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Original Articles

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Original Article

Effect of Different Liquids and Thermal Aging Procedures on the Shear Bond Strength of APC II, APC Flash-Free, and Conventional Ceramic Brackets: An *In Vitro* Study

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Main Points

- Thermo-aging procedure and fluids had a negative impact on the shear bond strength (SBS) value of each type of ceramic bracket.
- Even after exposure to gastric acid and coke, the SBS values of all three types of brackets were still higher than a clinically acceptable value.
- Despite their low-viscosity resin structure, flash-free brackets had a satisfactory SBS value.

ABSTRACT

Objective: The purpose of this study was to compare the effects of cherry juice, coffee, coke, gastric acid, and the thermo-aging procedure (TAP) on the shear bond strength (SBS) of APC II, APC flash-free, and conventional ceramic brackets.

Methods: A total of 180 human premolar teeth were randomly divided into three major groups according to the type of ceramic bracket. Then, six subgroups (n=10) were established from each major group: Group 1: control; Group 2: only TAP; Group 3: 72 hours of cherry juice exposure + TAP; Group 4: 72 hours of coffee exposure + TAP; Group 5: 72 hours of coke exposure + TAP; and Group 6: 24 hours gastric acid exposure + TAP. SBS was assessed for each specimen using a universal test device, and the adhesive remnant index (ARI) was scored under a light microscope. Kruskal-Wallis and post-hoc Tamhane tests were used to analyze the data.

Results: Among the control groups, the highest SBS value belonged to conventional ceramic brackets ($p<0.01$). SBS values for all groups decreased as a result of each liquid and TAP. Gastric acid and coke had the greatest detrimental effects on SBS, while TAP had the least negative effects. The SBS values of APC II, APC flash-free, and conventional brackets were found to be statistically insignificant after different liquid exposures and TAP.

Conclusion: TAP and various fluids had a negative impact on the SBS value of ceramic brackets. SBS values, however, were still higher than clinically acceptable (8-9 MPa) values, even after exposure to gastric acid and coke.

Keywords: Shear bond strength, APC II, APC flash-free, ceramic brackets

INTRODUCTION

Porcelain brackets are preferred for a variety of reasons, including their aesthetic appearance, biocompatibility, and magnetic resonance imaging safety.[1] Ceramic brackets, on the other hand, are inert materials that cannot create a chemical bond with the adhesive. Indentations or undercuts are typically placed at the base of the bracket to provide mechanical retention and interlocking.[2] Chemical bonding is not a viable option for porcelain

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brackets because it increases the risk of microcracks on the enamel surface during the debonding process.[3] Therefore, the value of shear bond strength (SBS) gains special importance when it comes to porcelain brackets. The SBS should not be high enough to crack the enamel during debonding. In addition, it should not be so low as to cause bracket failure during treatment.[4]

For decades, various orthodontic adhesive types developed by numerous companies have been compared in *in vivo* and *in vitro* studies.[5] The adhesive is routinely manually placed on the bracket base during the bonding procedure of orthodontic brackets. The excess resin material is then cleaned away by the orthodontist using a dental probe prior to light or chemical curing. Adhesives must provide a good marginal seal without excessive resin around the bracket to avoid white spot lesions or caries. This routine process can result in both adhesive waste and time loss.[6] To simplify and speed up the bonding process, the 3M company (3M Unitek, Monrovia, CA, USA) introduced APC brackets in 1991.[7] The product was later enhanced (less viscous, better handling properties, better blister package, and extended expiration date), and the second generation, APC II, was launched in 2000.[8]

In 2002, the third-generation adhesive precoated (APC) Plus system was created by the manufacturer. Instead of the resin composite, the APC Plus brackets include a pink-colored compomer adhesive at the base that changes color when curing. The compomer material is claimed to release fluoride during treatment and has a stronger tolerance to moisture.[9]

In 2014, APC flash-free brackets, which are the latest generation and do not require the excessive composite cleaning process, were introduced.[10] In this system, each bracket is individually packaged with the optimal amount of adhesive precoated on its base. The brackets are easily adapted to the tooth surface and cured without the need to remove excessive resin. During the fabrication process, the system, which is made of a nonwoven mat saturated with resin adhesive, can be placed at any orthodontic bracket base. The clear, low-viscosity resin forms a channeling border around the bracket's edges when it is forced up against the enamel surface.[11] Less filler resin content, according to some studies, lowers SBS and increases bracket failure.[12] However, the manufacturer asserts an acceptable bond strength of less than 2% bond failure based on internal data.[11] Other features include shorter bonding times and less discoloration around the bracket.[12]

Previous research, which mostly compared APC and regular adhesive systems, didn't look at how different fluids and thermal aging time procedures affected SBS. In the current comparative study, SBS values of APC flash-free porcelain brackets were assessed from a different point of view by exposing them to different liquids and/or thermos-aging procedures (TAP). The first null hypothesis was that the SBS values of APC flash-free, APC II, and conventional ceramic brackets (using the same manufacturer's regular adhesive system) did not differ after exposure to various liquids. The second null hypothesis was that TAP had no effect on SBS values.

METHODS

The current study's research protocol was approved by the Afyonkarahisar Health Sciences University Clinical Research Ethics Committee (approval no.: 2019/361, date: 01.11.2019). The G*Power 3.1.9.2 program (Franz Faul, Universität Kiel, Germany) was used to determine the sample size analysis (α=0.05, 1-β=0.80, and effect size: 0.38) revealed that at least 10 samples were required for each group.

In the current study, 180 human premolar teeth were used. A light microscope (Zumax, OMS2380, China) was used to inspect the enamel surfaces for cracks or fractures. Teeth with caries, fillings, or structural flaws in their crowns were excluded from the study.[13] After extraction, the debris on the teeth's surfaces was immediately removed, and the teeth were kept in the dark in a 0.1 percent thymol solution at the appropriate temperature until the investigation began.[14] The teeth were immersed in the thymol solution for a maximum of 3 months. The solution was renewed monthly.

To perform SBS tests properly, the teeth were embedded in autopolymerizing cylindrical acrylic blocks. The samples were kept in distilled water before progressing to the next stages of the research. Just before the enamel cleaning procedure, the teeth were randomly divided into three major groups, and a low-speed micromotor was used to clean the tooth surface with a rubber brush and fluoride-free paste just prior to bonding brackets. For 30 seconds, all of the crown surfaces of the teeth were etched with 37 percent phosphoric acid. The teeth were washed for 30, and dried for 30 seconds. Trasbond XT primer (3M Unitek, Monrovia, CA, USA) was then applied as a thin layer.

In the first major group, sixty conventional ceramic brackets (3M Unitek, Monrovia, CA, USA) were bonded to the teeth using a Transbond XT (3M Unitek, Monrovia, CA, USA) adhesive. First, the bracket base (mesh type) was covered with adequate adhesive, and it was properly positioned on the tooth surface. Gentle pressure was applied to the bracket with a probe to ensure full contact with the tooth surface, and excess adhesive was removed. The adhesive was polymerized for 3 seconds from the mesial and distal edges using the Valo Ortho Lighting Device (Valo, Ultradent Products Inc., USA) in extra-high power mode (3.200 Mw/cm^2).[15]

In the second major group, 60 APC II ceramic brackets (3M Unitek, Monrovia, CA, USA) were positioned on the teeth surface, and the probe was used to gently press against the brackets. The excess adhesive was removed.

In the third major group, 60 APC flash-free brackets (3M Unitek, Monrovia, CA, USA) were positioned on the teeth surfaces. Light pressure with the probe was used to achieve complete adaptation to the tooth surface. All the teeth in the three groups underwent the same light-curing procedure.

Following bonding, all samples were kept in distilled water at 37 °C for 1 day to complete polymerization.[16] The major groups were then subdivided into six subgroups: Group 1: control; Group 2: only TAP; Group 3: 72 hours of cherry juice exposure + TAP; Group 4:72 hours of coffee exposure + TAP; Group 5: 72 hours of coke exposure + TAP, Group 6: 24 hours gastric acid exposure + TAP. The definitions of the subgroups are shown in Table 1.

Except for the control group, all samples were subjected to an experimental aging protocol using a thermal cycle device (Esetron, MOD Dental, Ankara, Turkey). To simulate temperature changes inside the mouth, the cold tank was set to +5 °C and the hot tank to +55 °C. For each cycle, the samples were kept in each tank for 30 seconds. The transfer time between tanks was 5 seconds. The thermal cycle procedure was completed in 10.000 cycles.[10] This number of cycles corresponded to the 1 year contact time of the adhesive materials in the mouth.[17]

Glass containers for each subgroup were used in this step of the study. Group 3 samples were held in cherry juice for 3 days, Group 4 samples were kept in coffee for 3 days, Group 5 samples were kept in coke for 3 days, and Group 6 samples were kept in artificial gastric acid for 24 hours (Figure 1).[10] To mimic mouth temperature, the temperature of the liquids was set at 37 °C. Daily liquid changes ensured that the results would not be impacted by pH changes. A pH meter (AD12, ADWA, Szeged, Hungary) was used to measure the pH of the liquids. The content, pH value, and exposure time of the liquids used are shown in Table 2.

SBS test and adhesive remnant index (ARI) score

SBS values were measured using a universal test device (Esetron, MOD Dental, Ankara, Turkey). A chisel-edge plunger was placed in the device, and its speed was set to 0.5 mm/min. The acrylic cylinders were positioned on the device's table, and the plunger was moved. When debonding, the computer connected to the test device calculated the smallest force (Newton). By dividing the bracket base area, the force value was converted to megapascals (MPa).

The ARI was used to assess the amount of residual adhesive on the enamel surface following the SBS test. The residual composite on the teeth was scored using the Iidex as defined by Artun and Bergland:[18]

Score 0: The tooth's surface was free of any adhesive.

Table 1. Definition of the subgroups

Subgroups	Experimental procedure
Group 1 (n=10)	No thermal cycle or liquid exposure
Group 2 (n=10)	Only 10.000 thermal aging procedure (TAP)
Group 3 (n=10)	TAP + cherry juice (72 hours)
Group 4 (n=10)	TAP + coffee (72 hours)
Group 5 (n=10)	TAP + coke (72 hours)
Group 6 (n=10)	TAP + gastric acid (24 hours)

Score 1: Less than 50% of the adhesive remained attached to the surface of the tooth.

Score 2: More than 50% of the adhesive remained attached to the surface of the tooth.

Score 3: The total amount of adhesive was still on the tooth.

This procedure was carried out under a light microscope (Zumax, OMS2380, China) by a single researcher to ensure the reliability and reproducibility of the scoring.

Statistical Analysis

The SPSS 22.0 package (IBM, New York, USA) was used to analyze the data. First, the Shapiro-Wilk normality test was performed. The Kruskal-Wallis test and the post-hoc Tamhane test were used for the comparison of SBS values. A chi-square test was used for the comparison of ARI scores. The significance level was set at $p<0.05$.

RESULTS

The comparison results for SBS values are shown in Table 3. In the control group, the SBS value of the conventional brackets was found to be significantly higher than the other two types of brackets ($p<0.01$). In the group (Group 2) in which only the thermal aging procedure was performed, it was found that there was no difference between the bracket types in terms of SBS values ($p=0.223$). Similarly, no significant difference in SBS values was found between the three different brackets in the cherry juice ($p=0.365$), coffee ($p=0.357$), coke ($p=0.573$), and artificial gastric acid ($p=0.387$) groups.

Cherry juice, coke, and gastric acid exposure significantly reduced SBS values in all three bracket types when compared with the control group. While coffee exposure resulted in a significant decrease in SBS values in conventional brackets, it did not cause a significant decrease in the other two groups.

In the subgroup comparison of the ARI scores for each type of bracket, there was no statistically significant difference between

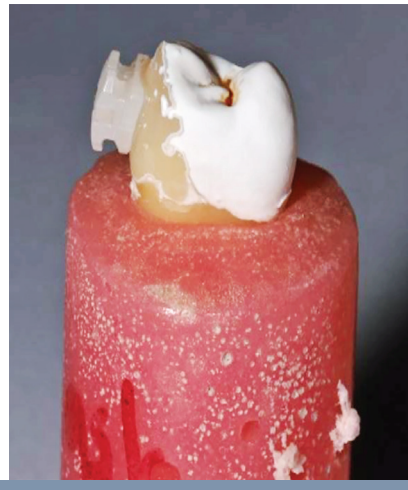

Figure 1. A sample following a 24 h wait in artificial gastric acid

the subgroups (Table 4). In the comparison of the main groups, however, only the control ($p<0.05$) and cherry juice ($p=0.037$) groups showed a statistically significant difference.

DISCUSSION

Numerous *in vivo*, *in vitro*, and *ex vivo* studies have been conducted to evaluate the performance of orthodontic adhesives.[12,19] These studies all share the same objective, which is to improve bonding strength and reduce bracket failure. Many factors affect bracket bond strength, including salivary contamination, poor clinician technique, bracket base feature, prepared enamel surface, masticatory forces, and patient diet or behavior.[20] Another cause of bracket failure is the frequent exposure of adhesives to low-pH liquids as a result of soft drink consumption.[21] The reason for the reduction in bonding strength is the softening of the enamel around the bracket or degradation in the adhesive interference. As a result, microleakage occurs between the bracket and the tooth surface, which negatively affects the SBS value.[22] Extrinsic erosive agents such as soft drinks, as well as intrinsic fluids such as stomach acid, may reduce adhesive performance.[23] Because the pH of gastric acid is lower than that of soft drinks, its enamel or adhesive abrasive effect is greater. In some populations, the prevalence of gastroesophageal reflux has increased by up to 50%.[24] According to this point of view, gastric acid is an important intrinsic factor that can negatively influence SBS values. Pace et al.[25] reported that 24% of gastroesophageal reflux patients had dental erosion, and 32.5% of those with dental erosion had reflux. The adhesive's aging is another factor that affects SBS. Orthodontic adhesive ages as the mouth temperature changes during food consumption. Bracket bond strength decreases as the adhesive ages.[10]

Table 2. The content, pH value, and exposure time of the liquids

Product	Ingredients	pH values	Immersion time of the samples
Coffee (Nescafe, Switzerland)	Soluble coffee	5.0	72 hours
Coke (The Coca Cola Company, USA)	Water, sugar, carbon dioxide, colorant, cola extract, caffeine, acidity regulator (phosphoric acid)	2.53	72 hours
Cherry juice (The Coca Cola Company Cappy, USA)	Water, sugar, cherry juice concentrate, acidity regulator (citric acid), fruit and vegetable extract (blueberry, carrot), flavorings	2.60	72 hours
Artificial gastric acid	0.06 M HCL 0.113% solution in deionized water	1.2	24 hours

Table 3. Comparison of SBS values

Groups adhesive type	Group 1 Mean±SD (MPa)	Group 2 Mean±SD (MPa)	Group 3 Mean±SD (MPa)	Group 4 Mean±SD (MPa)	Group 5 Mean±SD (MPa)	Group 6 Mean±SD (MPa)	p-value
Conventional	23.88 ± 1.50^{Aa}	19.11 ± 3.16^{Ba}	16.22 ± 3.88^{Ba}	17.69 ± 3.22^{Ba}	16.30 ± 3.45^{Ba}	15.24 ± 2.63^{Ba}	0.001*
APC II	21.40 ± 1.27^{Ab}	18.99 ± 3.09^{ABa}	16.11 ± 2.99^{Ba}	17.32 ± 3.48^{ABa}	16.24 ± 3.57^{ABa}	15.20 ± 3.84^{Ba}	0.008*
Flash-free	19.94 ± 1.16^{Ab}	16.99 ± 2.67^{ABa}	14.26 ± 3.30^{Ba}	15.44 ± 4.26^{ABa}	14.98 ± 2.10^{Ba}	13.39 ± 3.49^{Ba}	0.002*
p-value	0.001*	0.223	0.365	0.357	0.573	0.387	

Kruskal-Wallis and post-hoc Tamhane test. In each column and each row, different superscripts (uppercase for row and lowercase for column) indicate a statistically significant differences between groups ($p<0.05$).
SBS, shear bond strength; SD, standard deviation; MPa, megapascal; Group 1, Control; Group 2, only TAP (thermal aging procedure); Group 3, 72 hours of cherry juice exposure + TAP; Group 4, 72 hours of coffee exposure + TAP; Group 5, 72 hours of coke exposure + TAP; Group 6, 24-hour gastric acid

Table 4. Comparison of ARI scores

							p-value
			ARI 0	ARI 1	ARI 2	ARI 3	
	APC II	Count	$6_{a,b}$	$10_{a,b}$	35_{b}	9_{a}	
		% within bracket	10.0%	16.7%	58.3%	15.0%	
	Conventional	Count	0_{a}	3_{a}	23_{a}	34_{b}	
		% within bracket	0.0%	5.0%	38.3%	56.7%	
	Flash-free	Count	$8_{a,b}$	18_{b}	$23_{a,c}$	11_{c}	
		% within bracket	13.3%	30.0%	38.3%	18.3%	
Total		Count	14	31	81	54	
		% within bracket	7.8%	17.2%	45.0%	30.0%	0.01*

*Chi-square test results. Each subscript letter denotes a subset of ARI categories whose column proportions do not differ significantly from each other at the 0.05 level.
ARI, adhesive remnant index

In many studies, flash-free brackets have been compared to non-coated brackets.[10] In these studies, variables such as enamel demineralization, periodontal condition, microleakage, and debonding pain were investigated in addition to SBS. To our knowledge, the current study is the first to compare the effects of different fluids on the SBS strength of APC flash-free brackets with other brackets. According to the literature, the exposure times of resin materials to various liquids range from 1 day to 1 month.[26] Considering the average years of orthodontic treatment, the exposure time for sour cherry juice, coke, and coffee was determined to be 72 hours. However, because the pH of gastric acid is less than 2.0, the exposure time was limited to 24 hours.[12] Aldamaty et al.[27] exposed ceramic surfaces to gastric acid for 96 hours, simulating 10 years of intraoral exposure. In the current study, considering that orthodontic treatments last for an average of 2 years, the samples were kept in gastric acid for 24 hours.[28]

The adhesive used to bond conventional brackets, as well as the adhesive precoated on the base of APC II brackets, had the same content as in the current study. The adhesive on the flash-free bracket base, on the other hand, has a spongy, non-woven-mat structure. It also has a relatively low viscosity due to its lower filler content.[10] Faltermeier et al.[29] reported that low-viscosity adhesives reduce SBS value and increase bracket failure.

