the SE-NiTi groups at 12 weeks.

Canine AD and molar AD also significantly increased in both groups, favoring the HANT group, from 6.35 ± 0.63-7.02 ± 0.64 (mean increase of 0.67 mm) to 24.32 ± 0.93-24.94 ± 0.97 (mean increase of 0.62 mm), respectively, over 12 weeks. The repeated measure factor "time" showed statistical significance ($P < .001$). Bonferroni's post hoc analysis of mean differences in LII, ICW, IMW, and AD between different time intervals (0 week * 4 week, 0 week * 8 week, 0 week *12 week) showed statistically significant differences at $P < .001$ (Table 3).

To check the reproducibility of measurements, all measurements were analyzed twice, by both authors, for all 120 casts retrieved in this study. The reproducibility of repeated measurements was estimated by ICC at 0 and 12 weeks. It demonstrated good reliability, ranging from 0.75 to 0.90 (Table 4).

DISCUSSION

The first phase of fixed orthodontic treatment is leveling and alignment of the arches.[17] Besides biological influences that are beyond the orthodontist's influence, the choice of bracket system and archwires also has a significant impact on overall tooth movement.[10]

Several clinical trials have been performed to determine the efficiency of aligning archwires. Some have tried and failed to show one archwire's superior efficacy in alignment over another,[8,9,18,19] also others have reported no difference.[3,16] Systematic analyses by Riley et al.[20] and Jian et al.[21] found that clinical studies had provided inadequate evidence for the most efficient alignment archwire. Additionally, the authors reported that more well-designed randomized clinical trials were needed.

SE-NiTi and HANT archwires were compared in the present study to evaluate the amount of alleviation of lower anterior crowding as a primary outcome. The secondary outcome was to assess changes in ICW, IMW, and AD over 12 weeks. Other factors which may affect the outcome were standardized, such as bracket slot dimensions, play between archwire and slot (same diameter archwires), and interbracket span (only in the mandibular arch) between both groups. Ages of the participants recruited were similar; the mean was 17.4 years for group 1 and 17.1 years for group 2.

NiTi archwires must be deformed by 50-70 degrees to properly utilize their super-elastic properties. This deformation is clinically possible due to the extent of crowding and shortened interbracket span in lower anterior crowding situations.[22] In the

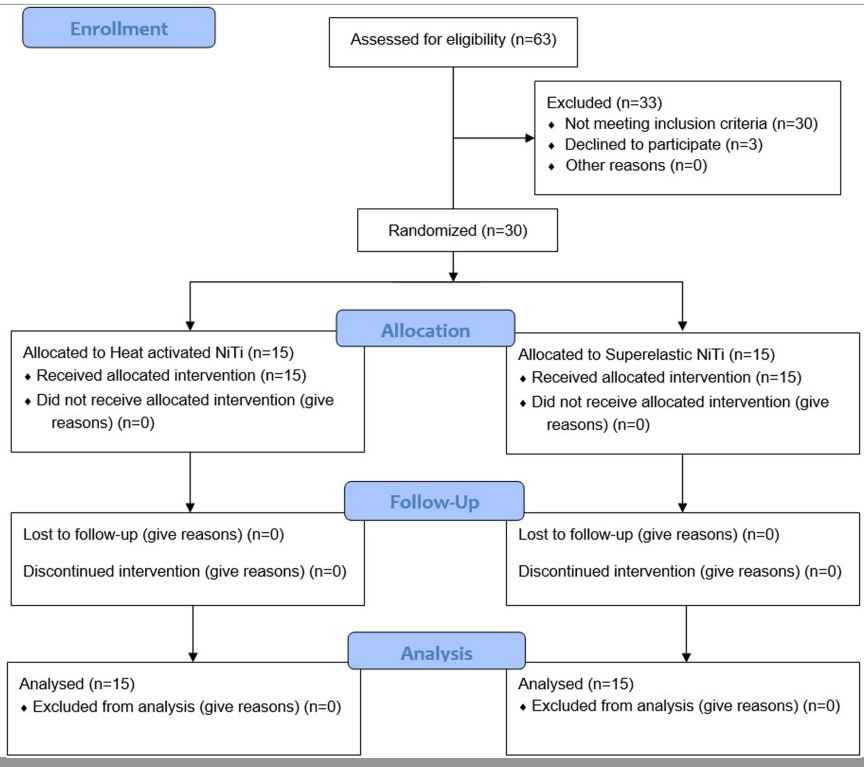

Figure 5. CONSORT flow diagram.

analysis, an LII > 4 was considered to optimize the archwires' super-elastic properties.

No relevant differences were noted in gender distribution between the groups, also helping in establishing unbiased results.

The key outcome variable was the amount of mandibular decrowding observed over 12 weeks for both wires. The group treated with HANT wires had a mean LII of 3.28 (± 1.57) at 12 weeks, while it was 3.63 (± 1.32) for the group treated with SE-NiTi archwires. The null hypothesis was not rejected. This agrees with studies published previously.[23,24]

Experiments conducted in vitro have demonstrated that SE-NiTi wires produce light forces that increase tooth movement and reduce discomfort,[1,25] though individual responses could act as confounding factors. Although these laboratory studies have shown the effectiveness of NiTi alloys characterized by superelasticity and shape-memory, the literature provides little clinical evidence supporting the benefits associated with these mechanical properties.[26]

West et al.[3] reported greater alignment using SE-NiTi when compared to multistranded SS in the lower anterior region, which was attributed to reduced interbracket span. In their analysis, the amount of alleviation of lower anterior crowding was 1.20 mm compared to the 1.95 mm noted in this study. This minor variance may be due to differences in initial crowding in participants, differences in ligation methods, or archwires being sourced from different manufacturers.

Table 1. Comparison of Group 1 and 2 regarding age, initial crowding, reduction in crowding and changes in arch width and depths from week 0 to 12 by Independent Student t test

Variable	Group 1		Group 2		*P*
	Mean	SD	Mean	SD	
Age	17.4	1.12	17.13	0.92	.48[a]
Initial crowding	8.59	1.44	8.87	1.29	.59[a]
Reduction in LII	5.31	0.28	5.24	0.24	.442[a]
Change in ICW	-1.98	0.24	-1.46	0.22	.001*[a]
Change in IMW	-1.41	0.15	-1.14	0.15	.001*[a]
Change in CAD	-0.67	0.18	-0.49	0.13	.006*[a]
Change in MAD	-0.62	0.12	-0.52	0.08	.012*[a]

*Statistically significant at p≤0.05, a: Independent Student t Test, SD: Standard deviation, Group 1: Heat activated NiTi, Group 2: Superelastic NiTi; LII: Irregularity index; ICW: Intercanine width, IMW: Intermolar width, CAD: canine arch depth, MAD: molar arch depth.

Table 2. Gender distribution regarding Group 1 and Group 2

Variable	Category	Group 1		Group 2		*P*
		n	%	n	%	
Gender	Males	6	40.0%	7	46.7%	.71[b]
	Females	9	60.0%	8	53.3%	

b: Chi Square Test, n: number, Group 1: Heat activated NiTi, Group 2: Superelastic NiTi.

Table 3. Comparison of LII, ICW, IMW, Canine AD, and Molar AD values between time intervals in Group 1 and Group 2 using Repeated Measures of ANOVA Test

		Group 1		Group 2		Difference Between Weeks	
Parameter	**Interval**	**Mean**	**SD**	**Mean**	**SD**	**Group 1**	**Group 2**
LII	0 weeks	8.59	1.44	8.87	1.29	a = 0.001** b = 0.001** c = 0.001**	a = 0.001** b = 0.001** c = 0.001**
	4 weeks	6.17	1.65	6.92	1.49		
	8 weeks	4.65	1.63	5.25	1.32		
	12 weeks	3.28	1.57	3.63	1.32		
	P value	.001*		.001*			
ICW	0 weeks	25.43	1.39	25.81	1.78	a = 0.001** b = 0.001** c = 0.001**	a = 0.001** b = 0.001** c = 0.001**
	4 weeks	25.99	1.4	26.23	1.73		
	8 weeks	26.78	1.36	26.92	1.85		
	12 weeks	27.41	1.29	27.27	1.83		
	P value	.001*		.001*			
IMW	0 weeks	37.13	3.24	40.18	1.83	a = 0.010** b = 0.001** c = 0.001**	a = 0.001** b = 0.001** c = 0.001**
	4 weeks	37.43	3.16	40.53	1.74		
	8 weeks	38.08	3.16	40.91	1.83		
	12 weeks	38.54	3.19	41.32	1.82		
	P value	.001*		.001*			
Canine AD	0 weeks	6.35	0.63	7.11	0.80	a = 0.001** b = 0.001** c = 0.001**	a = 0.001** b = 0.001** c = 0.001**
	4 weeks	6.66	0.65	7.26	0.78		
	8 weeks	6.80	0.65	7.40	0.77		
	12 weeks	7.02	0.64	7.61	0.76		
	P value	.001*		.001*			
Molar AD	0 weeks	24.32	0.93	25.34	0.65	a = 0.001** b = 0.001** c = 0.001**	a = 0.001** b = 0.001** c = 0.001**
	4 weeks	24.56	0.96	25.56	0.63		
	8 weeks	24.79	0.98	25.72	0.63		
	12 weeks	24.94	0.97	25.86	0.62		
	P value	.001*		.001*			

*Statistically significant, group 1: heat-activated NiTi, group 2: super-elastic NiTi, a: 0 week * 4 week; b, 0 week * 8 week; c, 0 week * 12 week; **$P < .05$ adjusted Bonferroni correction.
SD, standard deviation; LII, irregularity index; ICW, intercanine width; IMW, intermolar width; AD, arch depth.

Table 4. Intra-class correlation statistics to assess for the reproducibility of measurements between 2 observers at baseline and 12 weeks

		Group 1				Group 2			
			95% CI				95% CI		
Time	**Variables**	**ICC**	**Lower**	**Upper**	***P***	**ICC**	**Lower**	**Upper**	***P***
0 Weeks	LII	0.77	0.43	0.91	.002*	0.88	0.69	0.97	<.001*
	ICW	0.8	0.47	0.92	<.001*	0.84	0.33	0.97	<.001*
	IMW	0.8	0.47	0.92	<.001*	0.88	0.57	0.99	<.001*
	Canine AD	0.82	0.46	0.85	<.001*	0.87	0.53	0.97	<.001*
	Molar AD	0.81	0.43	0.87	<.001*	0.86	0.54	0.87	<.001*
12 Weeks	LII	0.85	0.78	0.99	<.001*	0.89	0.7	0.97	<.001*
	ICW	0.81	0.7	0.98	<.001*	0.88	0.7	0.98	<.001*
	IMW	0.79	0.46	0.98	.001*	0.85	0.73	0.98	<.001*
	Canine AD	0.87	0.51	0.89	<.001*	0.82	0.75	0.96	<.001*
	Molar AD	0.89	0.32	0.96	.001*	0.83	0.76	0.88	<.001*

*Statistically significant group 1: heat-activated NiTi, group 2: super-elastic NiTi.
ICC values < 0.50—Poor reliability; 0.50-0.75—moderate reliability; 0.75-0.90—good reliability; > 0.90—excellent reliability.
ICC, intra-class correlation coefficient; CI, class interval; LII, Little's irregularity index; ICW, intercanine width; IMW, Intermolar width; AD, arch depth.

A significant reduction in crowding was found with HANT in the initial period in the study. A mean reduction in LII of 2.42 mm was noted in the initial 4 weeks using HANT when compared to 1.95 mm using SE-NiTi. HANT provides the benefit of placing a large archwire with low force delivery at the start of treatment. Thus, at the outset of therapy, a better degree of rotational control and alignment was obtained relative to SE-NiTi wires, although the differences were not statistically significant.

Aydin et al.[11] compared conventional and CuNiTi archwires in relieving lower crowding and found no substantialdifferences between them in the alleviation of crowding. Contrary to the findings of the present and other studies,[9-12,24] Serafim et al.[13] found greater alignment with HANT. However, in their study, the archwire diameter was increased substantially. Changes in arch form (transverse) during the alignment process using rectangular archwires are required in non-extraction cases to reduce crowding.[27] The ICW changes were 1.46 mm with SE-NiTi and 1.98 mm with HANT. Previous studies have shown increases in ICW ranging from 0.54 to 1.96 mm.[28] However, lower arch form should remain in harmony with surrounding structures, to increase long-term stability.[29]

Both archwires caused an increase in ICW and AD in the study, favoring the HANT group at $P < .05$, similar to Aydin et al.[11] In this analysis, measurements of IMW in the SE-NiTi group were greater than HANT at the end of week 4, and this trend was reversed in the next 8 weeks. This is similar to findings by Aydin et al.,[11] who attributed it to an increase in the arch perimeter of the lower canines.

Mandibular crowding can be measured using LII. Previous studies have found this index to be a reliable indicator that could be used to standardize research.[30] The major drawback of LII is that it is not sensitive to rotations and axial inclinations. Two types of irregularity measurement methods exist: direct and indirect. Direct methods use Vernier calipers.[9] Measurements can also be done indirectly for three-dimensional calculations using advanced instruments such as a reflex metrograph,[8] reflection microscope,[3] or CMM.[16] The use of these specialized instruments provides a complete three-dimensional representation of movements of the contact point. Thus, a coordinate measuring system was used, which provided three-dimensional coordinates for each landmark on the dental casts, increasing the accuracy of measurements.

In clinical research, it is important to address the tendencies observed even when substantive differences are not found,[18] because the statistical mean does not always represent the clinical outcome. HANT wires showed a higher rate of reduction in irregularity in the initial 4 weeks from bonding, although the differences were not statistically significant. This may be due to variations in the in vivo transition temperature ranges, limiting the transformation of NiTi archwires, or the general irrelevance of the wires' mechanical behavior derived from the laboratory to clinical loading conditions. Additional variables influencing the clinical output of wires may include the effect of oral cavity conditions.

A limitation of the study is that it was relatively short-term. Elastomeric modules were used for ligation. A drawback of using these modules is that full engagement of the archwires is not always possible due to rotations and/or crowding. SS ligatures were intentionally not used in the study because using 2 different ligation methods can lead to confounding results. Another drawback is that the effects of periodontal ligament and bone in individual metabolic responses were not discussed.

CONCLUSION

HANT exhibited no superiority over SE-NiTi archwires in the alleviation of lower anterior crowding. However, the changes in ICW, IMW, and AD favored HANT wires.

Ethics Committee Approval: This study was approved by the Institutional Ethical Committee at Army College of Dental Sciences (ACDS/IEC/32/Oct 2018)

Informed Consent: Written informed consent was obtained from the patients who agreed to take part in the study.

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Review

Carbonated Soft Drinks and Orthodontics: Review of Literature

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Main points:

- Increased consumption of carbonated soft drinks has harmful effects on bone metabolism.
- Tooth movement is greatly affected by the increased carbonated soft drinks consumption.
- Shear bond strength, enamel surface, color stability, corrosion, and surface changes of different materials are greatly affected by the carbonated soft drinks.