The first and second null hypotheses of the current study were rejected. Only in the control group were the SBS values of conventional brackets found to be statistically significantly higher than those of precoated brackets in the current study. This finding was consistent with those of Bearn et al.[30] However, this study found no significant difference in SBS values between groups after exposure to TAP and different liquids. Similar studies in the literature have reported a variety of outcomes. Marc et al.[31] found no statistically significant differences between precoated and non-coated brackets. Alakttash et al.[32] found no difference in the bond failure rate between precoated and non-coated brackets in their systematic review and meta-analysis study. In a systematic review study by Thanetchaloempong et al.,[33] it was reported that the SBS of precoated and non-coated brackets was similar. In the systematic review and meta-analysis study by Wang et al.,[6] there were also no significant differences in bond failure rates between the two bracket types. Inconsistent results found in the literature could be because of different factors that affect the bonding process, such as the type of bracket used, the enamel etching protocol, the tooth structure, and the polymerization protocol. In the current study, there was no statistically significant difference between the subgroups in the comparison of the ARI scores for each type of bracket. However, only the control and cherry juice groups showed a statistically significant difference when the main groups were compared. Foersch et al.[11] found that ARI scores did not differ significantly between the APC flash-free and APC Plus groups. According to Grünheid and Larson[15] APC flash-free adhesives had higher ARI scores than conventional adhesives. However, they claimed that APC adhesive removal times were 22.2% faster than conventional adhesive removal times. A high ARI score indicates that there has been a failure between the bracket base and the adhesive, or within the adhesive itself. The fact that the adhesive remains on the enamel surface can be viewed as a benefit, as this reduces the risk of enamel surface damage, especially with porcelain brackets. The inconsistency in ARI score findings across studies may be due to differences in the etching procedure, light-curing method, and bracket type (metal or porcelain).

Study Limitations

One of the study's limitations is that it was conducted *in vitro*, and saliva buffering not being replicated. In addition, the effect of microbial flora on adhesive performance is unknown. More *in vitro* and *in vivo* studies with more samples are needed to generalize the results.

CONCLUSION

TAP and fluids had a negative impact on the SBS value of each type of ceramic bracket. Even after exposure to gastric acid and coke, the SBS values of all three types of brackets were still higher than a clinically acceptable value. Despite their low-viscosity resin structure, flash-free brackets had a satisfactory SBS value.

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Ethics

Ethics Committee Approval: The Afyonkarahisar Health Sciences University Clinical Research Ethics Committee approved the study protocol (approval no.: 2019/361, date: 01.11.2019).

Informed Consent: Written consent for publication was obtained from each participant.

Author Contributions: Surgical and Medical Practices - H.C., Ş.C.Ç.; Concept - H.C.; Design - H.C.; Data Collection and/or Processing - H.C., Ş.C.Ç.; Analysis and/or Interpretation - H.C., Ş.C.Ç.; Literature Review - H.C., Ş.C.Ç.; Writing - H.C.

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Original Article

Evaluation of Maxillary Protraction Using a Mini Screw-Retained Palatal C-Shaped Plate and Face Mask

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Main Points

- The use of a palatal plate face mask provides a minimally invasive skeletal approach that is comfortable for both the patient and operator.
- Maximum skeletal changes with minimum dentoalveolar changes can be obtained from palatal plate face mask combination.
- Combination of the palatal plate and face masks provides an excellent treatment alternative, particularly in patients with insufficient dental support.

ABSTRACT

Objective: To evaluate a newly designed minimally invasive palatal-plate face mask combination for the management of developing Class III malocclusion due to maxillary deficiency.

Methods: A sample of 16 Class III patients due to maxillary deficiency in the early mixed dentition (8 boys and 8 girls) aged between 7 and 9 years participated in this study and were treated with a combination of palatal plate face masks. Extra-oral elastics were attached between the intra-oral and extra-oral appliances; the elastics were set at 30° to the occlusal plane. The force magnitude was 250-300 g per quadrant. Cephalometric radiographs were taken before and immediately after maxillary protraction. In addition, skeletal measurements were measured, tabulated, and statistically analyzed. The pre- and post-protraction measurements were compared using the Student's t-test, and the significance level was set at a p-value <0.05.

Results: A statistically significant increase in SNA angle and maxillary length was observed by 3.13±1.52 degrees and 2.60±0.75 mm ($p<0.05$), respectively, indicating forward maxillary growth. The skeletal and soft tissue patterns were also improved, as evidenced by the statistically significant increase in the ANB angle, Wits appraisal, and H angle by 4.50±1.28 degrees, 5.30±1.86 mm, and 5.02±3.24 degrees ($p<0.05$), respectively. A favorable clockwise mandibular rotation was observed as evidenced by the increase in the SN/MP angle and the decrease in the SNB angle by 1.46±1.96 degrees and -1.38±1.86 degrees ($p<0.05$), respectively.

Conclusion: The palatal-plate facemask combination is an effective treatment alternative for Class III malocclusion due to maxillary deficiency with minimal pain and discomfort.

Keywords: Class III treatment, face mask, palatal anchorage, palatal plate, skeletal anchorage

INTRODUCTION

Maxillary protraction using a face mask is one of the most common alternatives for managing Class III malocclusion caused by maxillary growth impairment. Face mask therapy with dental anchorage is the most common approach for maxillary protraction. This approach can protract the maxilla by correcting the skeletal and soft tissue profiles. However, most of these changes were dental rather than skeletal, such as protrusion of the maxillary incisors, extrusion and mesial tipping of the maxillary molars with subsequent clockwise mandibular rotation, and elongation of the face.[1]

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Several studies[2-4] have evaluated surgical miniplates and miniscrews for providing skeletal anchorage for maxillary protraction in midface deficiency. Different techniques were described, varying according to the surgical miniplate placement site, force magnitude, and use of adjunctive intraoral or extraoral appliances. These techniques provided a treatment option for patients with a skeletal deformity that was judged too severe to be treated by dentoalveolar compensation alone, and the degree of maxillary hypoplasia and age were not favorable for facemask therapy. However, this technique is aggressive, as additional surgery to remove the miniplate is necessary with potential damage to the developing dental buds. Furthermore, injury to vital structures, such as the maxillary sinus, is a risk factor.[2,5]

Several studies[6,7] have evaluated the suitability of the palate as a skeletal anchorage site in the mixed dentition period and found that the palatal bone was suitable for TADS insertion in growing patients. In addition, the palatal area was used to support skeletally anchored intraoral distalization appliances without any surgical intervention using a minimally invasive approach.[8]

No previous clinical studies have evaluated palatal miniplate-anchored face mask therapy. Therefore, this study aimed to assess the dental and skeletal effects of a modified C- shaped miniplate fixed to the palate as a means of traction of the maxilla in combination with a face mask in growing Class III patients with maxillary deficiency.

METHODS

Sample Size Calculation

The sample size calculation was based on data obtained from a pilot study on four patients. The first outcome selected was a change in the SNA angle. The mean difference was 1.5 degrees, with a standard deviation of 1.45, a confidence level of 95%, and a power of 80%. The sample size calculation was performed using an online sample size calculator (Sample Size Calculator Version 1.058). The sample size calculated was 16.

The data used were a T1 mean of 77.14, a T2 mean of 80.27, a standard deviation of 1.52, an alpha two-sided value of 0.05, and a sample size per group of 16. The power of the study was 0.9999.

The Sample

The study sample comprised 16 patients (8 boys and 8 girls). The researcher explained the purpose of the study and treatment procedures to all patients. Furthermore, written informed consent was obtained from all participants, in accordance with the guidelines for human research adopted by the Research Ethics Committee. The Tanta University Faculty of Dentistry Research Ethics Committee approved the study protocol (approval no.: #R-ORTH-11-17-1, date: April 2022).

The participant patients were selected based on the following criteria: 1) Growing patients, 7 to 9 years old. 2) All of them had CIII malocclusion due to maxillary retrusion, as verified by clinical and radiographic examinations. 3) SNA <79. 4) ANB angle <-1. 5) All patients were in the early mixed dentition. The operator excluded patients with congenital anomalies and systemic conditions from the study.

Before and after maxillary protraction records, including extraoral and intraoral photographs, study models, panoramic radiographs, and lateral cephalometric radiographs, were obtained.

The Intervention

For maxillary protraction, the clinician used a combination of palatal plate and facial masks. The modified palatal plate was custom-made and adapted for each patient. The straight surgical miniplate (Ref 55-0851, Stryker Leibinger, Germany) was supplied. The first step was to bend the plate into a semicircular configuration using a freehand technique with three peak-bending pliers. Then, the miniplate was adapted to the palatal area of the patient's model. The maximum height of the contour of the semicircular plate was placed posteriorly, not extending beyond the line connecting the distal surfaces of the upper second deciduous molars. Next, the two arms were extended anteriorly to adapt to the deciduous canine on both sides. The two arms were raised above the deciduous canines to prevent pressure on the canines during elastic loading and maxillary protraction. End holes of the plate were cut using a carbide disc to serve as hooks for elastic loading. The last fabrication step was plate finishing and smoothening (Figure 1).

The palatal plate was fixed to the palate using four surgical self-drilling screws 2.1 mm in diameter and 11 mm in length (Ref 50-20706 Stryker Leibinger, Germany). The screws were inserted perpendicular to the sides of the palate; two screws on each side (Figure 2).

Figure 1. Adaptation of the plate on the patient's model

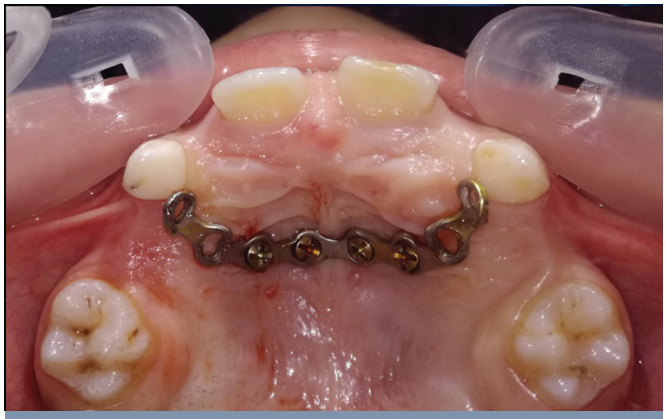

Figure 2. Occlusal view of the palatal plate after its fixation to the palate

The patients were instructed to take oral antibiotics, analgesics, and chlorhexidine mouthwash and were allowed 3 weeks to adapt to the miniplate before loading the elastics.

Application of the Facemask

After 3 weeks of fixation, the operator examined the patients to ensure that the palate plate was stable and not irritant to soft tissue. The elastics were then loaded using training intraoral elastics (100 g) for two weeks. Then, heavy extraoral elastics 3/8 in diameter, 250-300 gram per quadrant were loaded for two months. Then, 5/16 elastics were loaded.

The operator instructed the patients to wear a face mask for at least 16 hours a day. In the first month, patients were revised once biweekly and then once a month until the end of treatment. Patients were instructed to make contact in emergencies, including screw loosening, plate mobility, pain, swelling, and other problems.

Follow-up Periods

Patients were asked to attend a follow-up session every four weeks to assess the following: patient compliance, stability of the appliance (the surgical miniplate), stability of the mini surgical screws, any soft tissue enlargement around the device, amount of correction achieved, and clarification of the progress to the parents and encouragement of compliance.

Retention and Appliance Removal

After correcting the anterior crossbite and obtaining a positive overjet, a complete set of records was obtained. The surgical miniplates were left after completion of treatment for six months; during this period, a chin cup was used for retention and follow-up monthly.

Pre- and post-treatment cephalometric radiographs were digitally analyzed using Facad® software. Four angular and three linear measurements were used to evaluate skeletal changes. The angular measurements included the SNA, SNB, ANB, and SNMP angles. Linear measurements included the maxillary, mandibular, and Wits lengths. The angles between the upper incisor to the SN plane and the lower incisor to the mandibular plane were used to evaluate dental changes. The changes in the H angle were used to evaluate soft tissue changes.

A sample of 5 cases was randomly selected and remeasured by two other specialists, whose measurements were tabulated and compared with the operator's measurements for interexaminer reliability. The Kappa test of the agreement was used.

Statistical Analysis

Statistical evaluation was performed using SPSS for Windows version 16.0 (SPSS Inc., Chicago, IL, USA). A paired t-test was used to evaluate skeletal, dental, and soft tissue changes from T1 to T2. The statistical significance level was set at 0.05.

RESULTS

Clinical Findings

The modified palatal plate facemask combination corrected the development of Class III malocclusion into a Class I relationship in 7.79±2.23 months by improving the soft tissue profile. In addition, the anterior and posterior dental relations were improved.

Miniplate Stability

All miniplates were placed in positions with excellent primary stability. However, during orthopedic maxillary protraction, two miniplates showed signs of mobility with little patient discomfort, and one miniplate was completely avulsed. In these patients, the clinician retightened the screws on loose miniplates and paused loading for one week. The surgical miniplates became stable again, and the orthopedic maxillary protraction resumed. The avulsed miniplate was replaced 3 weeks later in the same position. Surgical emergency screws with larger diameters of 2.3 mm and 11 mm in length were used to fix the plate in the palate, and maxillary protraction was continued after healing for 3 weeks. Self-drilling conventional screws were used as guides for the emergency screws. They were then inserted and removed, after which the emergency screw was reinserted.

Gingival Enlargement

Only one patient exhibited palatal mucosal enlargement around the palatal plate after six months of treatment. This enlargement was due to excessive plate pressure, so the arm was raised slightly to decrease the irritation and continue treatment.

Radiographic Findings

The sample of this study consisted of 16 patients aged 7-9 years. The mean age was 8.19±0.75. The average active phase of treatment (T2-T1) was accomplished within 7.22±1.89 months. Descriptive statistics of cephalometric measurements at assessment times are presented in Table 1. Measurements used in this study are illustrated in Table 2.

There was a (T2-T1) significant increase in the ANB angle of 4.50±1.28, (p<0.05) with an improvement in the Wits appraisal of 5.30±1.86, (p<0.05). Furthermore, this was associated with a (T2-T1) significant increase in SNA angle 3.13±1.52, (p<0.05) and the maxillary length 2.60±0.75 (p<0.05, Table 3). This was accompanied by an overall (T2-T1) significant posterior movement at point B, as evidenced by the decrease in the SNB angle of -1.38±1.86, (p<0.05). In contrast, mandibular length showed an insignificant decrease of -1.06±1.05, (p=0.435).

Vertically, there was a significant increase in the SN-MP angle of 1.46±1.96, (p<0.05, Table 3). Regarding dental changes, the Up1/SNP group showed a significant statistical increase of 4.56±2.25, (p<0.05), on the other hand, the low 1/MP group showed a significant statistical decrease -4.89±2.36, (p<0.05). The H angle showed a statistically significant increase 5.02±3.24, (p<0.05) (Table 3).

Table 1. Sample age and treatment duration

	n	Range	Minimum	Maximum	Mean±SD
Age	16	2	7	9	8.19±0.75
Treatment duration	16	6	4	10	7.22±1.89

SD, standard deviation

DISCUSSION

Class III malocclusion due to maxillary deficiency is one of the most common problems in orthodontics' daily practice. Skeletally anchored maxillary protraction using infra zygomatic or lateral pyriform surgical miniplates is an excellent alternative treatment with a high success rate for correcting middle face deficiency with maximum skeletal effects rather than undesirable dental effects.[2,3,9,10] The problem with this approach was that it required two surgeries, one for insertion and the other for removal of the surgical miniplates, with subsequent unavoidable pain and discomfort.[2] The technique was also sensitive because it required presurgical consultation, minimally invasive surgery, excellet postsurgical wound care, and orthodontic follow-up. Moreover, bilateral placement doubles the invasiveness, risks, and cost. Therefore, this procedure can be aggressive, particularly for growing patients.[11]

Class III treatment is more effective at an early stage of dentition development. This intervention maximizes the skeletal adaptation that occurs in the mid-facial region during cervical maturity stages 1 and 2, with more opening of the circummaxillary sutures.[12] The sample inclusion criteria included only patients with early mixed dentition with cervical maturity stage 1-2 mean ages of 8.19±0.75.

Table 2. Definition of linear and angular measurements

Measurement	Definition
SNA	The angle between the anterior cranial base and the NA plane
SNB	The angle between the anterior cranial base and the NB plane
ANB	SNA minus SNB (skeletal relationship in the midsagittal plane)
Mand. length	It is the distance between points Co and Gn
Maxillary length	It is the distance between points Co and A
SN/MP	The angle between the anterior cranial base SN and the mandibular plane Go Gn
Wits app.	The distance between the vertical projections of A point and B point on the occlusal plane
Up1/SNP	The angle between the long axis of the maxillary central incisor and the anterior cranial base SN plane
Low1/MP	The angle between the long axis of the maxillary central incisor and the mandibular plane Go Gn
H angle	The angle between the facial plane (N"-Pog") and the H line (Pog"-Ls)

Table 3. Linear and angular measurements

Parameter	T1 Mean±SD	T2 Mean±SD	T2-T1	p-value
SNA	77.14±2.95	80.27±3.34	3.13±1.52	0.000*
SNB	80.45±2.88	79.07±3.84	-1.38±1.86	0.010*
ANB	-3.3±1.32	1.18±1.97	4.50±1.28	0.000*
Mand. length	100.16±7.60	99.09±4.99	-1.06±1.05	0.435
Maxillary length	74.11±4.24	76.71±3.77	2.60±0.75	0.044*
SN/MP	35.13±6.57	36.58±7.13	1.46±1.96	0.009*
Wits app.	-7.69±3.19	-2.41±2.24	5.30±1.86	0.000*
Up1/SNP	106.13±5.45	110.69±7.51	4.56±2.25	0.015*
Low1/MP	87.52±7.19	82.63±5.80	-4.89±2.36	0.003*
H angle	9.15±4.36	14.17±2.3	5.02±3.24	0.000*

p: p-value for t-test for comparing between before and after treatment; *: Statistically significant at p≤0.05; SD, standard deviation

The palate provided an excellent area for TADs insertion due to the thick keratinized masticatory mucosa, high accessibility, and reduced risk of root damage.[13] Moreover, it provided easy access and minimal pain, was minimally invasive as a flapless technique was used for insertion, and had a high success rate.[11] Using finite element analysis, it was found that the miniplates that were anchored palatally distributed force over the circum-maxillary sutures more evenly than the buccally anchored miniplates.[11]

Several studies[6,7] have evaluated palatal bone thickness and quality, and it was found that the thickness and density of the palatal bone are age- and sex-specific. The highest quality and density of the palatal bone were found in adults rather than in children and men. The palatal bone thickness was also the thickest in the anterior palatal area.[14] The anterior palatal area is a 10-mm high rectangular area and 20 mm-wide. The anterior boundary is an imaginary line extending 10 mm posterior to the incisive papilla, while the posterior border is 10 mm distal to the anterior line.[15] The thickness of the palatal mucosa also contributes to the success of palatal TADs. Maximum primary stability can be achieved when an adequate length of the orthodontic miniscrew is placed in areas of thinner soft tissues and thicker cortical bone.[16] The palatal mucosa provides keratinized masticatory mucosa that is firmly adherent to the underlying bone and can withstand the forces applied to it.[6,7] The thickness of the palatal mucosa is variable; it is thinnest at the midline and increases gradually laterally. The palatal mucosa also follows an anteroposterior pattern, being thin anteriorly and thicker posteriorly. Therefore, the anterior palatal region was selected for miniplate fixation in the current study. The surgical miniscrews were inserted at the angulation of the palatal bone to increase the amount of engaged bone. Increasing the length of the surgical miniscrews may provide the advantage of bicortical engagement of the palatal bone, which subsequently increases the stability of the screws.[16]

The surgical plates used in this study were mini surgical plates. These miniplates are commonly used for rigid submucosal fixation of orofacial fractures and orthognathic surgery. However, some authors used the transmucosal approach with surgical miniplates to fix fractures in the palatal and mandibular regions. The transmucosal approach minimized postoperative pain, swelling, and other surgical complications. Moreover, this approach eliminated the need for general anesthesia because it can be performed under local anesthesia.[17,18] In addition, the use of palatal plates for orthodontic purposes to enhance skeletal anchorage for maxillary molar distalization[19] and maxillary protraction[11] has also been reported.