ABSTRACT

This study aims to review the effects of various types of carbonated soft drinks on the behavior of different orthodontic materials as well as on the enamel surface and tooth movement. Articles and books from 1990 to 2020 explaining the effects of carbonated soft drinks on general health and orthodontic materials and tooth movement were electronically searched. The major effects of carbonated soft drinks are explained and discussed in this review. Patients with orthodontic problems must be warned about the side effects of carbonated soft drinks on general and dental health and orthodontic appliances in particular.

Keywords: Carbonated soft drinks, corrosion, elastic force decay, orthodontics, shear bond strength

INTRODUCTION

Carbonated soft drinks consumption has become a greatly perceptible and contentious public health and policy matter. They are considered as a chief contributor to obesity and associated with well-being tribulations by many, mostly among children.[1]

Numerous fitness problems are allied with ordinary utilization of carbonated soft drinks, but their effects on the health are unclear although epidemiological studies point toward their relationship with obesity, kidney disease, liver disease, and dental and bone problems.[2]

Carbonated soft drinks predominantly contain water, phosphoric acid, citric acid, caffeine, sugar (for example, sucrose) and other chemicals in the form of acid regulators, carbon dioxide, preservatives, colorings, and flavors.[3] Carbonated beverages are prepared by mixing flavored syrup with carbonated water, both of which are chilled. There are different types of carbonated beverages, including colas, energy and sports drinks, functional beverages, and low- and mid-calorie beverages.[4]

Different studies have shown that carbonated soft drinks can affect the rate of tooth movement and properties of various orthodontic materials; therefore, a comprehensive review of these studies is required. This study aimed to review the effects of diverse types of carbonated soft drinks on the behavior of different orthodontic materials as well as on the enamel surface and tooth movement.

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Effects of Carbonated Soft Drinks

Effects on Health

In their systematic review and meta-analysis, Vartanian et al.[5] reviewed 88 articles and reported that in many studies, a positive association was reported between increased consumption of carbonated soft drinks and energy intake, increased body weight and body-mass index, increased carbohydrate intake, and many negative health problems, such as type II diabetes, hypocalcemia, tendency of bone fracture, reduced bone mineral density, increased blood pressure and various cardiovascular diseases, kidney and liver diseases, tooth erosion, and increased vulnerability to dental caries.

Effects on the Tooth Movement

The effects of some carbonated soft drinks on the rate of tooth movement in rats were evaluated by Aghili et al.[6] They gave the rats Fanta® and Coca-Cola® for 2 weeks before orthodontic appliance placement. A force of about 60 gm was exerted through a 5-mm NiTi coil spring ligated between the right incisor and first molar for 2 weeks.The amount of orthodontic tooth movement between the maxillary first and second molars was then measured using an interproximal filler gauge. Their findings indicated that the rate of tooth movement decreased in the experimental groups than in the control group, being more with Fanta® than Coca-Cola®.

The possible explanations for these findings are discussed according to the drinks' components, such as sugar, citric acid, phosphoric acid, caffeine, and other additives.

Calvo[7] found that high phosphorus intake was shown to cause bone loss in animals; however, Amato et al.[2] concluded that Coca-Cola® intake causes significant hypercalciuria and hyper phosphaturia in immature and adult rats. The older animals also developed hyperparathyroidism.

Theoretically, diets that are high in phosphate and low in calcium lead to a decreased serum level of calcium and a provoking complex for parathyroid hormone, leading to decalcification of the bones and re-establishment of calcium homeostasis in the body, but the amount of phosphoric acid present in Coca-Cola® is not sufficient to cause this.[8]

Paldánius et al.[9] reported that high oral intake of glucose can lead to a rapid, statistically significant decrease in bone formation, resorption markers, and carboxylated-type serum osteocalcin.

The acid loads may also affect the bone content and metabolism. Lee et al.[10] found that acidemia will increase the bone degeneration and calcium release and decrease the activity of 1α-hydroxylase and production of 1α,25-dihydroxyvitamin D.[11] However, Amato et al.[2] found that high consumption of Coca-Cola® causes acidosis in immature rats.

The tested drinks contain acidic components (such as carbon dioxide and phosphoric acid in Coca-Cola® and citric acid in Fanta®) that may alter bone metabolism toward this condition. This may influence the bone remodeling process and subsequent orthodontic tooth movements.

Caffeine, as an additive in some drinks, especially cola, may also lead to excretion of calcium in urine, a condition known as calciuria.[12]

Wink et al.[13] showed that growing rats that received caffeine had significant histological differences, such as fewer osteocytes per femoral cross-section area, impaired structural remodeling of osteoblasts, and osteocytes with disrupted swollen mitochondria, compared with the control group.

Shirazi et al.[14] studied the effect of different doses of caffeine on orthodontic tooth movement in rats and found that with increasing caffeine dosage, the orthodontic tooth movement and bone resorption were significantly decreased. However, the ultimate effects of caffeine on the bone and calcium economy in human beings depend on other factors, mainly calcium intake from the diet, and the net effects are controversial.

Effect on the Shear Bond Strength

Önçağ et al.[15] determined the effects of Coca-Cola® and Sprite® on the shear bond strength of metal orthodontic brackets bonded to human teeth both *in vitro* and *in-vivo*; the findings proved a significant decrease in shear bond strength in both groups in comparison with artificial saliva as they thermocycled the bonded teeth, and thermocycling proved to decrease the bond strength by 20% to 70%. Using a scanning electron microscope (SEM), the areas of defect on the enamel surface around the brackets were observed in both groups owing to the erosive effect of these soft drinks.

Navarro et al.[16] studied the influence of Coca-Cola® and Schweppes Limón® on bond strength, adhesive remnants, and microleakage in stainless-steel brackets of maxillary incisors bonded to bovine teeth. They found that these drinks caused enamel erosion, loss of adhesive material, and microleakage but had no significant effect on the shear bond strength of the brackets or adhesive remnants.

Khoda et al.[17] evaluated the effects of a carbonated yogurt drink with a lactic acid base, 7-Up® and Pepsi-Cola®, on the shear bond strength of stainless-steel brackets. They concluded that these soft drinks did not decrease the shear bond strength significantly compared with artificial saliva, similar to the study by Navarro et al.[16]

Hammad and Enan[18] evaluated the effect of 2 brands of acidic soft drinks (Coca-Cola® and Sprite®) on the shear bond strength of metal brackets with and without resin infiltration treatment and assessed the enamel surface after debonding using SEM. They found that groups without resin infiltration demonstrated lower resistance to the shear forces. According to the findings of SEM, both groups after resin application showed a significant improvement compared with the results without resin use, as the enamel appeared smoother and less erosive.

Nahidh[19] studied the effect of One Tiger® (a carbonated energy drink) on the shear bond strength and site of bond failure of stainless-steel bracket to human teeth. He found that One Tiger® reduced the shear bond strength significantly below the acceptable limit.

Pasha et al.[20] assessed the effect of Coca-Cola® and orange Miranda® on the shear bond strength and site of bond failure in stainless-steel brackets bonded to intact human teeth; an SEM evaluation of the intact and sealed enamel was also performed. The results indicated that the shear bond strength was decreased significantly by both beverages, and this effect was stronger in orange Miranda® with greater adhesive failure at the site of bond failure. SEM results indicated a greater presence of defective areas because of erosion caused by acidic soft drinks on intact and sealed enamel surfaces in Coca-Cola® than in orange Miranda®.

In general, carbonated soft drinks can affect shear bond strength in 2 ways: by deteriorating the structure of the adhesive materials and by causing erosive lesions on the enamel surface around the brackets, with the main effect of the beverage compositions and total acid content, rather than beverage pH, determining the actual aggression toward the enamel.[15,20] Regarding the beverage matrix, there are additional composite interactions between the soluble and solid contents of a beverage, such as the acid/hydroxyapatite reaction, which yet again influences the impending erosion.[21]

The type of acid has also an effect on the severity of erosion. SEM comparison between Coca-Cola® and Sprite® groups indicated more extensive and noticeable enamel defects in the Coca-Cola® group because of the enamel-erosive effect of the phosphoric acid present in Coca-Cola®.[15]

The erosive potential of a citric-acid-based orange juice drink and a phosphoric-acid-based diet cola drink was studied by Rugg-Gunn et al.[21] They concluded that erosive potential of the phosphoric-acid-based diet cola was more than that of the citric-acid-based orange juice drink. Pasha et al.[20] confirmed the previous findings but reported lower shear bond strength with citric-acid-based drinks (orange Miranda®).

Waterhouse et al.[22] confirmed that low doses of citrate can increase the pH and hence decrease dental plaque acidogenicity and suggested that it be added to non-alcoholic soft drinks to decrease their carcinogenicity.

The One Tiger® energy drink contains citric acid, benzoic acid, taurine, caffeine, and carbonated water that cause enamel demineralization around the brackets.[15] This could be clarified by the high concentration of refined carbohydrates that encourage greater degrees of acid production. Moreover, citric acid and citrate can bind to calcium in the tooth, maintaining a low pH for a long time.

Studies have found that high acidity may act as a plasticizer that speeds up the water sorption rate by reducing the polymer interchain interactions. Degradation of the composite that leads to decrease in its mechanical properties has been proved to be caused by acidic pH solutions[23], which in turn may offer an adequate concentration of protonated protons to induce hydrolysis of the ester part found in the resin matrix.[24]

Effects on Chemical Properties, Corrosion Resistance, and Surface Topography

Shahabi et al.[25] studied the effect of Coca-Cola® on the corrosion of stainless-steel brackets *in vitro*. The brackets were weighted and immersed in Coca-Cola® at 37°C and in artificial saliva (control) for 6 weeks and re-weighted. The authors found that powerful corrosion took place after exposure to Coca-Cola® starting from the 1st week and continued at a fast and almost constant rate. This can be attributed to the presence of soluble carbonic acid in Coca-Cola®, an acidic solution with a relatively low pH that easily dissolves the protective oxide layer and makes corrosion take place faster and sooner, and the presence of small and ample carbon dioxide gas bubbles dissolved in Coca-Cola® and their adhesion to different bracket surfaces and very small but abundant pointed corrosions formed on them simultaneously. These corrosion sites developed gradually and adjoined, causing a large destruction in a limited time.

Parentiet al.[26] investigated the effect of Coca-Cola® and Gatorade® on the physical and chemical properties of 0.019×0.025-inch heat-activated NiTi orthodontic archwire. The wires were soaked in 10 mL of the drink for 60 minutes. They found statistically non-significant differences in terms of the Young's modulus, hardness, surface color change, topography, or chemical composition. They deduced that degradation of NiTi wires would not be caused by consumption of soft drinks.

Abalos et al.[27] evaluated the effect of soft drinks on the surface topography and corrosion behaviors of 0.016×0.022-inch NiTi archwires. Different surface patterns of NiTi archwires, such as smooth, scratch, dimple, and crack, were selected and characterized using SEM and laser confocal microscopy. The archwires were immersed in a soft drink with a pH of 2.5 for a period corresponding 28 days, and the results were compared to archwires immersed in artificial saliva with a pH of 6.7. They found an increase in surface defects and/or roughness with reduction in corrosion resistance in the dimple, crack, and scratch patterns. Moreover, the surface pattern had a direct correlation with the extent of corrosion with low-pH soft drinks.

Mikulewicz et al.[28] assessed the ions released (using multi-elemental inductively coupled plasma optical emission spectrometry) from a fixed orthodontic appliance after altered immersion in Coca-Cola® (5.5 h) and artificial saliva (18.5 h) using a continuous flow system specially designed for their *in vitro* study. The appliance included 20 brackets, 4 molar bands, and two 0.017×0.025-inch archwires, all manufactured from stainless steel. The duration of the experiment was 28 days. Compared with artificial saliva, Coca-Cola® intensified the release of Fe^{2+} ions (18 times), Mn ions (47 times), Mo ions (15 times), and Cd ions (5.6 times).However, the released Cr and Cu ions were lower than those released from artificial saliva. Moreover, the Coca-Cola® environment facilitated solubilization of Ni ions from the

stainless-steel alloys. All the released ion levels were below the daily recommended doses. Orthodontic appliances present in the oral cavity undergo rapid dissolution of the surface oxide layer of the metal when exposed to the aggressive action of low-pH acidic food and drink because of thermodynamic instability and release of Fe, Zn, Ag, Ni, and Cr ions until equilibrium is reached or impedance occurs. This also results in surface dissolution of ceramic materials, pitting corrosion, and surface roughness. Released cytotoxic elements can produce discoloration in the adjacent soft tissues and allergic reactions in susceptible patients.[29]

Nanjundan and Vimala[30] studied the *in vitro* effect of Pepsi-Cola® on the frictional resistance and surface characteristics of 0.019×0.025-inch stainless-steel archwires ligated to stainless-steel and polycrystalline orthodontic brackets. The archwire-bracket assemblies were immersed in Pepsi-Cola® for 24 hours and then washed, dried, and tested. The results revealed a significant increase in the surface roughness of the archwires and brackets with different degrees of pitting and surface irregularities, especially with polycrystalline brackets. Moreover, the static and kinetic frictional forces were significantly affected by Pepsi-Cola®. Brackets and archwires immersed in a highly acidic Pepsi-Cola® with a pH of 2.46 showed more surface irregularities, pitting, breakdown, debris, and roughness and had the highest static and kinetic frictional forces. This is owing to the acidic ingredients that promote corrosion and breakdown. As acidity increases, the tendency toward breakdown and surface roughness of orthodontic appliances increases as well.[31]

Coca-Cola® contains very high levels of sugar with a low pH (2.465). The cathodic reaction of corrosion can be intensified by the low pH. The suggested mechanism entails the formation of a passive layer of oxides at first and then its dissolution by the action of protons in acidic pH, resulting in the release of metal ions.[32]

Effects on the Color Stability of Clear Retainers, Esthetic Brackets, and Elastics

Lew[33] determined the *in vitro* susceptibility of clear elastomeric modules to staining from Coca-Cola® at 6, 12, 24, 36, 48, and 72 hours using a visual analog scale (VAS). He found that Coca-Cola® produced no staining even after 72 hours.

Al-Huwaizi and Kalhan[34] evaluated the effect of Coca-Cola® and Miranda® on the stainability of clear overlay retainers made from 3 types of thermoplastic materials (Duran, Clear, and Comfort) using a computerized spectrophotometer. They found that Coca-Cola® had a greater staining effect than Miranda® for all types of materials, with Comfort being the least affected and Duran being the most affected.

Ardeshna and Vaidyanathan[35] assessed the color stability of colored and clear orthodontic elastomeric modules from different manufacturers soaked in Coca-Cola® for 72 hours using a Minolta chromameter. They found that Cola-Cola® caused minimal color change.

Silva et al.[36] appraised the color stability of 5 different esthetic orthodontic elastic ligatures immersed in Coca-Cola® using an ultraviolet (UV)-visible spectrophotometer. They found that Coca-Cola® caused some color change in the esthetic elastic ligatures with significant differences among the different brands.

Aldrees et al.[37] evaluated the amount of discoloration in clear and semi-clear elastomeric chains from 8 manufacturers using a spectrophotometer after immersion in Pepsi-Cola® for 72 hours. They found that semi-clear elastic chains tend to present significantly less discoloration than their clear counterparts.