In the current study, treatment was continued until malocclusion and a positive overjet were achieved. The palatal miniplate was left during the retention period to be ready for facemask installation in case of any relapse. Prolonged retention using a chin cup with periodic follow-up is recommended because facemask therapy does not normalize the annual rate of forward maxillary growth. Patients may resume Class III growth due to deficient maxillary growth during the follow-up period.[20]

Although the suitability of the palatal bone for supporting TADs, no previous studies have used the palatal anchorage for maxillary protraction, and only a case report[21] has been found in the literature. Most of the studies in the literature used buccally placed TADs either with an extraoral face mask[2,3,10] or intraoral Class III elastics.[22] Therefore, the findings of the current study were compared with different techniques with different points of force application and other age groups.

The protraction technique used in the current study was able to displace the maxilla forward, as evidenced by the SNA angle increase of 3.130±1.520. Furthermore, it could increase the maxillary length by 2.60±0.75 mm. This forward maxillary movement was more significant than that previously reported by a previous study,[21] who used palatal anchorage to advance the maxilla by 1.5 mm. Furthermore, the amount of forward maxillary movement obtained by the palatal anchorage in the present study was comparable to the findings of other authors[9,23] who used a buccally placed submucosal surgical miniplate facemask combination with a range of advancement between 2.83-3.42 mm. On the other hand, authors[10,22] who used more extensive surgical techniques by placing submucosal surgical miniplates posterior to the maxilla and anterior to the mandible, could provide more forward movements ranging from 4.87 to 5.81 mm. This difference may be due to the differences in the mechanics used and the age groups.

Palatally anchored maxillary protraction showed a significant increase in the vertical height of the face, as evidenced by the significant increase in the Sn/Mp angle, which caused clockwise mandibular rotation. These findings follow the findings of previous studies,[4,9,23] as the SN/MP was increased by 1.46°-2.03°. In addition, the slight-opening rotation observed in the palatally anchored facemask explains why it has more control over the SN/MP angle. This makes it a suitable treatment option for Class III horizontal growers with short faces, as the clockwise rotation observed would improve the Class III skeletal pattern with subsequent improvement in facial esthetics.

Forward maxillary displacement and backward mandibular rotation contributed to improving the anteroposterior skeletal and soft tissue patterns, as evidenced by the significant increases in the ANB angle, Wits appraisal, and H angle by 4.5°, 5.3 mm, and 5.02°, respectively. These findings were compared with those reported in previous studies[5,6,20] in which the ANB angle increased ranged from 3.08 to 5.99 and the Wits appraisal ranged from 2.87 to 7.01 mm. Several studies[24-27] have evaluated maxillary protraction using a dental-anchored maxillary expander facemask combination and found that the maxilla can be displaced by 1.5+0.75 mm in the age range between six and eleven years old, with a marked clockwise mandibular rotation of 2.3°+0.83°. The results show that the palatal plate face mask combination is the best way to treat growing Class III patients with maxillary deficiency. This is because it is a successful, non-invasive way to fix developing Class III malocclusions caused by maxillary deficiency. Moreover, this technique can be used in patients with insufficient dental support.

Despite its advantages, some undesirable dental effects of palatally anchored maxillary protraction were observed in the current study, such as protrusion of the maxillary incisors. These findings are consistent with those of Elnagar et al.,[2] except for the maxillary incisors. This discrepancy could be attributed to the difference in protraction mechanics as in the palatal-plate facemask combination. The elastics were attached between the palatal plate and facemask, passing across the incisal edges of the maxillary incisors; this might cause pressure on the maxillary incisors with subsequent proclination. Moreover, the chin pad of the facemask exerted reciprocal pressure on the mandibular incisors, with subsequent retrusion of the mandibular incisors. This unavoidable side effect of facemask therapy has been reported by all authors who used it either with skeletal[2,4,9,23] or dental anchorage.[1] On the other hand, authors[2] who used Class III elastics with skeletal anchorage did not show dental changes.

Emergency screws were used when the screw holes become too large to provide sufficient grip for the screw threads to withstand axial loads.[27] In this study, an avulsion of the palatal plate was reported in one patient. In this case, four 2.3 mm emergency screws were used in the fixation of the avulsed miniplate reported in this study.

Gingival enlargement and initial disturbance of speech were also reported. The gingival enlargement may have occurred because the surgical miniplate used in this study had no lock in its holes, as overtightening of the screws causes pressure on the palatal mucosa with subsequent gingival enlargement. The double-lock miniplate may solve this problem because it has serrations within its holes, preventing overtightening and pressing the plate against the palatal tissues.[28] The effect on speech was reversible, which may be due to the high adaptability of the tongue.

According on the findings of the present study, the palatal-plate facemask combination was a successful non-invasive method for the early correction of developing Class III malocclusions due to maxillary deficiency. Moreover, this technique can be used in patients with insufficient dental support. In addition, opening the clockwise rotation of the mandible was advantageous for horizontal growers. These changes are comparable to other invasive techniques that provide skeletal anchorage for maxillary protraction. This technique cannot be used in patients with transverse deficiency because it cannot open the mid-palatal suture. More studies are needed to obtain a deeper understanding of the skeletal and dental changes observed in the current study using three-dimensional imaging.

CONCLUSION

Based on the findings of the current study, the following conclusions were obtained:

• Palatally anchored maxillary protraction is an effective alternative treatment for developing Class III malocclusions due to maxillary deficiency.

• This technique can be used for growing patients with insufficient dental support.

• This technique is not recommended for patients with transversal deficiency as it cannot open the mid-palatal suture.

Ethics

Ethics Committee Approval: The Tanta University Faculty of Dentistry Research Ethics Committee approved the study protocol (approval no.: #R-ORTH-11-17-1, date: on April 2022).

Informed Consent: In addition, written informed consent was obtained from all participants, considering the guidelines for human research adopted by the Research Ethics Committee.

Author Contributions: Concept - M.A.E., S.A.G., E.E.-S.; Design - M.A.E., S.A.G., E.E.-S.; Data Collection and/or Processing - M.A.E., S.A.G., E.E.-S.; Analysis and/or Interpretation - M.A.E., S.A.G., E.E.-S.; Literature Review - M.A.E., S.A.G., E.E.-S.; Writing - M.A.E., S.A.G., E.E.-S.

Conflict of Interest: The authors have no conflicts of interest to declare.

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Original Article

Evaluation of the Effects of Orthopedic Treatment on the Dentofacial Structure and Upper Airway of Subjects with Skeletal Class III Malocclusion

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Main Points

- In Class 3 anomalies with maxillary retrusion, ensuring early sagittal development of the maxilla has very positive effects on the upper airway.
- In skeletal treatments, airway evaluation before and after treatment, based on records obtained from the patient, is a crucial aspect that should not be ignored.
- Although there are many methods for airway measurement, it is important to choose a non-invasive and reliable method.

ABSTRACT

Objective: The present study aimed to evaluate the effect of rapid maxillary expansion (RME) and face mask treatment on the upper airway in patients with maxillary retrusion in two dimensions using digital cephalograms and volumetric evaluation using acoustic rhinometric measurements.

Methods: A total of 22 individuals with a concave profile and skeletal and dental Class III malocclusion during growth and development with a mean age of 9.9±1.38 years were included in the study. A bonded RME appliance and a petit face mask were adapted for the patients. Before treatment (T0) and after maxillary protraction (T1), lateral cephalometric films and acoustic rhinometric recordings were obtained. The dependent sample t-test was used for statistical evaluation.

Results: Cephalometric analysis revealed forward movement of the maxilla and backward downward rotation of the mandible. A significant increase was observed in the nasopharyngeal and oropharyngeal regions of the upper airway. Three-dimensional evaluation of the upper airway by acoustic rhinometry revealed only an increase in the volumes of the left nasal cavity after decongestant administration. A statistically significant increase in acoustic rhinometric measurements in nasal valves. When the correlation of the cephalometric findings of the nasopharyngeal region with the acoustic rhinometry findings was examined, no statistically significant relationship was found.

Conclusion: As a result of this study, we observed an increase in the cephalometric measurements of the nasopharyngeal and oropharyngeal areas. A significant increase was observed in the minimal cross-sectional area measured by acoustic rhinometry.

Keywords: Class III malocclusion, face mask, rapid maxillary expansion, upper airways

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INTRODUCTION

Skeletal Class III malocclusions are among the most difficult irregularities to correct in orthodontic treatment. These cases often present with skeletal features such as maxillary retrusion, mandibular protrusion, or a combination of both conditions.[1] When deciding on the treatment of Class III malocclusion, several factors, including age and various skeletal and dental characteristics, should be considered. Treatment options for patients with completed growth potential are limited to fixed orthodontic mechanics and camouflage,[2] or orthognathic surgery.[3] In the treatment of growing patients, orthopedic forces can effectively address skeletal problems through the use of functional appliances or extraoral appliances.[4-6] In order to stimulate the maxilla in the sagittal direction during growth and development, a face mask[4] can be used in patients with skeletal Class III malocclusion with mild or moderate maxillary retrusion.

In cases where there is maxillary retrusion in Class III patients, when orthopedic forces are applied to the maxilla with rapid maxillary expansion (RME) during the prepubertal and pubertal period, cellular activation in the sutures between the maxilla and the skull is increased, bone apposition is stimulated, and thus the growth of the relevant bones can be modified.[7-9] RME brings about significant changes in the craniofacial structures, such as increased intermolar width and nasal cavity volume, decreased nasal airway resistance, and increased nasal respiration.[10,11] It has been reported in the literature that the incidence of airway obstruction is increased especially in skeletal Class III individuals characterized by maxillary retrusion.[12] Nasal obstruction in children is believed to have a negative impact on orofacial development. Studies have pointed out that long face syndrome, maxillary stenosis, high palate, various anterior teeth, and lip structure disorders are encountered with nasal obstruction.[10,11,13] It has been suggested that the early development of the maxilla in the sagittal direction with face mask treatment positively affects the upper airway.[14]

Many different methods, such as lateral cephalometry,[15] computed tomography (CT),[16] magnetic resonance imaging (MRI),[17] and acoustic rhinometry (AR)[18] are used for the evaluation of the upper airway. The method should ideally be inexpensive and non-invasive, providing high-resolution information about the anatomy of the upper airways and surrounding soft tissues.

AR is an efficient, painless, non-invasive, and reliable method that can be performed easily and requires minimal patient cooperation. AR provides valuable information about the minimal cross-sectional area (MCA) and volume of the nasal cavity by using reflected sound waves. The size of the reflections may reflect changes in airway size, and the return time may provide the distance between the changes.[10,18]

The purpose of our prospective study was to evaluate the effect of RPE face mask treatment on the upper airways volumetrically using AR measurements. In addition, the changes caused by the RPE protocol in the MCAs of the nose, which is the narrowest part of the nose, were examined. In this study, the null hypothesis was that there would be no change in the volumetric measurements made with AR in the upper airways of patients who were wearing face masks.

METHODS

This prospective study included 22 patients with a concave profile and skeletal and dental Class III malocclusion who were referred to the Hacettepe University Faculty of Dentistry, Department of Orthodontics for treatment. All subjects (11 female and 11 male) were in the period of pubertal growth spurt, and their mean chronological age was 9.9±1.38 years at the beginning of the treatment. Developmental stages of the subjects were determined using hand-wrist radiographs.

The inclusion criteria for the patients were as follows; (1) patients with no systemic disease and congenital anomalies in the craniofacial region, (2) patients with an edge-to-edge relationship between incisors and who had not previously received orthodontic treatment, (3) patients with a concave profile during growth and development, (4) patients who had a skeletal and dental Class III relationship due to maxillary retrusion or mild mandibular protrusion with maxillary retrusion, (5) patients with negative overjet, mild narrow maxilla, or crossbite in the maxillary posterior region, and (6) no pathology found in the otolaryngology examination.

The ethics committee report dated 18.05.2010 (registration number: LUT 10/25 and decision number: LUT 10/25-7) was received by the Scientific Research Commission of Hacettepe University. A child information form and informed consent from parents were obtained from all patients.

Before starting treatment (T0) and after the completion of maxillary protraction (T1), the following records were obtained from the patients; intraoral and extraoral photographs, lateral cephalometric radiographs, hand-wrist radiographs, conventional maxillary occlusal radiographs, and acoustic rhinometric measurements.

Lateral cephalometric radiographs were obtained using a digital cephalometric X-ray device (Soredex, PO Box 148, 04301 Tuusula, Finland) under standard conditions with the teeth occlusion and the lips closed without tension. Patients were asked to look into the mirror of their own eyes after tilting their head up and down with decreasing amplitude until they felt relaxed. Acoustic rhinometric measurements were performed using an Ecco Vision AR device (Ecco Vision, Hood Instruments, Pembroke, MA) at Hacettepe University Faculty of Medicine, Department of Otorhinolaryngology.

A bonded RME appliance with a Hyrax screw (Dentsplay, GAC International, Bohemia, NY, USA) was used for the maxillary plaster models prepared in the laboratory (Figure 1). In order to facilitate the protrusion of the maxilla by creating mobilization

in the circummaxillary sutures, the modified Alt- RAMEC protocol was applied with the RME appliance.[19] The patients were asked to turn the appliance screw one-quarter turn a day for the first week. After completing the opening process for 2 weeks, the screw was closed by turning it one -quarter turn per day for 2 weeks. Occlusal film was taken from the patients to assess any separation in the maxillary median suture at the end of the first week following the opening of the screw. This protocol was repeated by opening the appliance screw in the same way for 2 weeks and closing it for 2 weeks. Thus, a total of 8 weeks were required to open and close the RME appliance screw every 2 weeks. In patients with a narrow maxilla, the protocol was terminated by opening the screw.

A bonded RME appliance and a Petit-type face mask (Dentsplay, GAC International, Bohemia, NY, USA) were adapted for the patients. A 200-g force per side was applied on the maxilla via 3/16-inch 4-oz elastics from the hooks placed distal to the canines (Dentsplay, GAC International, Bohemia, NY, USA). Two weeks later, the force was increased to 400 g per side.

After maxillary protrusion was achieved, post-treatment records (T1) were obtained, and orthodontic treatment was continued by following the dentition. The mean time between the T0 (beginning of treatment) and T1 (post-maxillary protraction) periods was 8.9±0.85 months.

Hard and soft tissue measurements and upper airway measurements were made by the same investigator (H.K.) on the lateral cephalometric radiographs obtained at T0 and T1. The planes and measured distances used for changes in the upper airway, as well as measurements to assess dentofacial changes, are shown in Figure 2.

Acoustic rhinometric measurements were performed at Hacettepe University Faculty of Medicine, Department of Otorhinolaryngology, by the same researcher (T.S.) using the EccoVision AR device. AR measurements were performed in a quiet room away from environmental influences. The patient was seated on a chair to support his/her head, and breathing exercises were performed before the measurement. At the same time, the wave tube of the AR device was calibrated before each measurement. During the measurements, the patients were asked to breathe deeply and hold their breath. After AR measurements were made at the right and left nasal cavity entrances, a nasal spray containing oxymetazoline (Oksinazal Spray, Eczacıbaşı İlaç Pazarlama, Turkey) that eliminated mucosal edema was administered as 2 puffs in both nostrils of the patients. After waiting for 15 min, the measurements were performed once more. The same procedures were repeated after the completion of maxillary protrusion.

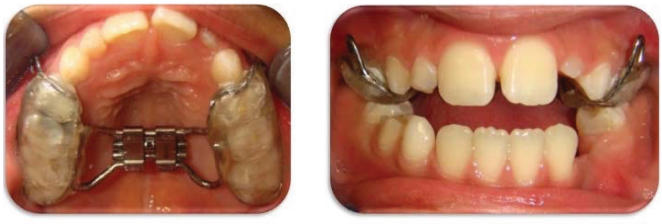

Figure 1. Occlusal and frontal intraoral views of the Bonded RME appliances

RME, rapid maxillary expansion

In the acoustic sinogram, the "y" axis shows the cross-sectional area (cm^2), while the "x" axis shows the distance from the nostril. The area under this section is the volume (cm^3). The horizontal segment before the 0^{th} point on the acoustic sinogram represents the nasal adapter. The MCA values in the acoustic sinogram and the volumes of the sections 10-30 mm, 30-60 mm, and 65-85 mm from the nasal cavity entrance were calculated (Figure 3). These regions were selected because they represent three clinically important and functionally relevant areas: the volume of the segment located from 10 to 30 mm from the nostril corresponding to the nasal valve region, the volume of the segment located between 30 and 60 mm from the nostril corresponding to the turbinate region, and the volume of the segment located between 65 and 85 mm from the nostril corresponding to the nasopharyngeal region.