Guignone et al.[38] assessed the color stability of 5 types of ceramic brackets after immersion in Coca-Cola® for 1, 3, 7, and 14 days using a UV-visible spectrophotometer. They found that despite presenting the lowest pH level, Coca-Cola® did not cause as much color alteration. They attributed the minimal effect of Coca-Cola® to the lack of yellow pigment in its composition.

Albo Hassan and Ghaib[39] used a UV-visible spectrophotometer to compare the stainability of sapphire ceramic brackets bonded with 3 types of light-cured orthodontic adhesives immersed in Pepsi-Cola® for 1, 7, and 14 days. They found that the brackets and adhesives underwent discoloration from Pepsi-Cola® that increased gradually until day 14. They found that the brand, immersing solution, and storage time might influence the degree of color change in the materials. The amount of fillers present and the resin matrix of the studied adhesives played important roles in the color stability and water sorption rate of the composites. It has been shown that Pepsi-Cola® contains approximately 32-39 mg of caffeine (which is less than that in tea) as well as carbonated water (soda), phosphoric acid, and citric acid that may have some cleaning action.

Talic and Almudhi[40] compared the stain resistance of 3 types of clear elastomeric modules exposed to Coca-Cola® for 72 hours through assessment by a group of dentists' perceptions of discoloration using a VAS. The study showed that Coca-Cola® caused staining in the tested modules, unlike reported previously that Coca-Cola® did not produce any staining. The difference between this study and previous studies was that the previous studies examined elastomeric modules from one company, whereas this study tested elastomeric modules from 3 different companies.

Noori and Ghaib[41] assessed the color stability of different types of esthetic archwires from 4 different companies after immersion in Pepsi-Cola® for 7, 14, and 21 days using a spectrophotometer. They found that Pepsi-Cola® had a weaker staining effect on the esthetic archwires. This might be related to the chemical and physical compositions of the esthetic arch wires, and the need for further study was suggested to investigate each company's products to identify the cause of this variation.

Mahmood[42] evaluated the degree of color change of epoxy-coated 0.019×0.025-inch stainless-steel archwires from different companies immersed in Miranda® for different time intervals using a visible spectrophotometer. She found that Miranda® had a minimal coloring effect on all the tested brands owing to the cleaning effect of its acidic contents (i.e., ascorbic and citric acids).

Effects on Elastics' Force Decay

Nattrass et al.[43] evaluated the effect of Coca-Cola® at different temperatures on the force delivered by the elastomeric power chain from Ortho-Care over different time intervals. They concluded that temperature, pH, and composition of Coca-Cola® had a great effect on the force decay of the elastomeric chain than distilled water.

Teixeira et al.[44] conducted an *in vitro* study to assess the effect of DietCoke®, phosphoric acid, and citric acid (pH=2.60) on the force decay of 2 types of elastomeric power chains immersed for 15 minutes twice daily over 3 weeks. They found a significant decline in the force of both elastomeric chains in the first 24 hours with no significant difference per the immersion media.

Hemed[45] evaluated the effect of Pepsi-Cola® on the remaining force of different types of elastomeric power chains immersed once daily for 8 minutes over 4 weeks. She found that Pepsi-Cola® decreased the remaining force over the 4-week period compared with the control group.

Leão Filho et al.[46] tested the force degradation effects of immersing 1/4 inch intermaxillary elastics in Coca-Cola® and artificial saliva (as a control). The immersion took place in 5 cycles. In the 1st and 2nd cycles, the elastics were immersed for 15 minutes in the tested beverages and were then immersed for 3 mintues in the artificial saliva. In the 3rd, 4th, and 5th cycle, the immersion lasted for 30 minutes followed by 3 minutes of immersion in artificial saliva. The results indicated that Coca-Cola® did not affect the force degradation of the tested elastics compared with the artificial saliva; hence, the chemical nature of Coca-Cola® had no additional effect.

Teixeira et al.[44] demonstrated that immersion in Diet Coke® was not able to alter the pattern of force degradation in 2 different types of elastomeric chains, in agreement with Leão Filho et al.[46] who found that diet beverages did not affect the force degradation of the tested elastics compared with artificial saliva; hence, the chemical nature of these beverages had no effect, unlike the findings from a study by Hemed[45]. One of the drawbacks of the study by Teixeira et al. was that they did not measure the pH of the tested beverages.

Pithon et al.[47] investigated the effect of Coca-Cola®, Fanta®, Guarana Antarctica®, and Sprite® on force decay in elastomeric chains in comparison with de-ionized water and artificial saliva. They immersed the chains in the soft drinks twice daily for 3 minutes with an interval of 6 hours between the exposures for over 6 intervals. They found that the pH of acidic substances, preservatives, pigments, chlorides, and phosphates had an effect on the elastic decay in (in decreasing order) Coca-Cola®, Fanta®, Guarana Antarctica®, and Sprite® but with less influence than the artificial saliva.

Aldrees et al.[37] compared the percentage of force decay in clear and semi-clear elastomeric chains from 8 manufacturers after immersion in Pepsi-Cola® for 72 hours. They found significant differences in the mean percentage of force decay between the clear elastomeric chain types.

Yuwana et al.[48] evaluated the effect of Coca-Cola®, Pepsi-Cola®, and BIG Cola® on the tensile strength of 1/4- inch, 4.5-oz orthodontic elastic immersed in each beverage for 90 seconds per day before being immersed in artificial saliva for 24 hours and 48 hours. The results indicated that these beverages increased force decay compared with artificial saliva with no significant differences among the tested beverages.

Barretto et al.[49] assessed the tensional strength of elastomeric chains immersed twice daily for 30 seconds in Coca-Cola® and cold water (at 5°C±1°C) compared with artificial saliva. They found that the tensional strength decreased over time and appeared to decrease more with cold water, indicating that the temperature rather than the composition of the beverage was the predominant contributing factor. This is the only study that considered the temperature of the beverages, and the exposure time was very short (30 seconds per day), as *in vivo* intake of water may change according to one's needs and the climate.

Suprayugo et al.[50] investigated the effect of Coca-Cola® on the force decay of elastomeric chains over 1, 24, 42, 72, 168, and 336 hours of immersion compared with distilled water. They found a significant reduction in the force levels with no significant effect of acidity or duration of immersion in these solutions. The drawbacks of this study were that the duration of immersion was too long and that the researchers used the same pieces of elastic over the period of study, which may have led to errors because of frequent extensions during the measuring procedures.

Sallam et al.[51] assessed the effect of some carbonated drinks (diet and regular Pepsi®) on the force decay of 2 types of short elastomeric chains and concluded that carbonated drinks revealed an increased capability to affect the force decay of the orthodontic elastomeric chains than that shown by the salivary medium.

In summary, the type, configuration, and method of manufacturing should be taken into consideration along with the content, pH, and temperature of the carbonated soft drinks.

CONCLUSION

- Increased consumption of carbonated soft drinks causes deleterious effects on the general health.
- Tooth movement is greatly affected with the increased use of carbonated soft drinks.
- Carbonated soft drinks have a great influence on the shear bond strength and enamel surface as well as the color stability of different materials.
- There are controversies regarding the effect of carbonated soft drinks on force degradation in different orthodontic elastics.
- Release of ions from orthodontic wires and corrosion with surface changes are obvious with the increased consumption of carbonated soft drinks.

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Processing – Z.A., M.N.; Analysis and/or Interpretation – M.N.; Literature Search – M.N., Z.A.; Writing Manuscript – Z.A., M.N.; Critical Review – M.N.