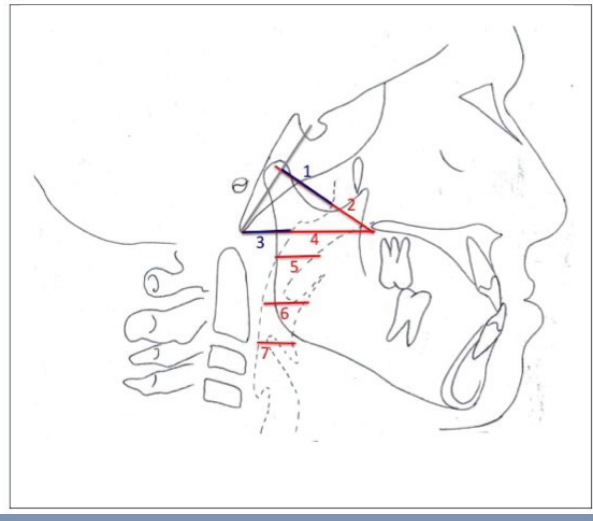

Figure 2. Planes used in airway evaluation in lateral cephalometric film analysis

1. AD2-H (upper adenoid thickness), 2. PNS-AD2 (upper airway distance), 3. AD1-BA (lower adenoid thickness), 4. PNS-AD1 (lower airway thickness), 5. SPS (superior pharyngeal space): anteroposterior width of the pharynx measured between the posterior pharyngeal wall and the dorsum of the soft palate on a line parallel to the Frankfort horizontal (FH) plane that runs through the middle of a line from PNS to pogonion (P), 6. MPS (middle pharyngeal space): anteroposterior width of the pharynx measured between the posterior pharyngeal wall and the dorsum of the tongue on a line parallel to the FH plane that runs through P, 7. IPS (inferior pharyngeal space): anteroposterior width of the pharynx measured between the posterior pharyngeal wall and the dorsum of the tongue on a line parallel to the FH plane that runs through C2

AD1, the point where posterior nasal spine (PNS) - basion (Ba) line intersects the posterior pharyngeal wall; AD2, the point where a line perpendicular to sella (S) - Ba plane passing through PNS intersects the posterior pharyngeal wall; H, the point where a line perpendicular to sella (S) - Ba plane passing through PNS

Statistical Analysis

To evaluate the changes from the beginning of the treatment to post-maxillary protraction, the data compliance with the assumption of normal distribution was tested using the Shapiro-Wilks goodness-of-fit test. The dependent samples t-test was used because the values showed a normal distribution. Mean, standard deviation, minimum, and maximum values are presented as descriptive statistics. For $p<0.05$, the results were considered statistically significant. Pearson's correlation coefficient was used to assess the correlation between cephalometric airway and AR volume assessments. Pearson's correlation test was also used to assess the correlation between the area and volume values of the narrowest regions of the nose in AR.

RESULTS

Significant changes were observed in all measurements of the maxilla according to the treatment protocol ($p<0.05$). A statistically significant increase of 3.14° in the SNA angle and 2.25° in the maxillary depth angle was observed ($p<0.05$). There was a statistically significant increase of 2.72 mm in A-Nperp ($p<0.05$). The convexity of the patients significantly increased, with an average of 0.3 mm ($p<0.05$) (Table 1).

Except for facial depth and the Pog-NB distance, all measurements of the mandible were statistically significant ($p<0.05$). A statistically significant decrease of 1.27° in the mean SNB angle was observed ($p<0.05$). At the end of treatment, a statistically significant increase of 2.89 mm in corpus length and 0.9 mm in SE distance was observed ($p<0.05$) (Table 1).

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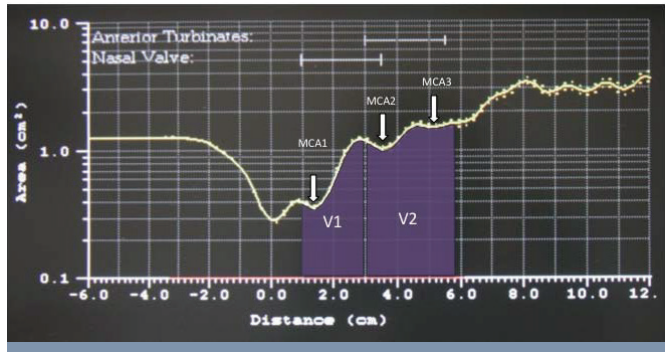

Figure 3. Acoustic rhinogram. The "y" axis shows the cross-sectional area (cm^2). The "x" axis shows the distance from the nostril. The area under this cross-section gives the volume (cm^3). The horizontal segment before the 0 point in the acoustic rhinogram represents the nasal adapter. The MCA values in the acoustic sinogram and the volumes of the sections 10-30 mm (V1), 30-60 mm (V2) from the nasal cavity entrance were calculated

MCA, minimal cross-sectional area

Table 1. Descriptive statistics and p-values for maxillary and mandibular measurements at the start of treatment (TO) and after maxillary protraction (T1)

Parameter		Average	Standard deviation	Distribution	Range	p-value
				Minimum	Maximum	
SNA (°)	T0	77.77	2.86	72	83	0.000*
	T1	80.91	2.70	75	85	
Maxillary depth (°)	T0	87.16	2.76	82	93	0.002*
	T1	89.41	2.90	83	96	
A-Nperp (mm)	T0	-3.02	2.78	-8	2	0.000*
	T1	-0.3	2.70	-6	6	
Convexity (mm)	T0	-1.86	1.92	-6	1	0.000*
	T1	-1.59	1.50	-1.5	4	
SNB (°)	T0	79.43	2.90	74	84	0.000*
	T1	78.16	2.88	73	83	
Facial depth (°)	T0	88.82	2.63	83	95	0.057
	T1	87.50	2.63	83	93	
Corpus length (mm)	T0	71.59	4.35	65	82	0.002*
	T1	74.48	4.68	64	85	0.171
Pog-NB distance (mm)	T0	0.68	1.07	-5	4	
	T1	0.90	1.25	-1.5	4.5	0.012*
SE distance (mm)	T0	17.30	2.28	13	22	
	T1	18.20	2.54	13	23	

*p<0.05

Regarding the cephalometric values of the upper airway, all measurements except the AD1-Ba (lower adenoid thickness) and AD2-H (upper adenoid thickness) distances showed statistically significant increases (p<0.05). The PNS-AD1 (lower airway thickness) distance showed a statistically significant increase with an average of 3.75 mm (p<0.05). A statistically significant increase of 2.59 mm was also observed in the PNS-AD2 (upper airway thickness) distance (p<0.05). The superior pharyngeal space SPS), middle pharyngeal space (MPS), and nferior pharyngeal space (IPS) distances, showing the pharyngeal airway dimensions, also showed statistically significant increases. SPS increased by an average of 2.55 mm, MPS by an average of 2.32 mm and IPS by an average of 1.68 mm (p<0.05) (Table 2).

When the volume values of the upper airwat measured using AR were examined, statistically significant changes were observed only in the volume values of the left nasal cavity after decongestant administration. The post-decongestant volumes of 10-30 mm sections of the left nasal cavity showed a statistically significant increase of 0.9 mm^3 on average (p<0.05). A statistically significant increase of 1.33 mm^3 was observed in the section volumes of 30-60 mm of the left nasal cavity after decongestant administration (p<0.05) (Table 3). No correlation was found between the volume values measured by AR in the nasopharynx (65-85 mm part of the upper airway) and the cephalometric measurements (p<0.01, p<0.05) (Table 4).

In acoustic rhinometric measurements, the MCAs in the narrowest part of the nasal cavity (nasal valve) showed a statistically significant increase, except for pre-decongestant measurements of the right side of the nasal cavity. A significant increase of 0.16 cm^2 was observed in the narrowest MCA on the right side of the nasal cavity after decongestant administration (p<0.05). The MCA of the nasal valve region on the left side of the nasal cavity increased significantly by 0.21 cm^2 before and 0.25 cm^2 after decongestant administration (p<0.05) (Table 5).

Table 2. Descriptive statistics and p-values of upper airway cephalometric measurements (mm) at the start of treatment (T0) and after maxillary protraction (T1)

Parameter		Average	Standard deviation	Distrubution	Range	p-value
				Minimum	Maximum	
PNS-AD1	T0	16.82	6.68	2	27	0.000*
	T1	20.57	5.70	4	28	
PNS-AD2	T0	13.64	4.26	7	23	0.000*
	T1	16.32	3.87	9	24	
AD1-Ba	T0	21.20	4.16	14	32	0.833
	T1	21.32	4.13	15	35	
AD2-H	T0	21.68	3.25	15	28	0.880
	T1	21.59	3.29	14	30	
SPS	T0	9.70	2.33	4	13	0.000*
	T1	12.25	2.40	5	17	
MPS	T0	13.77	3.11	10	20	0.045*
	T1	16.09	4.85	8	26	
IPS	T0	9.59	2.99	5	17	0.046*
	T1	11.27	4.08	6	20	

*p<0.05
SPS, superior pharyngeal space; MPS, middle pharyngeal space; IPS, inferior pharyngeal space; PNS-AD1, lower airway thickness; PNS-AD2, upper airway distance; AD1-BA, lower adenoid thickness; AD2-H, upper adenoid thickness

Table 3. Descriptive statistics and p-values of pre-decongestant (DE) and post-decongestant (DS) volume values (mm^3) for the right and left nasal cavity at the start of treatment (T0) and after maxillary protraction (T1)

Parameter			Average	Standard deviation	Distrubution	Range	p-value
					Minimum	Maximum	
Right Nasal Cavity	10-30 mm DE	T0	3.49	0.87	1.6	5	0.109
		T1	3.13	0.75	1.6	4.7	
	10-30 mm DS	T0	3.57	1.01	0.4	4.9	0.185
		T1	3.93	0.77	2	5	
	30-60 mm DE	T0	6.75	1.36	3.9	9.4	0.156
		T1	6.12	1.51	2.5	8.2	
	30-60 mm DS	T0	6.73	1.72	1.9	9.3	0.426
		T1	7.17	1.78	2.8	9.4	

Table 3. Continued

Parameter			Average	Standard deviation	Distrubution	Range	p-value
					Minimum	Maximum	
	65-85 mm DE	T0	5.75	1.05	3	8	0.197
		T1	5.2	1.50	2.6	7.9	
	65-85 mm DS	T0	5.48	1.41	2.6	7.8	0.570
		T1	5.78	1.97	2.3	8.4	
	10-30 mm DE	T0	3.05	1.05	1.1	4.8	0.111
		T1	3.48	0.62	2.6	4.8	
Left	10-30 mm DS	T0	3.1	0.63	1.8	4.4	0.000*
		T1	4	0.71	2.7	5.5	
Nasal	30-60 mm DE	T0	5.9	1.95	1.9	8.3	
		T1	6.6	1.15	4.4	8.2	0.203
Cavity	30-60 mm DS	T0	6.4	1.39	3.4	8.5	0.024*
		T1	7.73	2.04	3	12.3	
	65-85 mm DE	T0	4.8	1.5	2	7	0.169
		T1	5.39	1.18	3.4	7.8	
	65-85 mm DS	T0	4.8	0.99	3.2	7.1	0.077
		T1	5.63	1.66	2	8.4	

*p<0.05

Table 4. Correlation coefficients and p-values of the correlation of nasopharynx pre-decongestant (DE) and post-decongestant (DS) acoustic rhinometric volume values (65-85 mm) and cephalometric values (PNS-AD1, PNS-AD2)

		65-85 mm DE right T1	65-85 mm DE left T1	65-85 mm DS right T1	65-85 mm DS left T1
PNS-AD1 T1	r	0.312	0.227	0.345	0.053
	p	0.158	0.310	0.115	0.813
PNS-AD2 T1	r	0.372	0.206	0.028	-0.197
	p	0.088	0.357	0.902	0.380

Table 5. Descriptive statistics and p values of pre-decongestant (DE) and post-decongestant (DS) minimal cross-sectional area (MCA) (cm) values for the right and left nasal cavity at the start of treatment (T0) and after protraction (T1)

Parameter			Average	Standard deviation	Distribution	Range	p-value
					Minimum	Maximum	
	DE	T0	0.66	0.18	0.3	1	0.401
Right MCA		T1	0.7	0.18	0.3	1	
	DS	T0	0.68	0.19	0.2	1	0.012*
		T1	0.84	0.26	0.1	1.2	
		T0	0.59	0.21	0.2	0.9	0.001*
Left MCA	DE	T1	0.8	0.15	0.5	1.2	
	DS	T0	0.67	0.16	0.3	1	0.000*
		T1	0.92	0.18	0.5	1.2	

*p<0.05
MCA, minimal cross-sectional area

When the correlation between the MCAs and volumetric sections (10-30 mm) of the nasal valve region pre-decongestant (DE) and post-decongestant (DS) values was examined, there was a correlation between the right and left volumes and MCAs before decongestant (p<0.01, p<0.05). Likewise, a correlation was found between the volume and area values in the left part of the nasal cavity after decongestant administration (p<0.01, p<0.05) (Table 6).

Table 6. Correlation coefficients and p-values of the correlation of minimal cross-sectional areas (MCA) and volumetric sections (10-30 mm), pre-decongestant (DE) and post-decongestant (DS) values of the nasal valve region

		10-30 mm DE Right T1	10-30 mm DE Left T1	10-30 mm DS Right T1	10-30 mm DS Left T1
Right MCA DE T1	r	0.820**	0.034	0.339	-0.073
	p	0.000	0.882	0.123	0.747
Right MCA DS T1	r	0.523	-0.045	0.328	-0.009
	p	0.012	0.841	0.136	0.969
Left MCA DE T1	r	0.458*	0.472*	0.062	0.042
	p	0.032	0.027	0.783	0.851
Left MCA DS T1	r	0.408	0.248	0.250	0.601**
	p	0.059	0.265	0.261	0.003

*p<0.05, **p<0.01
MCA, minimal cross-sectional area

DISCUSSION

Skeletal Class III malocclusions result from maxillary retrusion in 65-67% of cases.[3] In this study, sagittal forward movement of the maxilla was achieved, in line with other face mask studies in the literature.[20,21] This significant forward movement in the maxilla can be attributed to the fact that the patients were in their growth and development period, as well as to the separation of the sutures made by the adjacent bones of the maxilla using the AltRAMEC protocol.

It has been reported that the mandible is displaced downward and backward as a result of the force passing under the condylar region in face mask applications that receive support from the chin tip and forehead.[22] Angular and dimensional measurements of the mandible used in the present study showed that the mandible rotated downward and backward in accordance with the literature.[21,22] The rotation observed in the mandible also contributed to Class III correction.

When the effects of the present treatment protocol on the upper airway were evaluated cephalometrically, significant increases were determined in the nasopharyngeal and oropharyngeal airway dimensions, in line with the literature.[23,24] It is thought that the increase detected cephalometrically in the upper airway was due to the increase in the distance between the posterior part of the maxilla and the posterior pharyngeal wall during the anterior movement of the maxilla. Even though the cephalometric films used in the present study to determine the changes in the airway provide information in two dimensions, this method, which is used in many studies, is advantageous due to its ease of application and low cost.[14,25] In addition, it has been stated that there is a significant relationship between cephalometric films and CT imaging techniques.[26]

Studies in the literature have evaluated nasal volumes in adults[27] and nasopharyngeal geometry after adenoidectomy and tonsillectomy[28] using AR. However, no study has evaluated the changes in the upper airway as a result of applying a face mask with a bonded RME appliance volumetrically using AR. In the present study, statistically significant increases were observed in the volumes of the 10-30 mm (nasal valve) and 30-60 mm sections of the left nasal cavity after decongestant administration. Nasal decongestants are recommended for precise measurement of nasal resistance. These medications work by constricting blood vessels in the nasal passages, thereby reducing swelling and congestion. The temporary opening of the nasal airway allows for more accurate measurements of nasal resistance.[29] It is thought that this increase in nasal volume may have been obtained by applying RME in parallel with other studies in the literature.[14,15]

When we examined the relationship between the results of increased nasopharynx size in the cephalometric measurements and the volume findings in AR, no correlation was found. The lack of correlation between the increase detected cephalometrically and AR may be due to disturbances during the measurement of the nasopharynx volume caused by the movement of the soft palate. It is also stated that the MCAs of the nose and nasal passage are the two most important factors affecting the accuracy of AR measurements and that AR cannot provide reliable information for evaluating the posterior parts of the nasal cavity.[30,31]

The MCA, often called the "nasal valve", is an important formation located between the nasal cartilage and aperture pyriformis and is the narrowest point of the nasal cavity. This area has a significant effect on nasal breathing because of its narrowed structure.[31,32] In the study of Cakmak et al.,[32] it was determined that there was a significant correlation between CT and AR measurements performed to evaluate nasal valve areas. It has also been reported that AR can be a valid method for evaluating the nasal valve area. Approximately 50% of the anatomical structure of the nasal cavity is formed by the maxillary bones. Therefore, treatment options that cause changes in the morphological structure of the maxillary dental arch, such as RME, may affect the geometry and function of the nasal cavity. The RME procedure provides triangular separation of the maxillary bones at the level of the incisors, which coincides with the lower part of the nasal valve area. With this separation in the midpalatal suture, displacement

also occurs in the lateral walls, leading to an increase in nasal cavity volume. In the present study, a statistically significant increase was observed in some nasal valve areas.

When we looked at the correlation between the area and volume values of the nasal valve section, which is the narrowest part of the nasal cavity, it was expected that the statistically significant volumetric and area (MCA) increases observed in the nasal valve region of the left nasal cavity (10-30 mm) would correlate with each other. Since no significant increase in volume was detected in the nasal valve area of the right nasal cavity, it can be considered that there was no correlation with the MCA after decongestant.

The airflow through the nasal passages is commonly found to be asymmetric in normal individuals. This phenomenon, known as the nasal cycle, is considered a physiological phenomenon. However, most subjects were completely unaware of any changes in nasal airflow because the total resistance to airflow remained relatively constant owing to a reciprocal relationship between the nasal passages. It has been noted that the nasal cycle may not always be detectable or may not always be reciprocal at all between the two sides of the nose.[33]

Study Limitations

Since the short-term results of maxillary expansion and protraction were examined in our study, the fact that long-term treatment results were not known and that tomographic evaluation could not be performed at the same time could be considered limitations of our study. Additionally, repeating the AR measurements after RPE application could have helped improve the evaluation of the results.

CONCLUSION

In the present study, the following results were obtained:

• While forward movement of the maxilla was evident, downward and backward movements were observed in the mandible. The soft tissue relationship showed positive development in parallel with the skeletal and dentoalveolar changes.

• In cephalometric findings of the upper airway, a significant increase in two dimensions was observed in the nasopharyngeal and oropharyngeal regions.

• In the AR evaluation of the upper airway, an increase was observed only in the post-decongestant volumes of the left nasal cavity. No statistically significant relationship was found between the cephalometric and AR findings of the nasopharyngeal region. A significant increase was observed in the MCA measured by AR.

• When we examined the correlation of the area and volumes values of the nasal valve section, which is the narrowest part of the nasal cavity, it was determined that there was a correlation between the measurements of the right and left sides before decongestant.

Ethics

Ethics Committee Approval: The ethics committee report dated 18.05.2010 (registration number LUT 10/25 and decision number LUT 10/25-7) was received by the Scientific Research Commission of Hacettepe University.

Informed Consent: A child information form and informed consent from parents were obtained from all patients.

Author Contributions: Concept - S.C., O.Ö.; Design - S.C., O.Ö.; Data Collection - H.K., Analysis - H.K., T.S. - Writing - H.K.

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Original Article

Evaluation of the Effects of TENS Therapy and Acetaminophen on Pain Alleviation in Initial Orthodontic Treatment

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Main Points

- Pain associated with initial archwire alignment during orthodontic treatment can be managed with Transcutaneous Electric Nerve Stimulation (TENS) therapy.
- Both acetaminophen and TENS equally relieve pain in fixed orthodontic treatment.
- Repeated application of TENS can improve pain management better than acetaminophen.

ABSTRACT

Objective: This prospective study aimed to evaluate the analgesic effects of acetaminophen and Transcutaneous Electric Nerve Stimulation (TENS) therapy for pain control.

Methods: Forty orthodontic patients who underwent fixed orthodontic treatment were randomly assigned to one of 3 groups: (1) acetaminophen, (2) TENS therapy, or (3) control. Pain was evaluated at 12, 24, 36, and 48 hours after the placement of both 0.014" NiTi and 0.016" NiTi archwires using a 10 cm visual analogue scale (VAS). Because the data were found to be non-normal, Kruskal-Wallis test was employed for both stage I and stage II intra-group comparisons.

Results: For both stage I and stage II, evaluation of the VAS scores for all 3 groups at different time intervals showed that the difference between groups A and B was statistically insignificant ($p>0.05$). The scores of Group A compared to Group C were significant, and Group B compared to Group C showed significant values.

Conclusion: Both TENS and acetaminophen reduced the pain experienced by patients compared with the placebo group. The acetaminophen group showed VAS results similar to those of the TENS group.

Keywords: Acetaminophen, orthodontic, pain, transcutaneous electric nerve stimulation, visual analogue scale

INTRODUCTION

The most commonly reported sequelae of orthodontic treatment that affect quality of life are pain and discomfort. Several studies have found that the pain associated with an initial aligning archwire is perceived after 4 hours, is significantly more intense at the 24th hour, and later decreases by the 3rd day, lasting approximately 5 days.[1-6]

To overcome the post-adjustment pain and discomfort associated with the initial alignment of archwires and separator placements, many authors have suggested various modalities. Chumbley and Tuncay[7], in their study, used pharmacologic means of analgesia, such as indomethacin, a non-steroidal anti-inflammatory drug

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(NSAID), to reduce discomfort and pain after orthodontic adjustment. They concluded that indomethacin was effective in reducing pain; however, it had a detrimental effect on the rate of orthodontic tooth movement. Kehoe et al.[8] investigated the deleterious effect of NSAIDs on the rate of orthodontic tooth movement and recommended acetaminophen as the analgesic of choice during orthodontic treatment.

Further, it was found that Transcutaneous Electric Nerve Stimulation (TENS), a non-invasive, non-pharmacological therapy, has been reported to be efficient for pain alleviation during separator placement and debonding procedures.[9,10]

Prolonged analgesia induced by TENS is attributed to the secretion of endogenous opioids. Endorphins have long-lasting effects on the central nervous system; thus, TENS-produced analgesia persists for hours even after the cessation of electrical stimulation. The secreted opioids produce analgesia at peripheral, spinal, and supraspinal sites. Other neurochemicals have also been found to be responsible for producing TENS-induces analgesia, including GABA, acetylcholine, 5-HT, noradrenaline, and adenosine.[11] Maximum analgesia is produced when TENS generates a strong, non-noxious electrical sensation beneath the electrodes. The onset of pain relief is rapid and disappears shortly after TENS is turned off.[11]

In clinical practice, TENS therapy is mostly used to relieve pain. In addition, there is an increasing use of TENS in other spheres of medicine like antiemetics and for restoration of blood flow to ischemic tissue and wounds.[12] However, limited research is available on the role of TENS in orthodontic patients. Hence, the present study aimed to evaluate and compare the analgesic effects of acetaminophen and TENS therapy for the control of pain during orthodontic treatment.

METHODS

The present study received ethical clearance from the Institutional Review Board of Santosh Deemed to be University (F. No. SU/2019/1531[15], date: 22.10.2019). The study was conducted at the Department of Orthodontics and Dentofacial Orthopedics, Santosh Dental College and Hospital. The subjects included in the study were patients undergoing non-extraction fixed orthodontic treatment between the ages of 13 and 35 years. Both male and female patients with permanent dentition and good oral hygiene were included.

Patients with crowding greater than 2 mm, pacemakers, patients with a known history of allergy to acetaminophen, epileptic patients, cerebrovascular problems, cleft lip, cleft palate, or both, and patients who did not provide consent for the study were excluded from the study.

The sample size was calculated using the G*Power 3.1 software (Heinrich-Heine-Universität Düsseldorf, Düsseldorf, Germany). The power of the study was considered to be 80% with a confidence interval of 95%. A total sample size of 40 patients was selected based on an old study on the effect of TENS on controlling pain associated with tooth movement.[9] Forty patients were divided into three groups randomly using an online number list generator:

Group A (n=10): Patients in Group A received TENS therapy.

Group B (n=10): Patients in this group were given acetaminophen tablets.

Group C (n=20): Patients in this group did not receive either of the following treatments: this was the control group.

All patients were pre-examined using the standard protocol, which included facial and intraoral photographs, dental modal analysis, panoramic radiography, and cephalometric analysis.

Patients were enrolled according to the inclusion criteria, and all were treated with a 0.022" slot prescription pre-adjusted edgewise appliance system. Initial leveling and alignment of the upper and lower arches were performed using sequential NiTi wires, with the diameters of the wires progressively increased from 0.014" NiTi to 0.016" NiTi. After placement of the wires, Group A received TENS therapy for 20 minutes at 0.5 Hz and 500 microamperes (Figures 1 and 2). In Group B, patients were administered 500 mg of acetaminophen. Patients were asked to take their first dose 2 hours before the appointment and continue taking it orally every 6 hours for 48 hours. Group C was the control group, which was given nothing for pain management. Patients were asked to mark their pain level using the visual analogue scale (VAS)[13] at four intervals of 12 hours for a total period of 48 hours. Patients in the TENS and control groups were asked to take the tablet with a combination of paracetamol (325 mg) and ibuprofen (400 mg) as rescue medicine in case of unbearable pain. Patients were asked to record the number of tablets they consumed. Patients who required rescue medicines were excluded from the study.

Scoring System for Pain and Discomfort

Pain and discomfort were measured during the first two days after the placement of the aligning archwire. Scores were assessed using the VAS[13] scale of 10 cm in length. Marks were made at 1-cm intervals from 0 to 10.0 on the scale. 0, no pain, and 10, unbearable pain. The score can be interpreted as follows:

Score 0: No pain.

Score 1-3: Mild pain.

Score 4-6: Moderate pain.

Score 7-10: Severe pain.

Statistical Analysis

All data were entered into an Excel spreadsheet (version 2007) and then imported into SPSS (Statistical Package for Social Sciences, version 23.0, IBM, NY, USA). After applying the Kolmogorov-Smirnov test, the data showed a non-normal

distribution, so they were expressed as median ± interquartile range. The Kruskal-Wallis test was employed at both stage I and stage II for inter-group comparisons. A two-tailed p-value <0.05 was considered significant. The reliability of the study was calculated as 0.736 using Cronbach's alpha.

RESULTS

The mean ages of the participants in groups A, B, and group C were around 20.10±4.654, 19.60±4.858, and 20.80±5.126 years, respectively (Table 1). Upon examination, the median VAS scores in stage I (0.014" NiTi) for group A were 2.5±1.0, 3.5±1.0, 4.0±1.0, and 3.0±1.0 at 12, 24, 36, and 48 hours, respectively.

Figure 1. Transcutaneous electrical nerve stimulation machine with surface electrodes

Figure 2. Patient receiving TENS therapy demonstrating electrode placement on the left side

The median VAS scores for group B were 2.0±1.0, 4.0±1.0, 3.0±1.0, and 3.0±1.0 at 12, 24, 36, and 48 hours, respectively. On the other hand, the median VAS scores for group C were 7.0±1.0, 7.0±1.5, 6.0±1.0, and 5.0±1.0 at 12, 24, 36, and 48 hours, respectively. All readings were found to be highly significant (Table 2).

In stage II (0.016" NiTi), the median VAS scores for group A were 2.0±1.0, 3.0±1.0, 3.0±1.0, and 3.0±0.0 at 12, 24, 36, and 48 hours, respectively. The median VAS scores for group B were 3.0±1.0, 3.5±1.0, 3.0±0.0, and 2.0±1.0 at 12, 24, 36, and 48 hours, respectively. On the other hand, the median VAS scores for group C were 6.0±1.5, 6.0± 1.0, 5.0±1.0, and 5.0±1.0 at 12, 24, 36, and 48 hours, respectively. All readings were found to be highly significant (Table 3).

In stage I, when the VAS scores for all three groups were compared at different time intervals, the scores of Group A and Group B were comparable, and the difference between the two was statistically insignificant (p>0.05, Kruskal-Wallis test). The scores of Group A compared to Group C were highly significant for 12 and 24 hours and significant for 48 hours. The VAS scores of Group B compared to Group C showed highly significant values for all time intervals (Table 4).

Similar results were observed in stage II. The scores of groups A and B were comparable, and the difference between the two was statistically insignificant (p>0.05, Kruskal-Wallis test). The scores of Group A compared to Group C and Group B compared to Group C showed highly significant values (Table 5).

DISCUSSION

In any dental treatment, including orthodontics, besides a positive treatment outcome, the most important aspect of the treatment is the management or elimination of pain, which can often be experienced by patients. In Orthodontics, tooth pain is often experienced by patients. Oliver and Knapman[12] surveyed two centers to investigate the attitudes of patients and parents undergoing orthodontic therapy. The results revealed that both patients and parents were happy with the treatment outcome. However, pain related to the appliance and its appearance was the main discouraging factor.[1]

Pain is experienced by patients during nearly all phases of orthodontic treatment. One of the first experiences of pain

Table 1. Age distribution in all 3 groups

Group	Number of participants	Mean age (Years)	95% Confidence interval for mean	
			Lower bound	Upper bound
A (TENS)	10	20.10±4.654	16.77	23.43
B (Acetaminophen)	10	19.60±4.858	16.12	23.08
C (Control)	20	20.80±5.126	18.40	23.20
Total	40	20.33±4.848	18.77	21.88

and discomfort occurs immediately after the insertion of the initial aligning archwire. Erdinç and Dinçer[3] found that pain and discomfort after the insertion of initial aligning archwire during orthodontic treatment was first perceived at the 4th hour. The discomfort then increased significantly by 24 hours. The study also found that the discomfort decreased to a more bearable degree by the 3rd day.[3] Under pharmacological modalities, many analgesics, such as ibuprofen, naloxone, ketorolac, and acetaminophen, are effective for orthodontic pain control.[14] Although analgesics have been found to reduce pain and discomfort, in most cases they do not fully eliminate it. To overcome this issue, higher doses of medications have been administered, but as a result, many clinicians observed a delay in the orthodontic treatment time. NSAIDs control pain by inhibiting cyclooxygenase activity and thus retarding the production of prostaglandins.[15-17] This characterizes the involvement of prostaglandins in orthodontic tooth movement. Chumbley and Tuncay[7] conducted a study on indomethacin, an aspirin-like drug, and a potent inhibitor of PG synthesis. The study found that indomethacin delayed orthodontic tooth movement, and the authors recommended that aspirin-like drugs should not be administered to patients undergoing orthodontic tooth movement as they may extend the treatment time.[7] Kehoe et al.[8] studied the effect of acetaminophen, ibuprofen, and misoprostol on prostaglandin synthesis and orthodontic tooth movement. The study reported a significant difference in mean tooth separation among the drugs. The acetaminophen group showed the least effect on the rate of tooth movement. Thus, the authors recommended acetaminophen as the analgesic of choice during orthodontic treatment.[8] It is also believed to have fewer and rare side effects like nausea, and rashes, compared to other NSAIDs. In isolated antipyretic doses, acetaminophen is safe and well-tolerated.[18]

Although pharmacological methods are convenient and easy to use, the biggest drawbacks of these methods are allergic reactions observed in patients and side effects caused by prolonged use of the medication. It is for this reason that non-pharmacological pain control methods have piqued the interest of many clinicians and patients alike.

Recently, major developments have been observed in the understanding of pain mechanisms and new approaches to the management of pain. Various methods have been developed over the years like low-level laser therapy, vibratory devices, and transcutaneous electrical nerve stimulation (TENS). One study measured pain levels over 7 days and concluded that TENS was effective in reducing pain associated with separator placement. It is also worth noting that a single application of TENS produced a satisfactory analgesic effect for the entire duration of the study.[9]

In the present study, it was planned to evaluate the effect of TENS therapy to control pain associated with initial aligning archwire insertion and further compare the effect of this non-pharmacological TENS therapy with that in subjects who were on pharmacological therapy, such as acetaminophen, to control pain associated with the insertion of the initial aligning archwire during the initial phase of orthodontic treatment. A VAS was used to evaluate the pain experienced by the patients. The VAS scale was preferred over other scales because of its simplicity; it is more understandable and easier to use by patients. The scale does not include any words; thus, it is independent of language. The VAS was found to be the most reliable method for pain assessment.[13]

Table 2. Median VAS values recorded in stage 1 (0.014" NiTi wire) in all 3 groups at different time intervals

Group	Group A (TENS)		Group B (Acetaminophen)		Group C (Control)		p-value
	Median	Interquartile range	Median	Interquartile range	Median	Interquartile range	
Time							
12 hours	2.5	1	2	1	7	1	0.00*
24 hours	3.5	1	4	1	7	1.5	0.00*
36 hours	4.0	2	3	1	6	1	0.00*
48 hours	3	1	3	1	5	1	0.00*

VAS, visual analogue scale, *p<0.05

Table 3. Median VAS values recorded in stage 2 (0.016" NiTi wire) in all 3 groups at different time intervals

Group	Group A (TENS)		B (Acetaminophen)		Group C (Control)		p-value
	Median	Interquartile range	Median	Interquartile range	Median	Interquartile range	
Time							
12 hours	2	1	3	1	6	1.5	0.00*
24 hours	3	1	3.5	1	6	1	0.00*
36 hours	3	1	3	0	5	1	0.00*
48 hours	3	0	2	1	5	1	0.00*

VAS, visual analogue scale, Kruskal-Wallis test, *p<0.05

Table 4. Difference between VAS values recorded in stage 1 (0.014" NiTi wire) in all 3 groups at different time intervals

Time interval	Group		p-value
12 hours	A	B	1.000
	A	C	0.000*
	B	C	0.000*
24 hours	A	B	1.000
	A	C	0.000*
	B	C	0.000*
36 hours	A	B	0.759
	A	C	0.016
	B	C	0.000*
48 hours	A	B	0.759
	A	C	0.001*
	B	C	0.000*

VAS, visual analogue scale, Kruskal-Wallis test, *p<0.05

Table 5. Difference between VAS values recorded in stage 2 (0.016" NiTi wire) in all 3 Groups at different time intervals

Time interval	Group		p-value
12 hours	A	B	1.000
	A	C	0.000*
	B	C	0.000*
24 hours	A	B	0.988
	A	C	0.000*
	B	C	0.000*
36 hours	A	B	0.988
	A	C	0.000*
	B	C	0.000*
48 hours	A	B	0.055
	A	C	0.000*
	B	C	0.000*

VAS, visual analogue scale, Kruskal-Wallis test, *p<0.05

Our study found that all 20 subjects in the control group who had not undergone any pain therapy experienced different intensities of pain at each time interval. Most patients experienced pain by the 12th hour after the insertion of the initial aligning archwire. Later, most subjects in the control group experienced peak pain at 24 hours. By the 2nd day, many subjects experienced moderate pain, which gradually reduced by the 3rd day after the initial alignment of the archwire. These findings are consistent with those of other studies.[2-5]

In the present study, patients receiving TENS therapy experienced significant reduction in pain from the 4th hour to the 4th day. This finding could be attributed to TENS therapy. The subjects in the acetaminophen group also showed consistently decreased pain scores at 12, 24, 36, and 48 hours after archwire placement compared with the control group. The data obtained align with the findings from a study comparing the effects of three drugs: ibuprofen, misoprostol, and acetaminophen, which concluded that acetaminophen was the drug of choice for controlling orthodontic pain.[8]

Further, acetaminophen is believed to have fewer side effects such as nausea and rashes which are rare. In isolated antipyretic doses, acetaminophen is safe and well-tolerated.[18] Finally, the main aim of this study was to compare the effects of TENS and acetaminophen. In the present study comparing the TENS and acetaminophen groups, the results showed that both acetaminophen and TENS were equally effective in reducing pain in patients undergoing orthodontic therapy.

It is worth noting that although TENS and acetaminophen were effective in reducing pain, the TENS therapy group experienced slightly more discomfort than the acetaminophen group after 24 hours. Furthermore, in the TENS group, the initial onset of analgesic effect at 12 hours was comparatively greater, the duration of pain reduction was very effective, and the mean pain scores at 24 hours were highly reduced; however, this did not occur after 24 hours. To better control pain, repeated TENS sessions can be administered on the second day; however, it requires an additional dental visit, and thus, it might be inconvenient for patients.

In the present study, we found that TENS therapy and acetaminophen were extremely effective in controlling pain and providing relief to patients during the initial phase of orthodontic treatment.

Study Limitations

The limitations of the study include the fact that blinding was not possible because of the obvious differences between the study groups. The study did not take into consideration the level of anxiety and fear of pain experienced by the participants after bonding. In addition, when investigating outcomes that are self-reported by patients, subjectivity always has the opportunity to creep in, and these obvious limitations inherently affect reliability. Further studies with larger sample sizes are recommended to compare both systems in detail. Studies have also correlated the variation of pain with age and diurnal variation of pain.

CONCLUSION

The following conclusions can be drawn from this study:

- TENS therapy can effectively control pain associated with initial archwire alignment during orthodontic treatment.
- TENS is as effective in controlling pain as acetaminophen.

Ethics

Ethics Committee Approval: The present study received ethical clearance from Institutional Review Board of Santosh Deemed to be University (F. No. SU/2019/1531[15], date: 22.10.2019).

Informed Consent: Informed consent was obtained from the patients.

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

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Original Article

Corrosion Behavior of Nickel-Titanium Arch Wires Following the Use of Different Mouthwashes: An *In Vivo* Study

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Main Points

- Mouthwashes with different active agents are generally prescribed to orthodontic patients according to their special needs.
- Mouthwashes cause an increase in surface rougness of NiTi archwires
- Soft bristle toothbrush and aloe vera toothpaste may be suggested to orthodontic patients since they did not cause significant difference in surface roughness on NiTi archwires.

ABSTRACT

Objective: The aim of this double-blind *in vivo* study was to compare the extent of corrosion on the surface of nickel-titanium (NiTi) wires in various mouthwashes.