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Case Report

Early Maxillary Expansion with the Ni-Ti Memory Leaf Expander-A Compliance-Free Fixed Slow Maxillary Expansion Screw: A Report of 2 Cases

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ABSTRACT

Transversal problems such as crowding and crossbite are one of the most common problems dealt with in early orthodontic treatments. Early correction of these problems may ease or even eliminate the future need for treatment. This paper presents the management of 2 cases with transverse discrepancy using the Ni-Ti Memory Leaf Expander—a new compliance-free slow maxillary expansion appliance. The total treatment time for both cases was 9 months. In both cases, the inter-canine, inter-premolar, and inter-molar distances, as well as the arch length, have all increased.

Keywords: Non-compliance therapy, leaf expander, posterior crossbite, transverse discrepancy

INTRODUCTION

Transversal problems due to insufficient palatal arch dimension are usually accompanied by upper arch crowding and/or crossbite.[1] Early maxillary expansion treatment allows the permanent teeth to erupt into normal occlusion, eliminating interferences and providing more favorable dental and skeletal changes during growth.[2] The method used for maxillary expansion may vary depending on the activation frequency, magnitude, and duration of the force applied, and age of the patient.[3] Rapid palatal expansion (RPE) is one of the most commonly used methods to treat transversal discrepancies. However, the opening of the mid-palatal suture may sometimes cause discomfort for the patient. On the other hand, slow maxillary expansion (SME) allows more physiological adaptation of the mid-palatal suture and therefore causes less discomfort. Despite applying smaller forces, SME has been shown to have orthopedic effects in growing patients.[4] Lanteri et al.[5] compared the volumetric changes in the upper airways after rapid and slow maxillary expansion in growing patients using the Leaf Expander as the SME device. They concluded that effective maxillary expansion can be achieved with SME. Moreover, posterior crossbite correction by SME in mixed dentition has been reported to have 84% stability in permanent dentition.[6] The Ni-Ti Memory Leaf Expander screw shows similarities in design to conventional rapid palatal expander (RPE) screws. However, unlike a typical RPE screw, it applies constant small force through its double nickel-titanium leaf springs and eliminates the need for parent or patient cooperation as there is no need for home activation. The aim of this paper is to present 2 cases of maxillary expansion using the Leaf Expander to show the treatment results of this new compliance-free expansion method.

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Figure 1. Case 1: An 8-year-old female patient with unilateral posterior crossbite and unerupted lateral incisor.

CASE PRESENTATION

Case 1

Diagnosis

A female patient aged 8 years and 2 months was referred to the Department of Orthodontics with the chief complaint that her lateral inciors had not erupted. After a detailed clinical intra-oral examination, dental radiographs and impressions were taken and a detailed evaluation of the patient was carried out. The patient had moderate crowding, single-tooth crossbite on the left first molar area, and 2.5 mm of dental midline shift to the right on the lower arch. The panoramic radiograph further revealed that the right lateral incisor had failed to erupt due to inadequate space. Lateral cephalometric analysis revealed no skeletal anomalies (Figure 1).

Treatment Goals

Our primary goal was to expand the maxilla and create enough space for the natural eruption of the right lateral incisor, and simultaneously solve the single-tooth crossbite on the left side. Written informed consent was obtained from the patient's parents.

Treatment Plan and Progress

The Leaf Expander was chosen as the expansion appliance. It was anchored to the deciduous second molars (Figure 2). The Leaf Expander has a double nickel-titanium leaf spring that recovers its shape during deactivation. There is no need for home activation. All the activations were done during the patient's monthly visit to the clinic. The expansion screw was pre-activated in the laboratory to produce 3 mm of expansion, and it was ligated with metal ligatures by squeezing the leaves of the expander before placing it in the patients' mouth. The Leaf Expander was bonded to deciduous teeth and the ligatures were then cut to allow expansion. Our choice of the Leaf Expander screw was 6 mm, which delivers an amount of 450 g force during deactivation. The patient visited the clinic every 4-5 weeks for the activation of the Leaf Expander. During each visit, the screw was activated by 10 quarter-turns until the

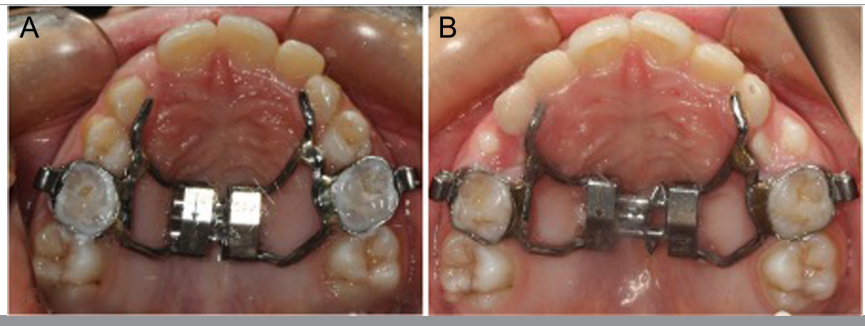

Figure 2. A. Leaf expander in place. B. Leaf Expander after 6 months of active expansion.

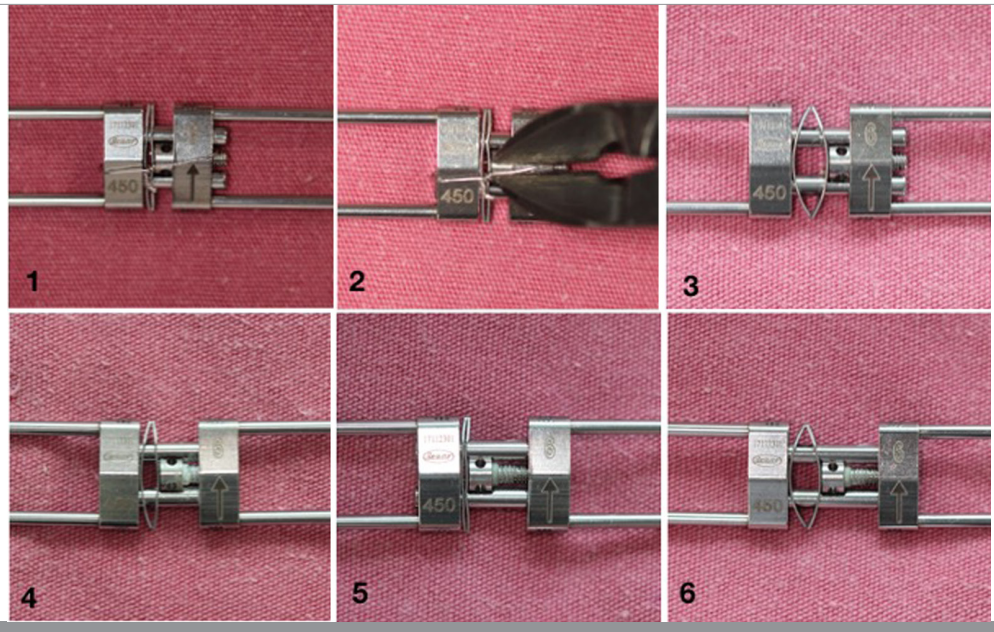

Figure 3. Activation protocol for Ni-Ti Memory Leaf Expander. (1, Pre-activated expander screw blocked with metal ligatures in the laboratory; 2, Ligature cut to activate the Nickel-Titanium Leaves. 3, Deactivated Leaf spring indicating expansion is achieved. 4, Leaves re-activated by 10 quarter-turns of the screw to produce 1 mm expansion. 5, Re-activation complete. 6, Additional expansion produced by Leaf spring).

expansion was completed (Figure 3). The maximum number of activations was 30. After the completion of active expansion (6 months), the appliance was kept in place for 3 more months for retention purposes. Therefore, the total treatment lasted 9 months.