Methods: A total of 80 patients who received orthodontic treatment with as-received 0.016x0.022 inch NiTi wires were included in the study, and they were split into 4 groups. The first group used 0.05% of (225ppm F^-) sodium fluoride (NaF) (Colgate Plax®) containing mouthwash, 21.6% alcohol (Listerine Cool Mint®) containing mouthwash, and 0.2% clorhexidine (CHX) (Klorhex®) containing mouthwash and the control group used drinking water with melt menthol as mouthwash. After 30 days of using mouthwash, the surfaces of NiTi wires were examined with atomic force microscopy (AFM), and surface roughness values were calculated.

Results: Mouthwashes containing fluoride, essential oils, and CHX created higher surface roughness on NiTi wires than the control group. The floride-containing mouthwash group showed less corrosion than the CHX group, whereas there was no difference between the essential oil group. AFM images show supportive data with the results of the clinical study. The results were assessed using a 95% confidence interval and a significance level $p<0.05$.

Conclusion: CHX, essential oil, and floride-containing mouthwashes cause corrosion of NiTi wires. Floride-containing mouthwash can be preferred over CHX mouthwash due to its lesser corrosion effect.

Keywords: Corrosion, NiTi wires, CHX, essential oil, fluoride mouthwashes

INTRODUCTION

During orthodontic therapy, wires, brackets, and bands increase the areas for plaque retention and make it harder for patients to clean their teeth efficiently.[1] As a result, the oral flora alters, resulting in a higher risk of gingivitis and caries.[2] To prevent or treat gingival disease and tooth decay, clinicians generally prescribe mouthwashes containing different active agents in accordance with the patients' needs. These active agents

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include chlorhexidine (CHX), fluoride, and essential oils. Despite their frequent use, until now, only a few *in vitro* studies have evaluated the effects of fluoride[3-5] or CHX[6] and essential oils[7] on nickel-containing arch wires.

Previous *in vitro* studies have presented potential results and conclusions but they cannot provide certain statements because they cannot reliably mimic the oral environment. The oral environment contains a variety of substances, such as saliva and acids arising from the decomposition of food. This variable medium can alter the effects of mouthwash on nickel-titanium (NiTi) wires.

The purpose of the present study was to compare the corrosion effects of mouthwashes with different active agents, such as CHX, fluoride, and essential oil, on NiTi wires by measuring the changes in surface roughness of the wires after regular mouthwash use.

METHODS

The aim of this study was explained to the participants, and informed consent was obtained before the clinical trial (registration no.: 1067). The study was approved by the Clinical Research Ethics Committee of Yeditepe University (approval no.: 62/497, date: 26.06.2015).

Sample size was calculated using G*Power (version 3.1 Franz Foul, Universitat Kiel, Germany), and the effect size was calculated to be 0.40 with an alpha value of 0.05 and a power of 80%. A total of 80 subjects (43 females and 37 males) were included in this study. These patients were treated with fixed orthodontic treatment at the Department of Orthodontics, Yeditepe University. Orthodontic appliances consisted of an average of 4 tubes, 20 bonded brackets (Mini Master Series; American Orthodontics, Sheboygan, Wisconsin, USA), and NiTi wires (G&H® wire company, Greenwood, Indiana, USA).

One hundred and twenty patients were given nutrition forms and asked to list their daily diet for seven days before participating in the study. After one week, the dietary charts of each patient were evaluated for meal and each day. Patients with a convenient diet (non-acidic and sugary snacks and drinks) were included, while 40 patients who had acidic, sugary or starch-rich eating and drinking habits were eliminated from the study. During the study period, patients were informed to avoid acidic juice, ice tea, fizzy drinks, coffee, alcohol, chocolate, and sugary snacks.

Patients were randomly assigned to four study groups of 20 patients each. Randomization was achieved by assigning patients to different groups depending on their protocol number sequence. The first group used Colgate Plax [0.05% sodium fluoride (NaF) 225ppm F^-, pH: 6.9, Colgate-Palmolive Company, ABD], the second group used Listerine Cool Mint (%21.6 alcohol, pH: 4.1, Johnson & Johnson Healthcare Products Division of McNEIL-PPC, Inc, ABD), the third group used Klorhex (0.2% clorhexidine, pH: 5.5, Drogsan), and the fourth group, serving as the control group (CG), used a placebo with water, including melt menthol. Additionally, a fifth group was formed, which consisted of unused (as-received state) archwires. Patients were instructed to use mouthwash twice a day, 20 mL for 30 seconds after brushing their teeth. Standard equipment for brushing was provided to the patients. The toothpaste used was fluoride-free and aloe vera-containing [Forever Bright® (Forever Living Products, Scottsdale, AZ; 888.440.2563)], and the toothbrush was Colgate Slim Soft (Colgate-Palmolive Company, ABD) with thin and soft bristles to minimize the risk of creating surface roughness on the arch-wire while brushing.

In the upper arch 0.016x0.022 inch NiTi archwires were ligatured with elastomeric modules to prevent galvanic or fretting corrosion. The patients were instructed to brush their teeth with the provided equipment for three days before starting the use of mouthwash. After three days, the patients began using the mouthwashes as instructed for one month. Neither the participants nor the researcher knew which mouthwash was given for use in the double-blind experiment.

After one month of mouthwash use, the areas to be evaluated were marked using a diamond drill, before retrieving the arch-wire inter-bracket spaces. The retrieved wires were first cleaned under running water to remove fats and organic debris, then dried with air spray and soft paper. The retrieved archwires were placed in self-sealed envelopes, with the name of the patient and the code number of the mouthwashes recorded.

The three-dimensional surface roughnesses (R_a) of the archwires was examined using an atomic force microscopy (AFM, XE-100, PSIA Corp. Sungnam, Korea). The AFM images were obtained in non-contact mode using a cantilever (10M-NSC15, PSIA Inc.). The scan was performed at the surface with an average scanning speed of 0.5 Hz. Images with a scan size of 10 µm x 10 µm were obtained and analyzed using the XEI image processing program (version 1.8.0, Park Systems Corp. Suwon, Korea). The surface roughness of each wire was calculated by measuring and taking the average of the surface roughness values of three different regions (R_a).

Statistical Analysis

The Statistical Package for the Social Sciences (SPSS Inc., Chicago Illinois, USA) for Windows 21.0 was used for data analysis. The average surface roughness values, namely the R_a values of the NiTi arch-wires, were compared using the one-way (ANOVA) test. Tukey's test was used for two-group comparisons.

RESULTS

Figure 1 shows the AFM analysis results for five different groups in the 3D images of the NiTi arch wires. After mouthwash use, the characteristic surface topographies were obvious for each group of NiTi arch wires. Greater surface roughness was evident for the CHX, alcohol or fluoride-containing mouthwash groups compared to the control and as-received groups. There

was a statistically significant difference in the average surface roughness differences among the groups (Table 1, p=0.000, p<0.05).

Tukey's test analysis results (Table 2) showed that R_a value of fluoride-containing mouthwash group (FG) was statistically significantly different from that of the CHX-containing mouthwash group (CXG) (p=0.07), as well as the control, and as-received groups (p=0.00). Likewise, the control and as-received groups had statistically significant differences (p=0.00) compared to the alcohol-containing mouthwash group (AG). No significant difference was observed between the alcohol-containing mouthwash and the other commercial mouthwashes. Although a considerable difference in surface roughness values between AG and CXG was observed (-12.2 nm), this difference was not statistically significant (p=0.076).

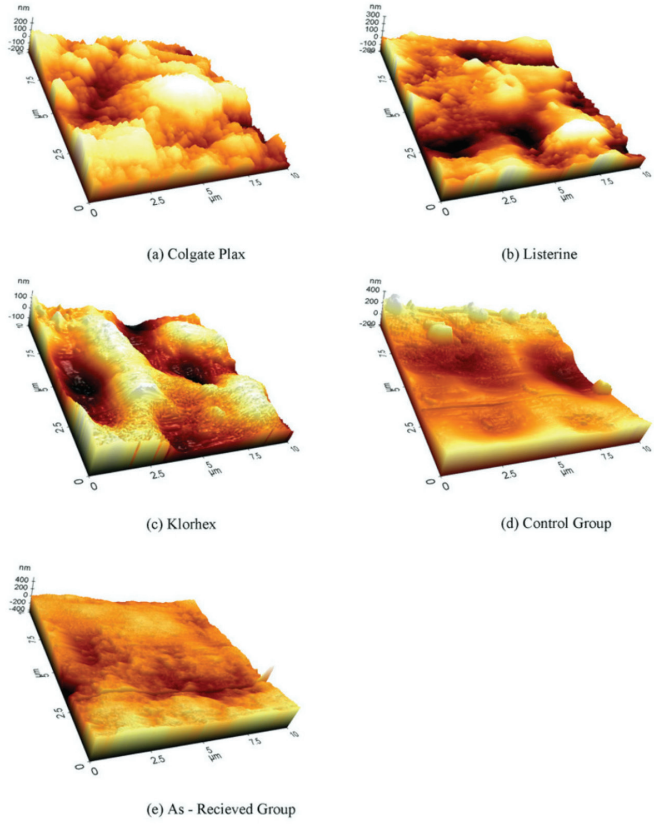

Figure 1. Atomic force three-dimensional reconstructed micrographs (10μm x 10μm)

Table 1. One-Way analysis of surface roughness differences of the NiTi arch-wires before (as-received) and after clinical mouthwash use

	Mean Ra (nm)	SD (±)	p value
Group 1 (Colgate Plax)	51.83	13.82	**0.000***
Group 2 (Listerine)	55.78	24.02	
Group 3 (Klorhex)	67.98	16.47	
Group 4 (control group)	30.47	6.77	
Group 5 (as-received)	19.37	1.42	

N: 20 Patients per group, Ra: Surface roughness (nanometer: nm), SD: Standard deviation, p<0.05

Discussion

In this *in vivo* study, the corrosion effects of different mouthwashes on NiTi wires were evaluated on the basis of previous *in vitro* studies.[3-7] For standardization, participants were selected based on nutritional forms supported by intraoral findings, which were expected to be free of erosion and abrasion that resembling a non-acidic oral environment.

Before using the mouthwash, our patients were instructed to have mouthwash free for 3 days, based on previous studies.[8,9] They brushed only with prescribed equipment to minimize the complexity of the intraoral environment, especially in reltion to previously used mouthwash and toothpaste ingredients, which may have contained active agents similar to those evaluated in this study. Aloe vera toothpaste was preferred because it does not contain any common active mouthwash ingredients and does not cause corrosion.[10]

The non-contact AFM technique was preferred for high-resolution AFM because it is non-destructive and the only mode capable of genuine atomic resolution. This technique not only allows imaging but also involves high-precision manipulation.[11]

Table 2. Tukey test analysis for statistical comparison of the groups

		p value
Group 1 (Colgate Plax)	Group 2 (Listerine)	0.915
	Group 3 (Klorhex)	**0.007***
	Group 4 (control group)	**0.000***
	Group 5 (as-received)	**0.000***
Group 2 (Listerine)	Group 1 (Colgate Plax)	0.915
	Group 3 (Klorhex)	0.076
	Group 4 (control group)	**0.000***
	Group 5 (as-received)	**0.000***
Group 3 (Klorhex)	Group 1 (Colgate Plax)	**0.007***
	Group 2 (Listerine)	0.076
	Group 4 (control group)	**0.000***
	Group 5 (as-received)	**0.000***
Group 4 (control group)	Group 1 (Colgate Plax)	**0.000***
	Group 2 (Listerine)	**0.000***
	Group 3 (Klorhex)	**0.000***
	Group 5 (as-received)	0.130
Group 5 (as-received)	Group 1 (Colgate Plax)	**0.000***
	Group 2 (Listerine)	**0.000***
	Group 3 (Klorhex)	**0.000***
	Group 4 (control group)	0.130

*p<0.05

The study design included 0.016 x 0.022 inch NiTi wires, which were easily stabilized during AFM measurements. Related to the evaluation of friction, it has been argued that tying a wire into the bracket creates a force and tension, making it difficult to objectively measure the tying force and maintain its constancy. These compression and tension areas may show fretting and galvanic corrosion. The reason to use a leveled arch was made to observe the effects of mouthwash corrosion while minimizing other types of corrosion.[12,13]

Since the frequency of the appointments for patients with fixed orthodontic appliances varies from 4 to 6 weeks, this study opted to investigate the arch wires after 1 month of clinical exposure and mouthwash use. In addition to reflecting regular appointment intervals, several studies have demonstrated that the levels of ion release caused by corrosion reaches peak level between 7 days[14] to four weeks.[15,16] Thus, the highest corrosion effects can be observed within this duration.

The present study identified a significant surface roughness increase, indicating more severe corrosion morphology on NiTi archwires during the use of all the commercial mouthwash, whereas the CG showed the lowest surface roughness value (Ra=30.47 nm). Since the CG used water as a mouthwash, the results of this group mimicked the effects of the oral environment on the NiTi arch-wires. Even if there was no statistically significant difference between the as-received and CG, a quantitative increase of 11.1 nm in the surface roughness of the arch wires was observed after a month of clinical exposure. This verifies that corrosion or a proteinaceous biofilm with a rougher surface, likely forming a calcified layer, developed on the wires,[11] Other similar studies have assessed the effects of the oral environment on NiTi wires using electron or optical microscopy and/or SEM.[17,18] Ghazal et al.[19] reported an increase of 25.74 nm in the surface roughness of NiTi wires after a month of clinical exposure. Unlike our results, this higher amount of surface roughness found in their study may result from the use of a different arch-wire brand, partial bonding of the dentition compared to full bonded patients in our study, the lack of standardized eating habits in their study compared to the standardized diet in the present study, and differences in oral hygiene equipment and disinfection procedures.

The comparison of the surface roughness of NiTi arch wires caused by mouthwashes revealed that CXG had higher values than FG, CG, and as-received archwires, but was not significantly different from AG. The pH of CHX-containing mouthwash (pH=5.5) was more acidic than that of fluoride-containing mouthwash (pH=6.9), yet it was less acidic than that of alcohol-containing mouthwash (pH=4.1). Although the pH values of CHX- and alcohol-containing mouthwashes had different levels of acidity, there was no statistically significant difference in surface roughness. Therefore, the greater amount of corrosion on the NiTi archwires may be attributed to the corrosiveness of CHX rather than its pH value. This finding is in accordance with studies in which CHX was used as an irrigation solution[20,21] and another study that compared different mouthwashes that cause ion release from orthodontic brackets.[21] On the other hand, the study by Nik et al.[22] reported that CHX did not affect the surface roughness of NiTi archwires, but their study was designed with an *in vitro* methodology, which did not precisely mimic the oral environment.

Titanium is an essential component of NiTi archwires, and CHX gluconate is an active ingredient in CHX-containing mouthwash. A complex interaction was observed between titanium and gluconate.[23,24] The titanium oxide (TiO_2) layer, which is a protective layer formed on archwires, can be increasingly dissolved in the presence of this complex reaction.[25]

It has been reported that at physiological pH, CHX is a highly positively charged molecule[26] with an affinity for negatively charged groups. During the formation of TiO_2 layer, multiple reactions and negatively charged molecules are involved. These unexpected electrochemical interactions can create a barrier to the maturation of TiO_2 layer. This prolonged or inhibited formation of the TiO_2 layer may explain the greater corrosion of NiTi wires in the presence of clorhexidine.

In our study, the NiTi arch-wires in the AG and FG exhibited significantly high surface roughness values. The only study that evaluated and compared the corrosion resistance of nickel-containing orthodontic arch-wires against alcohol-containing mouthwash showed that the Cr-Ni alloy exhibited the highest corrosion resistance in alcohol-containing mouthwash compared to Hank's solution and sodium fluoride containing mouthwash.[7] This opposite finding could be due to different factors, such as differences in the composition of the archwire, *in vitro* methodology, examination technique, and constant temperature. The corrosion rate of different types of NiTi archwires has been shown to increase with temperature.[27] Bhola et al.[28] evaluated the effect of alcohol-containing mouthwash on implants and reported corrosion of Ti6Al4V alloys. Our finding are in accordance with Bhola's study[25,28] and the induction of corrosion by alcohol-containing mouthwash on NiTi archwires. Alcohol-containing mouthwash contains ingredients such as essential oils, alcohol (ethanol) and it has an acidic pH of 4.1. It has been reported that with decreasing pH, the ethanol absorption of TiO_2 increases.[29] These cumulative factors and possible reactions could explain the protective TiO_2 degradation and corrosion observed in AG.

The corrosion observed in FG was statistically higher than that in the as-received group and lower than that in the CXG group, yet there was no significant difference compared to the AG group. Although the pH of the sodium fluoride-containing mouthwash (pH=6.9) was higher, the average corrosion observed on NiTi wires was similar to that in the AG group. These results might be attributed to the presence of fluoride ions. Earlier *in vitro* studies[5,30,31] have shown that fluoride-containing mouthwashes (250 ppm) can cause corrosion on NiTi arch-wires. Because our study design was *in vivo*, interactions within the oral environment should be considered, as they may affect the extent of corrosion.

Carbohydrate metabolism by bacteria in the oral cavity, results in the formation of acetic acid.[32] When acetic acid is formed, it reacts with fluoride to produce hydrofluoric acid (HF). Higher concentrations of fluoride ions in the oral cavity result in more HF. HF reacts with TiO_2, dissolving the protective TiO_2 layer by forming TiO_2 fluoride or titanium fluoride.[33,34] The degradation of the protective layer results in the exposure of the underlying alloy and rapid corrosion. In our study, the TiO_2 layer was most likely destroyed in this manner, as shown in the Table 3.[35]

Table 3. Titanium oxide layer reactions in the presence of hydrofluoric acid[35]

$Ti_2O_3 + 6HF \rightarrow 2TiF_3 + 3H_2O$
$TiO_2 + 4HF \rightarrow TiF_4 + 2H_2O$
$TiO_2 + 2HF \rightarrow TiOF_2 + H_2O$

TiO_2: Titanium oxide, HF: Hydrofluoric acid

Corrosion causes pit defects on archwires, which create suitable areas for plaque accumulation. Since a rougher surface results in more friction between brackets and wires, we believe that the success of orthodontic treatment could be negatively affected.

Study Limitations

A limitation of the present study was the standardization of the oral environment, which is complex and contains variables. In future studies, careful consideration should be given to standardizing solid variables that affect the amount of corrosion, such as crowding, wire type, ligation technique, and oral hygiene practices.

CONCLUSION

All mouthwashes containing different active agents created corrosion on the surface topography of the NiTi archwires.

Floride-containing mouthwash can be preferred over CHX mouthwash due to its lesser corrosion effect.

The changes in the NiTi archwires caused by the oral environment were not statistically different from the as-received wires.

Ethics

Ethics Committee Approval: The study was approved by the Clinical Research Ethics Committee of Yeditepe University (approval no.: 62/497, date: 26.06.2015).

Informed Consent: The aim of this study was explained to the participants, and an informed consent form was obtained before the clinical trial.

Author Contributions: Surgical and Medical Practices - Concept - Design - Data Collection and/or Processing - Analysis and/or Interpretation - Literature Review - Writing - All authors contributed equally.

Declaration of Interests: All authors declare that they have no conflict of interest.

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Original Article

Pain Perception, Knowledge, Attitude, and Diet Diversity in Patients Undergoing Fixed Orthodontic Treatment: A Pilot Study

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Main Points

- Majority of patients undertake orthodontic treatment to improve aesthetics and are internally motivated.
- Patients perceived most pain from separator placement, and least from taking impressions. Most patients experience pain on their teeth and mucosa while eating which is dull in nature and agree that orthodontic treatment affects their food intake.
- Majority of patients have good orthodontic knowledge and present with a positive attitude towards their treatment.
- Patients have a moderate diet diversity. The avoidance of some of the food groups, in some patients can be managed better by a nutritionist to overcome the dietary insufficiencies resulting in patient's overall wellbeing.

ABSTRACT

Objective: This study aimed to determine the correlation between pain perception and knowledge, attitude, and diet diversity in patients undergoing fixed orthodontic treatment.

Methods: A total of 103 patients (15-40 yrs.; 67 females, 36 males) undergoing orthodontic treatment with a 0.022-inch slot (MBT prescription) in both arches were recruited. Information on pain perception, knowledge, attitude, and diet diversity scores was collected through validated questionnaires using visual analogue scale and close-ended questions at one time point. The correlation between variables was analyzed using the Pearson's correlation coefficient.

Results: Of the patients, 48.5% were aged 15 to 19 years old, with 65% females and 73.8% of Chinese ethnicity. Approximately 90% of the orthodontic patients perceived low levels of pain from orthodontic treatment, and 98% had a positive attitude toward orthodontic treatment. The patients had a good level of knowledge (Mean: 6±0.65). Approximately 49.5% of patients reported having moderate diet diversity. No significant correlation was found between pain perception and knowledge, or pain perception and diet diversity ($r=0.062$, $p=0.534$). However, a significant weak negative correlation ($r=-0.289$, $p<0.05$) between pain perception and attitude was observed.

Conclusion: Patients undergoing fixed orthodontic treatment presented with overall low pain perception, a positive attitude, and good knowledge about their treatment with moderate diet diversity. Informing the patient in advance about different orthodontic procedures encourages a positive attitude and facilitates patient cooperation. An interprofessional approach involving nutritionists can provide a holistic patient approach during orthodontic treatment.

Keywords: Pain perception, knowledge, attitude, diet, fixed orthodontic appliance

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INTRODUCTION

Orthodontic treatment is often sought by patients to improve their aesthetics. The ideal clinical management of patients seeking fixed orthodontic treatment largely depends on the clinician's skills; however, patient cooperation, motivation, and compliance greatly contribute to treatment success. These factors, in turn, are influenced by pain perception, knowledge, attitude, and diet diversity.[1,2]

The course of orthodontic treatment is commonly accompanied by pain and discomfort, with almost all patients claiming to have encountered some pain during their treatment.[3] Discomfort is identified as light tactile pressure on the teeth, soft tissue stretching, pressure on the oral mucosa, tooth sensitivity, and pain[4-6] Özkalaycı et al.[7] have reported that patients undergoing orthodontic treatment experience eating difficulties and pain, which decreases over time. Even though the pain is mild and brief, many patients may discontinue treatment because of it.[8-10] Pain perception, however, is subjective, with individual variations influenced by age, gender, pain threshold, stress, emotional state, and previous dental experience.[3,5,9-11] Pain plays a major influence in patient compliance.[7] An in-depth understanding of orthodontic treatment is important to ensure long-term cooperation by patients willing to undertake orthodontic treatment.[12] Well-informed patients with positive attitudes have been found to have been found to have fewer pain experiences and develop a positive attitude toward their treatment.[1,3,6,13-15]

Orthodontists often advise patients to consume a soft diet to minimize pain and prevent appliance breakage, which may affect their nutritional status.[16] Most orthodontic patients are adolescents, an age at which their nutrition should be optimal because they are in their period of rapid growth. A well-balanced diet is important for adolescents because the body requires sufficient nutrients to accommodate pubertal growth as well as emotional stress.[17] Studies have reported that poor nutrition in orthodontic patients affects the biological response of the periodontal ligament and bone to orthodontic forces.[18] The preferential intake of a soft diet during treatment results in reduced fiber and carbohydrate intake and an increased intake of fats.[19] Kausal et al.[20] showed that this dietary modification has a positive impact, as patients adopt healthier eating habits consisting of boiled vegetables, mashed rice, and various juices. Although the orthodontic literature has dietary guidelines, its effect on patient diet diversity has been less studied. Understanding the patient's diet diversity during treatment will help identify patients in need of appropriate dietary guidance to avoid compromising their nutritional status.

Despite the many benefits of orthodontic treatment, it may negatively impact patient quality of life. Thus, further understanding of the patient's perception of pain, knowledge about orthodontic treatment, attitude, and diet diversity will enable the orthodontist to facilitate a more patient-centered approach for the success of orthodontic treatment. The hypothesis posited is that patients undergoing fixed orthodontic treatment have a deficient perception of pain, insufficient knowledge, exhibited unfavorable attitudes, and have limited dietary diversity. Hence, the present study was designed to assess the perception of pain, knowledge, attitude, and diet diversity in patients undergoing fixed orthodontic treatment at a selected university dental clinic.

METHODS

This study was approved by the Joint Research and Ethics Committee of the International Medical University [grant no.: BDS I-01/2019(13)].

Study Protocol

A total of 103 participants were recruited, over five months from the active patient list of the Oral Health Centre at IMU University in Malaysia. Written informed consent was obtained from all patients. For patients aged below 18 years, consent was obtained from both the patient and their parents. The inclusion criteria were: (1) Patients undergoing orthodontic treatment with a 0.022-inch slot (MBT prescription) in both arches; and (2) agreeable to participate in the study and provide consent from themselves or through their guardians. The exclusion criteria were: (1) patients with a history of any craniofacial anomaly, systemic disease, or those who were on any medication. (2) inability to complete the questionnaire.

Study Instruments

A questionnaire was developed based on existing validated questionnaires. The questionnaire consisted of six parts: Socio-demographic information, pain profile,[20] pain expectation, pain experience,[14] knowledge of patients on fixed orthodontics appliances,[21,22] Patient's Attitude Toward Orthodontic Treatment (PATOT),[14] and Diet Diversity Questionnaire.[23] Most of these questions consisted of close-ended questions and visual analogue scales (VAS), which were easily comprehendible by the patients. All questions were translated and back-translated into Bahasa Malaysia and Mandarin. A brief oral examination was conducted, and the orthodontic treatment records were checked to document the patient's stage of orthodontic treatment. All patients were briefed about the study, and a researcher was available to counter any patient queries.

The questions on pain perception included questions regarding location, duration, timing, type, pain relief method, effect on daily routine, diet, social behavior, and psychological temperament. VAS has been found to be an easy, reliable, sensitive, and convenient method for measuring pain intensity.[12] Pain experience and expectations regarding the orthodontic procedures were assessed using the VAS marked on a 0 -10 scale with 0 representing "No hurt" and 10 representing "Hurts most" for different orthodontic procedures. Each patient was instructed to mark the line nearest to their expectation or experience.

The scores for pain expectation and pain experience were averaged to obtain the final pain perception score. A patient with a higher score indicates greater pain experience during the treatment.[14]

The knowledge domain comprised seven statements. All participants were asked to indicate whether they agree or disagree with the statements. The items were scored such that "Agree" was scored 1 and "Disagree" was scored 0, and the mean was calculated for the knowledge component.[21] "Agree" corresponded to a higher level of knowledge about their treatment.

PATOT was used to study the attitudes of the patients. The questionnaire consisted of twelve statements that were assessed using the VAS on a scale of 0-10, with 0 representing "Extremely Unlikely" and 10 representing "Extremely Likely" for different orthodontic procedures. The variables for each statement were rescored such that a high score corresponded to a positive attitude toward fixed orthodontics.[14]

Diet diversity was measured through a qualitative 24-hour recall of all foods and drinks consumed by the participants. "1" was scored in the column next to the food group if at least one food from this group was consumed by the respondent on the previous day. Diet diversity was assessed using a score based on the Individual Dietary Diversity Score (DDS). The score ranges from 0 to 9. A score of ≤3 is considered as having a low diet diversity, 4 -5 is considered moderate, and ≥6 is considered as high diet diversity.[23]

Statistical Analysis

The statistical analysis was performed using IBM SPSS 23.0 Software. Descriptive statistics, including frequency, percentage, and mean, were used to describe the characteristics of the survey respondents. Kolmogorov-Smirnov test was used to test the normality of the data. The independent t-test was used to determine gender dimorphism. The correlation between pain perception and knowledge, attitude, and diet diversity in patients undergoing fixed orthodontic treatment was analyzed using Pearson's correlation coefficient. The sample size required for the study was determined using G*Power 3.1.9.7 software. Assuming an effect size of 0.25, significance level of 0.05, and power of the study of 0.80, the minimum number of samples required was 95.

RESULTS

Table 1 shows the sociodemographic distribution of the recruited orthodontic patients. Most (48.5%) of the patients were aged 15 to 19 years, with the majority being female (65%) and of Chinese ethnicity (73.8%). The main reason for undergoing orthodontic treatment was to improve esthetics (68.9%), and most (59.2%) patients were internally motivated. A similar distribution of all stages of fixed orthodontics was observed, with most patients (37.9%) in the leveling and alignment stage, followed by space closure (35.9%) and finishing (26.2%).

Perception of Pain from Orthodontic Treatment

Table 2 shows the pain profile of the orthodontic patients. The majority (80.6%) experienced dull pain, primarily in their teeth (55.3%) and mucosa (43.7%) while eating (66%). The pain occurred occasionally (51.5%) lasted for a few hours (38.8%) and most patients (65%) did not use any means to relieve it. Most (59.2%) patients reported that pain from orthodontic treatment affected their food intake.

Table 3 presents the pain perception of the patients. Lower scores indicate less intensity of pain experienced/expected from orthodontic treatment, whereas higher scores indicate more intense pain.[19] Although most pain was reported due to separator placement (4.17±3.24), it was of low intensity. The least pain (1.65±2.4) was perceived during impression-taking.

Knowledge of Orthodontic Treatment

The patients' knowledge level regarding their orthodontic treatment are shown in Table 4. Most respondents agreed with statements like, "Orthodontic treatment improves

Table 1. Socio-demographic characteristics of the patients

Parameters		Total, n (%)
Gender	Male	36 (35.0)
	Female	67 (65.0)
Age group (yrs.)	15-19	50 (48.5)
	20-24	34 (33.0)
	25-29	14 (13.6)
	30-34	2 (1.9)
	35-40	3 (2.9)
Ethnicity	Malay	11 (10.7)
	Chinese	76 (73.8)
	Indian	4 (3.9)
Concerns regarding orthodontic treatment	Esthetics	71 (68.9)
	Improve dental hygiene	23 (22.3)
	Improved chewing efficiency	7 (6.8)
	Others	2 (1.9)
Motivation	Internal	61 (59.2)
	Parents	28 (27.2)
	Peers	5 (4.9)
	Dentist	7 (6.8)
	Others	2 (1.9)
Treatment stages	Leveling and alignment	39 (37.9)
	Space closure	37 (35.9)
	Finishing	27 (26.2)

esthetics" (99%), "Orthodontic treatment corrects teeth and jaw abnormalities" (98.1%); "Incomplete treatment may lead to more problems" (96.1%), and "Retainer wear is important after orthodontic treatment (95.1%)". A few patients (29.1%) disagreed with the statement, "Orthodontic treatment duration is long," which still shows a higher level of knowledge in most patients. In the present study, most participants had good levels of orthodontic knowledge (Mean: 6±0.65).

Table 2. Characteristics of pain

Characteristics	Parameters	Total number of participants (%)
Pain areas	Teeth	57 (55.3)
	Mucosa	45 (43.7)
	TMJ	1 (1.0)
Time of pain occurrence	Day	18 (17.5)
	Night	12 (11.7)
	While eating	68 (66.0)
	While speaking	5 (4.9)
Duration of pain	Few minutes	25 (24.3)
	Few hours	40 (38.8)
	Full day	20 (19.4)
	A few days later	18 (17.5)
The type of pain	Dull	83 (80.6)
	Throbbing	20 (19.4)
Frequency of pain	Continuous	50 (48.5)
Pain relief	Occasional	53 (51.5)
	Medication	6 (5.8)
	Topical anesthesia	3 (2.9)
	No treatment	67 (65.0)
	Relief wax	27 (26.2)
Effects of pain	**Yes, n (%)**	**No, n (%)**
The daily routine	21 (20.4)	82 (79.6)
Effects of food intake	61 (59.2)	42 (40.8)
Social behavior	17 (16.5)	86 (83.5)
Psychological temperament	14 (13.6)	89 (86.4)

Attitude toward Orthodontic Treatment

Table 5 shows the patient attitudes toward treatment. Lower scores indicated a negative attitude toward orthodontic treatment, whereas high scores indicated a positive attitude toward it.[14] The majority of patients scored 8.80±1.77, more inclined to disagree with the statement, "Orthodontic treatment often has no use at all" showing a more positive attitude toward their treatment. The mean score of 5.32±3.04 for the statement "When you wear braces, you need to adjust your dietary habits" was the lowest among all statements, indicating that patients had a slightly positive inclination toward their treatment. Most patients exhibited a positive attitude toward their treatment. A significant difference ($p<0.05$) between sexes was observed regarding the statement, "It is not required to visit an orthodontist after your braces have been removed".

Diet Diversity among Patients Undergoing Orthodontic Treatment

Table 6 depicts the consumption patterns of different food groups along with gender dimorphism. No significant difference in the consumption patterns of all food groups between genders was reported.; Vitamin A-rich vegetables and tubers, white tubers and roots, Vitamin A-rich fruit, other fruits, organ meats, legumes, nuts, and seeds were "not consumed" by many of the subjects. Approximately 6.8% of patients had a score of ≤3 indicating a low diet diversity range; 49.5% had a moderate diet diversity score, and 43.7% had a high diet diversity score (≥6).

Based on the results of our current study, no correlation was be found between pain perception and knowledge, as all patients had a good level of knowledge. Similarly, no correlation was observed between pain perception and diet diversity among patients undergoing orthodontic treatment ($r=0.062$, $p=0.53$). However, a significant but weak correlation ($r=-0.289$, $p=0.003$) between pain perception and attitude was observed.

DISCUSSION

The present study included 103 patients undergoing orthodontic treatment at Oral Health Centre at IMU University in Malaysia. Most patients were adolescent (15 to 19 years)

Table 3. Pain perception of the participants

	Procedures	Total	Male	Female	*p-value
		Mean ± SD	Mean ± SD	Mean ± SD	
Pain perception	Separators	4.17±3.24	5.05±3.33	3.69±3.14	0.135
	Bands	3.57±2.96	4.11±2.73	3.29±3.07	0.343
	Bonding brackets	2.13±2.61	2.11±2.49	2.13±2.69	0.965
	Wire change	2.92±2.79	2.78±3.03	3.00±2.67	0.701
	Elastics	4.01±2.52	4.03±2.57	4.00±2.51	0.963
	Retainers	2.35±2.39	2.31±2.42	2.37±2.39	0.891
	Impression taking	1.65±2.40	1.61±2.38	1.67±2.43	0.903
	Debonding	2.16±2.18	2.14±2.06	2.16±2.26	0.953

Independent t-test was used and *$p<0.05$ was considered as statistically significant, SD: Standard deviation

Table 4. Mean orthodontic knowledge among orthodontic patients

	Parameters	Response	
		Agree, n (%)	Disagree, n (%)
Domains knowledge	Orthodontic treatment improves esthetics	102 (99.0)	1 (1.0)
	Orthodontic treatment is expensive	98 (95.1)	5 (4.9)
	Orthodontic treatment corrects tooth and jaw abnormalities	101 (98.1)	2 (1.9)
	Orthodontic treatment duration is long	73 (70.9)	30 (29.1)
	Important to adhere to the food guidelines established by orthodontists	92 (89.3)	11 (10.7)
	Incomplete treatment may lead to additional problems	99 (96.1)	4 (3.9)
	Retainer wearing is important after orthodontic treatment	98 (95.1)	5 (4.9)

Table 5. Attitude of the patients toward orthodontic appliances

	Parameters	Total	Male	Female	*p-value
		Mean ± SD	Mean ± SD	Mean ± SD	
Attitude	The use of braces causes a lot of trouble	5.47±2.43	5.31±2.15	5.55±2.57	0.625
	When wearing braces, you should adjust your dietary habits	5.32±3.04	4.81±2.82	5.60±3.13	0.209
	Orthodontists always advise that patients must wear braces more often than necessary	6.14±3.10	5.42±3.18	6.52±3.01	0.085
	Orthodontic treatment is often of no use	8.80±1.77	8.81±1.95	8.79±1.68	0.969
	It is necessary to take greater care of your oral hygiene when you are wearing braces	8.58±1.96	8.39±1.68	8.69±2.11	0.466
	People wearing braces are often more bullied than people without braces	8.53±2.05	8.19±2.07	8.72±2.03	0.219
	It is not necessary to visit an orthodontist after the removal of braces	8.12±2.60	7.19±2.83	8.61±2.36	0.008*
	Elastics that should be worn with braces are often not used	7.92±2.35	7.86±2.22	7.96±2.44	0.848
	It is all right to stop treatment if the teeth are straight	7.71±2.39	7.56±2.47	7.79±2.37	0.636
	Orthodontists provide indistinct information	7.15±2.91	6.86±3.09	7.30±2.82	0.469
	Orthodontists often provide reminders	8.25±2.33	7.69±2.45	8.55±2.22	0.074
	Orthodontists spend very little time with their patients	7.37±2.90	6.81±2.81	7.67±2.92	0.14

Independent t-test was used and *p<0.05 was considered statistically significant, SD: Standard deviation