Treatment Results

Successful expansion of the maxillary arch was achieved, providing enough space for the right lateral incisor to erupt. The crossbite on the left side was corrected and lower midline deviation was improved but not fully corrected, as it was mostly a dental problem rather than a functional shift (Figure 4). After the treatment, the pre- and post-treat ment dental models were scanned using the 3Shape D700 3D Scanner (Copenhagen, Denmark) and converted to digital models. The digital models were then evaluated using Blender Software Version 2.90. The inter-canine, inter-premolar, and inter-molar distances, as well as the arch length, were all found to have increased (Figure 5 and Table 1).

Figure 4. Case 1: Treatment results after 9 months of treatment (6 months of active expansion followed by 3 months of retention) with Ni-Ti Memory Leaf Expander.

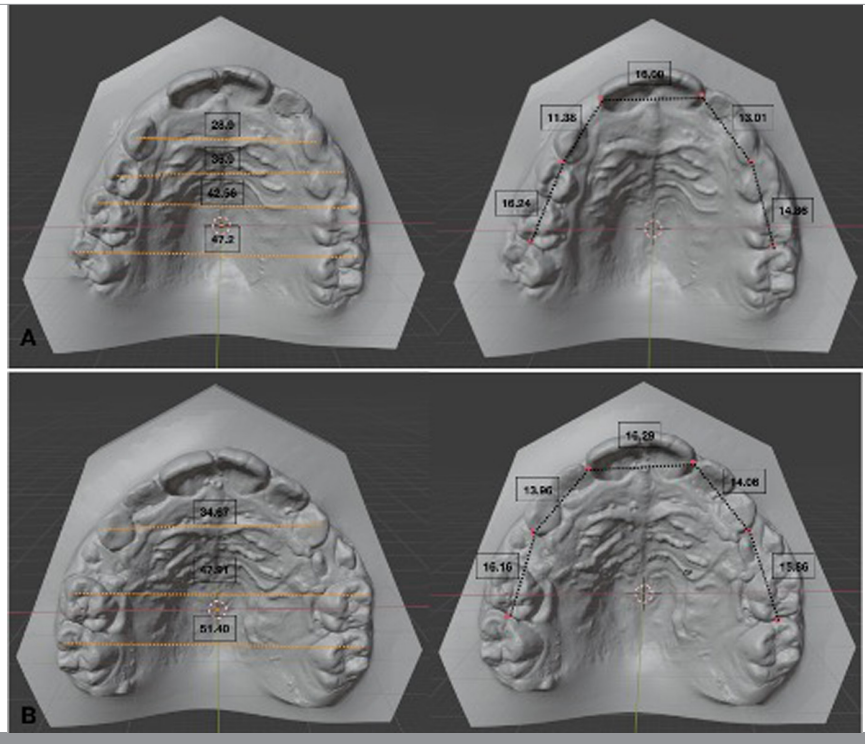

Figure 5. A. Pre-treatment and B. Post-treatment model analyses for Case 1.

Table 1. Arch width and aArch length measurements on STL (Standart Triangle Language) digital casts obtained from patients before and after treatment

	Case 1		Case 2	
Parameter	**Pre-treatment, T_0**	**Post-treatment, T_1**	**Pre-treatment, T_0**	**Post-treatment, T_1**
III-III (mm)	28.9	34.67	27.37	34.65
IV-IV (mm)	36.9	-	33.57	43.54
V-V (mm)	42.56	47.91	44.10	49.91
6-6 (mm)	47.2	51.40	-	-
Total Arch Length (mm)	71.32	76.37	74.2	79

Case 2 Diagnosis

A 7-year-old male patient was referred to our clinic from the Department of Pediatric Dentistry. The patient was in the early mixed dentition stage. Clinical examination showed the presence of bilateral crossbite in the primary canine region. Both upper and lower midlines were coincident with the facial midline. The patient had a Class I molar relationship on the right side and normal overjet and overbite values. His panoramic radiograph and lateral cephalometric analysis showed no skeletal or alveolar abnormalities, while his posteroanterior radiographs revealed mild transverse deficiency in the upper arch (Figure 6).

Treatment Goals

The primary goal was to widen the maxilla and free the primary canines of the crossbite, providing the necessary space for permanent teeth to erupt. Written informed consent was taken from the patient's parents.

Treatment Plan and Progress

The Leaf Expander was chosen as the expansion appliance for maxillary expansion (Figure 7). The same procedures and protocols were applied, as detailed in the above description.

Treatment Results

Expansion of the maxillary arch using the Leaf Expander was achieved, and the bilateral crossbite of the primary canines was corrected (Figure 8). As a result of the maxillary expansion, inter-canine, inter-premolar, and arch length increased (Figure 9 and Table 1); a possible crossbite of the first molars was prevented even though the expansion screw was anchored to the deciduous teeth. The scanning process and

Figure 6. Case 2: A 7-year-old male patient with bilateral crossbite in the primary canine region.

measuring methodology used were the same as described above for Case 1.

DISCUSSION

Early orthodontic intervention is recommended in cases of crossbite and space deficiencies.[7] Maxillary expansion in mixed dentition allows the permanent teeth to erupt into normal occlusion, providing favorable dental and skeletal changes.[8-10] Both patients presented in this report were in the early mixed dentition stage, and maxillary expansion with the Leaf Expander was successfully carried out, both correcting the crossbite, and in Case 1, providing enough space for the lateral incisor to erupt.

Figure 7. Case 2: Leaf Expander anchored to deciduous molars.

In both cases, the Leaf Expander was bonded to second primary molars. Primary teeth are used as anchorage for the Leaf Expander during early mixed dentition, allowing spontaneous expansion of the permanent molars,[1] whereas the conventional fixed expansion screws are usually anchored to permanent teeth, which has some drawbacks such as buccal tipping, buccal alveolar bone resorption, root resorption, and periodontal damage to the anchorage teeth.[10-13] In a recent study, it was shown that reduction in buccal bone thickness around permanent molars was insignificant in cases where the Leaf Expander was used as the SME device.[14]

Moreover, the compliance-free nature of the Ni-Ti Memory Leaf Expander is a big advantage compared to conventional RPE screws. When the activation is left to parents, they often have difficulty turning the screw because they fear hurting the child, or simply because they cannot locate the hole on the expander screw. Doing away with the home activation process solves this problem and means that the patient does not need to visit the clinic as often.

Another advantage of the Leaf Expander over traditional RPE appliances is that its nickel-titanium leaves apply constant small force, which is easier for the patient to tolerate. In a recent study, it was also shown that the patients experience considerably less pain and discomfort with the Leaf Expander.[15]

One may argue that treatment with the Leaf Expander takes more time compared to RPE protocols. However, the overall time of treatment, including the retention period, is similar. It could be criticized that no overcorrection was made for both cases. A drawback of the Leaf Expander is that the capacity of the screw is fixed, and in these cases, it could be said that the 6 mm

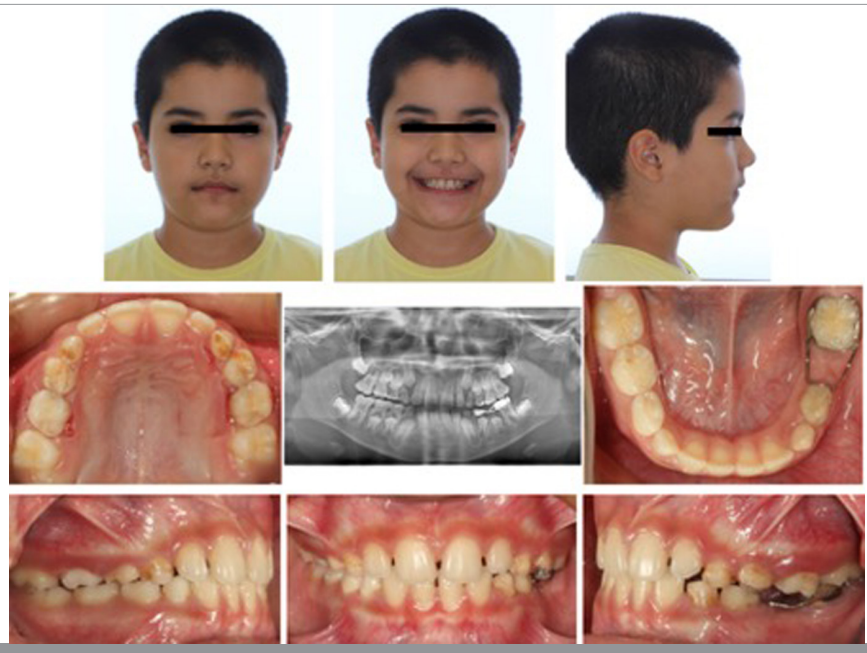

Figure 8. Case 2: Treatment results after 9 months of expansion treatment (6 months of active expansion followed by 3 months of retention) with the Ni-Ti Memory Leaf Expander

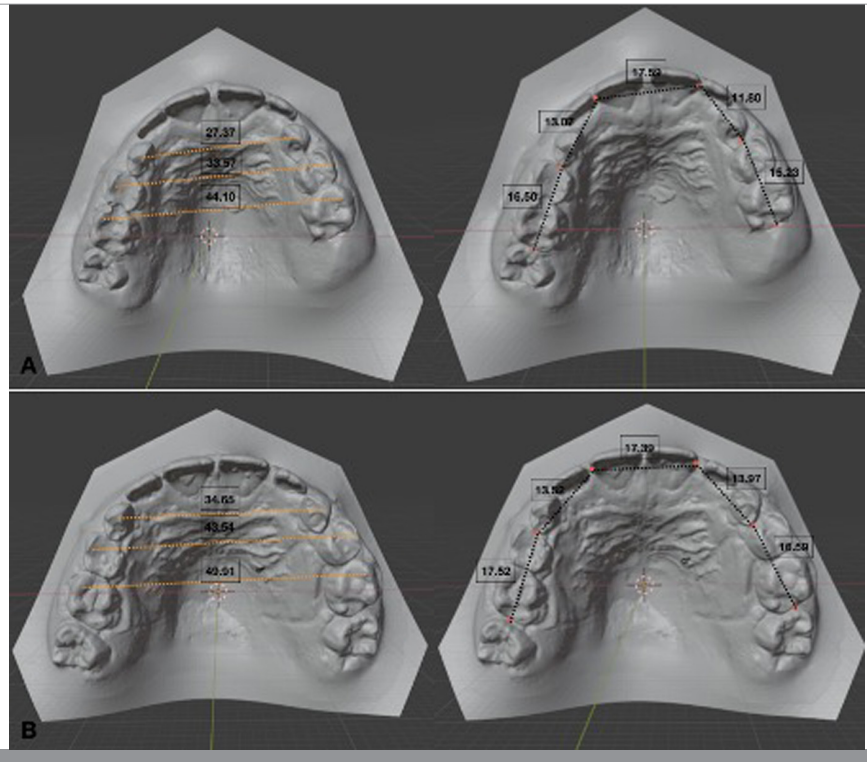

Figure 9 . A. Pre-treatment and B. post-treatment model analyses for Case 2.

expansion screw was inadequate for overcorrection. However, there are more options to choose from, and a wider expansion screw can be chosen if overcorrection is desired.

CONCLUSION

The nickel-titanium Memory Leaf Expander provides a good alternative to conventional RPE screws for maxillary expansion in mixed dentition. Furthermore, the compliance-free nature of the expander provides an advantage over the conventional expansion screws as it eliminates the need for home activation.

Informed Consent: Written informed consent was obtained from the patients who agreed to take part in the study.

Peer Review: Externally peer-reviewed.

Author Contributions: Conflict of Interest: The authors have no conflict of interest to declare.

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Reader's Forum

Comment on recently published article "Assessment of Knowledge, Behaviors, and Anxiety Levels of the Orthodontists about COVID-19 Pandemic"

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The Turkish Journal of Orthodontics recently published a research paper titled "The Assessment of Knowledge, Behaviors, and Anxiety Levels of the Orthodontists about COVID-19 Pandemic."[1] It was a well-written manuscript addressing one of the most pertinent contemporary issues in dentistry and orthodontics. The COVID-19 pandemic has had severe effects which might stay for a long time, if not forever. Because of their commendable research goals, we read this paper with great interest.[1] In the process, we could identify few methodological errors and paucities of this paper in the interest of qualitative research.

The study was conducted in one region only, which limits the generalizability of the results. Future researchers can target a better sampling frame with people from different regions of the same country or different countries. Similarly, ignoring the level of education of the participants and their clinical experience (in form of years in practice) can lead to bias.[2,3] The knowledge of orthodontists and hence their behavior and anxiety levels are bound to be affected by this aspect and must have been addressed in greater detail. Even the use of appropriate statistical methods such as meta-regression can be of some help.[2]

Additionally, according to the principles of qualitative research, a questionnaire is a tool for the assessment of one or more outcomes.[2,3] The questionnaire must first be developed using techniques and understanding of qualitative research, tested for its validity and reliability, and then administered.[2] Lack of these details is a major paucity in this paper and most of the papers of similar nature. In the absence of this methodological purity, the survey results cannot be considered as accurate and primarily reflect the trends regarding the subject.

In concluding, we would again thank the authors for igniting our minds with these novel aspects and would hope that future researchers address the points raised by us for the interest of science.

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Author's response

Response to Comment on recently published article "Assessment of Knowledge, Behaviors, and Anxiety Levels of the Orthodontists about COVID-19 Pandemic"

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First of all, we would thank to the authors for the letter to the editor for the research titled "The Assessment of Knowledge, Behaviours, and The Anxiety Levels of The Orthodontists about COVID-19 Pandemic". In response to the author's recommendation to involve orthodontists from different regions and countries for a better sampling frame, the questionnaire of the present study was sent to the all registered orthodontists among the country by Turkish Orthodontic Society. However, most of the participants were from Istanbul, Ankara and Izmir which were the most populous cities in Turkey. There were only sporadic participants from other cities, so all of them were grouped into one group named as "other" in the tables. It would be a better sample with people from different countries as the author suggested however the main aim and the target group of the present study was to evaluate the behaviors of the orthodontists in Turkey.

With regard to the clinical experience and education of the participants, the ages of the participants were included and grouped in the questionnaire since the time spent in the profession and therefore the experience increases with increasing age. Additionally, as it was explained in the results section, the relation between the age of the participants and the behavior or anxiety levels was evaluated statistically however no statistically significant difference was found when the prevalence of anxiety was stratified by age. Considering the statistical analysis for the evaluation of that relation, the statistician selected and analyzed the method. Furthermore, you suggested meta-regression analysis as the statistical method. However, all the suitable analyzes selected and applied by a statistician.

Regarding the concerns about the principles of qualitative research, the Turkish version of the 7 items Generalized Anxiety Disorder (GAD-7) test was applied in the last part of the questionnaire to assess the anxiety levels of orthodontists and the validity and reliability of that version was already tested in a previous study.[1] The rest parts of the questionnaire were about demographic information, general questions about COVID-19, treatment strategies and the protective measures that were not thought necessary for testing of their validity and reliability.

Thank you again for your kind and valuable comments to the article, and also contributions to the literature which will be extremely beneficial for future studies.

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