Table 6. Consumption patterns of food groups by gender

Food groups	Consumed n (%)	Not consumed n (%)	Total Mean ± SD	Male Mean ± SD	Female Mean ± SD	p value
Cereal	102 (99)	1 (1)	0.99±0.099	1±0	0.99±0.122	0.466
Vitamin A rich vegetables & tubers	32 (31.1)	71 (68.9)	0.31±0.465	0.25±0.439	0.34±0.478	0.334
White tubers and roots	32 (31.1)	71 (68.9)	0.31±0.465	0.42±0.5	0.25±0.438	0.09*
Dark green leafy vegetables	56 (54.4)	47 (45.6)	0.54±0.501	0.64±0.487	0.49±0.504	0.158
Other vegetables	80 (77.7)	23 (22.3)	0.78±0.418	0.78±0.422	0.78±0.42	0.985
Vitamin A rich fruits	9 (8.7)	94 (91.3)	0.09±0.284	0.08±0.28	0.09±0.288	0.916
Other fruits	39 (37.9)	64 (62.1)	0.38±0.487	0.47±0.506	0.33±0.473	0.154
Organ meat (iron-rich)	1 (1)	102 (99)	0.01±0.099	0	0.01±0.122	0.466
Flesh meats	85 (82.5)	18 (17.5)	0.83±0.382	0.89±0.319	0.79±0.41	0.216
Eggs	64 (62.1)	39 (37.9)	0.62±0.487	0.67±0.478	0.60±0.494	0.911
Fish	52 (50.5)	51 (49.5)	0.50±0.502	0.50±0.507	0.51±0.504	0.163
Legumes, nuts and seeds	45 (43.7)	58 (56.3)	0.44±0.498	0.44±0.504	0.43±0.499	0.911
Milk and milk products	65 (63.1)	38 (36.9)	0.63±0.485	0.72±0.454	0.58±0.497	0.163
Oils and fats	102 (99)	1 (1)	0.99±0.099	0.97±0.167	1	0.174
Sweets	64 (62.1)	39 (37.9)	0.62±0.487	0.67±0.478	0.60±0.494	0.492
Spices, condiments, beverages	102 (99)	1 (1)	0.99±0.099	1	0.99±0.122	0.466

Pearson's correlation test was used and *p<0.05 was considered as statistically significant, SD, standard deviation

females of Chinese ethnicity. They opted for orthodontic treatment to improve their esthetics and were self-motivated. The distribution of patients across the various stages of fixed orthodontics was almost even, with the majority (37.9%) undergoing leveling and alignment, followed by space closure (35.9%) and finishing (26.2%). Most patients perceived dull pain in their teeth for a few hours while eating, but they did not seek any treatment for it. Across all orthodontic procedures, patients perceived the least pain during impression-taking. Even though they perceived most pain from the placement of separators, the pain was rated very low. This may be due to increased pain tolerance levels because the patients were self-motivated to enhance their esthetics. Previous studies by Scheurer et al.[3], Sergl et al.[6], and Bergius et al.[24] have reported that orthodontic treatment is generally associated with frequent pain. The present study showed no significant difference in pain perception between sexes, which agrees with the results of Ngan et al.[5], Bergius et al.[25], and Jones and Chan.[26] However, there are several other studies[14,24,27,28] which reported that females perceive more pain than males during fixed orthodontic treatment and are more sensitive to pain, whereas males tolerate pain better. Very few patients consumed medications for pain, a finding supported by previous studies conducted by Jones and Chan[26] and Vallerand et al.[29] previously. Most patients experienced pain while eating, and many reported that the pain had affected their diet. The impact of pain on diet has been reported previously in the literature.[10,28]

Orthodontic patients generally have a good level of knowledge, as demonstrated by several studies.[21,22] In the present study, no correlation was observed between pain perception and patient knowledge. Most patients agreed that "Orthodontic treatment improves esthetics," "Orthodontic treatment corrects teeth and jaw abnormalities," "Incomplete treatment may lead to more problems," "Retainer wear is important after orthodontic treatment," only a few of them disagreed that "Orthodontic treatment duration is long" and "It is important to adhere to food guidelines by orthodontist" which must be explained and reinforced to improve patient expectations and treatment outcomes. Overall, patients in this study had good orthodontic knowledge and perceived low pain levels overall. Abu Alhaija et al.[14] and Touyz and Marchand[15] have reported that dissemination of orthodontic information about expected pain reduces the pain experienced during treatment.

Most patients had a positive attitude toward their orthodontic treatment, as supported by Mendigeri et al.[22] Most patients showed a positive attitude overall, the statement "When you wear braces, you need to adjust your dietary habits" scored the lowest, though it still showed a positive attitude. The statement "It is necessary to care more for your oral hygiene when you are wearing braces" scored the highest. There was a significant difference between genders regarding the statement, "It is not required to visit an orthodontist after your braces have been removed". Females were more likely to visit the dentist after the removal of fixed appliances for follow-up on retention than males. A weak negative correlation between pain perception and attitude was found in accordance with several other studies.[1,6,14] A positive attitude was observed among patients who experienced less pain during orthodontic treatment.

Most patients experienced pain while eating and reported that their diet was affected. Kausal et al.[20] showed that patients have a healthier diet while undergoing treatment, avoiding sticky food like chocolates and snacks, and instead opting for softer food such as porridge and boiled vegetables. However, many patients in this study consumed cereal, dark green leafy vegetables, other vegetables, flesh meat, eggs, fish, milk and milk products, oils, fats, sweets and spices, condiments, and beverages. This indicates that patients are able to maintain a normal diet despite experiencing pain, while adhering to the dietary guidelines recommended by their orthodontist. These factors contribute to the rejection of the hypothesis that patients undergoing fixed orthodontic treatment had a deficient perception of pain, insufficient knowledge, exhibited unfavorable attitudes, and limited dietary diversity.

Nevertheless, there are several food groups that patients did not consume, including Vitamin A-rich vegetables and tubers, white tubers and roots, Vitamin A-rich fruit, other fruits, organ meats, legumes, nuts, and seeds. Ozdemir et al.[30] also reported a decline in the intake of vitamins A, C, and E within the first few months of orthodontic treatment among adolescents. Vitamin A, along with calcium and phosphorus, are essential for bone and tooth formation, and their deficiency can retard jaw, teeth, and condylar growth. The reasons for avoidance of these food groups, however, could be multifactorial, such as the patient's food preference, instructions given by the orthodontist, or pain experienced from wearing braces.

Most patients were found to have moderate diet diversity. This suggests that contrary to Singh et al.[13] patients undergoing orthodontic treatment may not necessarily consume fewer carbohydrates and fiber. However, considering that 6.8% of patients have low diet diversity, dietary interventions by nutritionists could help ensure a more holistic approach to orthodontic treatment. Avoidance of certain food groups and healthy nutritive alternatives could be advised by a nutritionist. It is important that an inter-professional approach to treatment can overcome dietary insufficiencies, thereby improving the patient's overall well-being.[30]

The present study also investigated the correlation between pain perception and diet diversity among patients undergoing orthodontic treatment. Some studies showed that patients had difficulty in chewing due to the pain experienced after the appliance was bonded or adjusted, and some studies stated that healthier eating habits developed in response to pain and inability to chew.[19,20] However, no correlation was observed between pain perception and diet diversity among patients undergoing orthodontic treatment in the present study.

Study Limitations

Despite the significant findings, there are several limitations to this study. For instance, it only examined the pain perception, knowledge, attitude, and diet diversity of patients at one time interval in a university clinic. In this pilot study, the complexity of malocclusion was excluded, and the age range was wider. Future research should focus on the individuals' longitudinal changes in pain perception, knowledge, attitude, and diet diversity over time, including more patients with specific malocclusions, at different stages of treatment across smaller age ranges to generalize the results.

CONCLUSION

Pain caused by orthodontic treatment is one of the primary causes that negatively affects an individual's quality of life. In this study, patients who underwent fixed orthodontic treatment had an overall low perception of pain, a good level of orthodontic knowledge, a positive attitude, and moderate diet diversity. Patients who were well informed of the pain and orthodontic procedures prior to treatment reported low levels of pain, thereby strengthening a positive attitude toward their treatment. Pain during treatment can affect dietary intake through restrictions for certain food groups. Hence, to prevent malnutrition during this period of treatment, it is recommended that a nutritionist should work hand in hand with the orthodontist to ensure a holistic approach to treatment. An inter-professional approach along with a nutritionist would benefit such patients without compromising their nutritional well-being due to the pain caused by the treatment.

Ethics

Ethics Committee Approval: This study was approved by the Joint Research and Ethics Committee of the International Medical University [grant no.: BDS I-01/2019(13)].

Informed Consent: Written informed consent was obtained from all patients. For patients aged below 18 years, consent was obtained from the patient and their parents.

Author Contributions: Concept - K.S.; Design - S.M., K.S.; Data Collection and/or Processing - M.E.-V., U.S.B.A.R.; Analysis and/or Interpretation - M.E.-V., U.S.B.A.R., S.M.; Literature Review - M.E.-V., U.S.B.A.R., K.S.; Writing - M.E.-V., K.S.

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Original Article

Pharyngeal Airway Space Changes after Single Mandibular and Two-Jaw Surgery in Patients with Skeletal Class II Malocclusion

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Main Points

- The results of single-jaw mandibular advancement surgery and double-jaw surgery have demonstrated a positive impact on the increase of oropharyngeal and hypopharyngeal airway size.
- In patients with severe skeletal Class II malocclusion and hyperdivergent, a reduction in nasopharyngeal airway dimensions has been observed following the implementation of preferred double-jaw surgery.
- The reduction in the nasopharyngeal airway following double-jaw surgery can be attributed to maxillary impaction.
- In addition to the anterior displacement of the hyoid bone observed following single-jaw mandibular advancement surgery, superior displacement of the hyoid bone was also observed following double-jaw surgery.

ABSTRACT

Objective: To retrospectively evaluate the effects of single mandibular advancement (MA) and two-jaw surgery (2J-S) on the pharyngeal airway space (PAS) and hyoid position for the correction of skeletal Class II malocclusion.

Methods: Eleven adult patients who underwent only MA surgery and twelve adult patients who underwent Le Fort I maxillary impaction-MA surgery (2-JS) were included in the retrospective study. A total of 46 cephalometric recordings obtained before (T1) and after treatment (T2) were examined. Craniofacial changes, area, and linear measurements of the pharyngeal airway and hyoid bone position were obtained in both groups. The Wilcoxon signed-rank test was used to evaluate time-dependent changes within groups. The Mann-Whitney U test was used to compare differences between groups.

Results: Hyoid-Vert values increased significantly in both groups (MA, $p<0.01$; 2J-S, $p<0.05$); however, Hyoid-Hor values decreased significantly only in the 2J-S group ($p<0.01$). The anteroposterior dimensions of the airway increased in both groups, except for the PNS-P and PPS groups ($p<0.01$). Although a significant increase was observed in the nasopharyngeal area (A1) in the MA group ($p<0.05$), the decrease was found to be statistically significant in 2JG ($p<0.01$). Significant increases were found in the oropharyngeal (A2) and hypopharyngeal areas (A3) in both groups ($p<0.01$, $p<0.05$).

Conclusion: Both surgical procedures for the correction of Class II malocclusion resulted in increased hypopharyngeal, oropharyngeal, and total airway measurements.

Keywords: Class II treatment, orthognathic surgery, mandibular advancement, pharyngeal airway, non-growing patients, skeletal malocclusion

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INTRODUCTION

Sixty percent of individuals with Class II division 1 malocclusion have posterior positioning of the mandible, and a smaller percentage have anterior positioning of the maxilla.[1] Muto et al.[2] reported that patients with Class II malocclusion had pharyngeal dimensions that specifically decreased in the anteroposterior direction in the retroglossal region of the oropharynx. Therefore, a direct relationship was observed between the sagittal position of the mandible and the pharyngeal airway space (PAS) dimensions.

Lateral cephalograms are reproducible diagnostic tools that can effectively examine the PAS and hyoid bone position.[3,4] PAS measurements made on lateral cephalometric recordings were highly correlated in terms of predictability when compared with measurements made on three-dimensional (3D) imaging methods.[5] It has also been stated that it is used for diagnostic purposes and staging of pharyngeal airway obstruction in obstructive sleep apnea symptoms (OSAS) patients.[6]

Orthognathic surgical inevitably affects not only the hard tissues but also all soft tissues associated with the maxilla and mandible. The most affected areas are the PAS, which has many vital functions, such as breathing and swallowing. It was detected that the morphology of many complex structures was affected and respiratory efficiency changed after orthognathic surgery.[7,8] Moreover, it is known that in Class II individuals due to mandibular retrognathia, PAS dimensions are increased as a result of moving the mandible forward, and as a result, sleep breathing disorders such as snoring and OSAS can be reduced.[6]

The aim of our study was to assess pharyngeal airway changes after mandibular advancement (MA), combined with LeFort I maxillary impaction and MA [two-jaw surgery (2J-S)], and compare the results for each surgical procedure; our study also included postoperative evaluation of the hyoid bone.

METHODS

This retrospective study was conducted using data obtained from patients at Ankara University Faculty of Dentistry, Department of Orthodontics and Maxillofacial Surgery. The study was approved by the Ankara University Faculty of Dentistry Clinical Research Ethics Committee (approval no.: 36290600/70, date: 07.07.2017).

Study Design and Subject Selection

Sample size was determined via power analysis (G*Power, Ver. 3.1.9.2, Franz Faul; Universitat Kiel, Germany), concluding that a maximum of 10 subjects per group was sufficient. The calculation of the sample size based on the study of Jiang et al.[4] indicated that 20 patients would be sufficient for each group with a power greater than 80%, an alpha error of 0.05, a beta error of 0.20, and an effect size of 0.9. Therefore, the analysis included the radiographs of 23 adult patients: 11 patients with severe skeletal Class II malocclusion underwent single MA surgery (mean age: 25.29±7.70 y; six females, five males) and 12 patients with severe skeletal Class II malocclusion underwent 2J-S (mean age: 23.18±3.98 y, eleven females, one male). All patients included in the study were in the Ru stage according to hand-wrist radiographs and had completed 100% of their development.

When selecting patients for the groups, pre- and post-treatment radiographs were evaluated, and those who met the following criteria were included: Non-syndromic, skeletal Class II adult patients who underwent MA only and combined Lefort I maxillary impaction and MA surgery, and completed postsurgical orthodontic treatment. The exclusion criteria were previous orthognathic surgery, genioplasty, OSA, stained and poor-quality radiographs, and craniofacial anomalies.

Fixed orthodontic treatment was applied to each patient for decompensation before orthognathic surgery. After surgical treatment was completed, orthodontic treatment was continued for a certain period to achieve ideal occlusion. The mean treatment duration was 1.72 years in the MA group and 2.10 years in the 2-JS. While combined maxillary impaction and MA surgery was performed in the 2-JS group, single MA surgery was performed in the MA group.

Cephalometric Method and Data Acquisition

Lateral cephalometric radiographs obtained before (T1) and after treatment (T2) were included in the study. Measurements were performed using a computer software (Dolphin Imaging 11.95, Dolphin Imaging & Management Solutions, Chatsworth, CA, USA). As in previous studies, a horizontal plane (Hor) angled +7° clockwise to the SN line passing through Sella and a vertical plane (Vert) passing through Sella and perpendicular to this line were used as reference planes in this study (Figure 1).[4,9] Similar to the study of Ono et al.[10] and Tsuiki et al.[11], PAS reference points were used. Six linear and three area measurements were performed to determine changes in the PAS (Figures 2 and 3). Moreover, the PAS was divided into 3 regions and the area changes in PAS were evaluated.[11] A digital planimeter (Ushikata X plan380dll/460dll, Tokyo, Japan) was used for area measurements. In order to minimize the error rate, each determined area was measured 3 times and the average of the 3 measurements was obtained.

Statistical Analysis

The data obtained in this study were evaluated using the SPSS 11.5 package. The Shapiro–Wilk test was used to test the normality of parameter distribution. The Wilcoxon signed-rank test was used to evaluate changes in skeletal, dental, and pharyngeal airway parameters from T1 to T2 in the study group. The Mann–Whitney U test was used to compare the changes obtained in T2-T1 between groups and for comparisons between groups at T1. In the parametric evaluation of the changes from T1 to T2 in all patients, the paired sample t-test was used for data with normal distribution, and the Wilcoxon signed-rank test was used for data not conforming to normal distribution. Significance was predetermined at $P<0.05$.

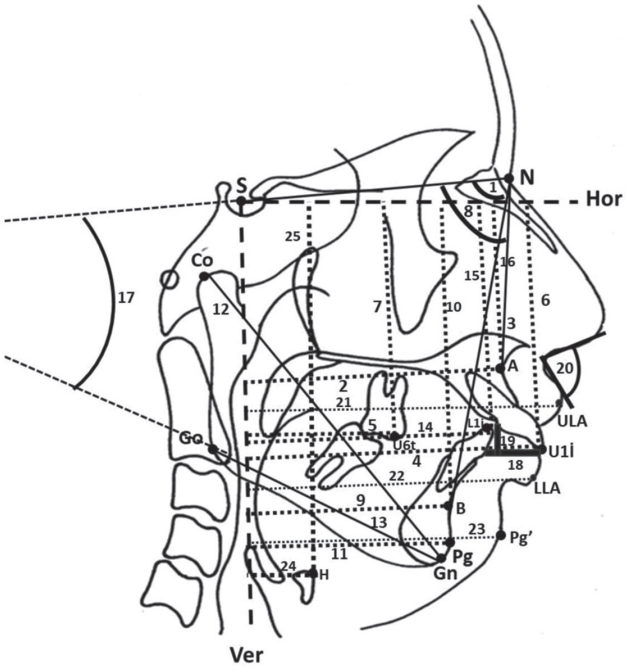

Figure 1. Cephalometric measurements. Maxillary skeletal and dental measurements: (1) SNA; (2) A-Vert; (3) A-Hor; (4) U1i-Vert; (5) U6t-Vert; (6) U1i-Hor; and (7) U6t-Hor. Mandibular skeletal and dental measurements: (8) SNB; (9) B-Vert; (10) B-Hor; (11) Pg-Vert; (12) Co-Gn; (13) Go-Gn; (14) L1i-Vert; and (15) L1i-Hor. Maxillo-mandibular skeletal and dental measurements: (16) ANB; (17) GoGn/SN; (18) Overjet; (19) Overbite. Soft Tissue Measurements: (20) Nasolabial angle; (21) ULA-Vert; (22) LLA-Vert; and (23) Pg'-Vert. Hyoidal measurements: (24) Hyoid-Vert; (25) Hyoid-Hor

RESULTS

In this study, all measurements made in a total of 20 lateral cephalometric records taken at the beginning and end of the treatment of 10 randomly selected individuals included in the treatment group were repeated 4 weeks later. The intraclass correlation value between the first and second measurements was found to be between 0.68 and 1.00 with confidence intervals, and it was observed that all measurements were reproducible.

Cephalometric Measurements

Comparisons of the values obtained in T1 for MA and 2-JS are presented in Table 1. Among the parameters in the T1 period, ANB, GoGn/SN, and B-Hor values were significantly higher in 2-JS ($P<0.05$), whereas Pg-Vert ($P<0.05$) and overbite ($P<0.01$) values were higher in MA. Apart from this, all values were found to be similar in the comparison between groups at T1 ($P>0.05$) (Table 1).

Changes in the craniofacial and hyoid position and PAS measurements from T1 to T2 in MA are presented in Table 2. Significant increases were observed in all measurements of mandibular skeletal, dental, and soft tissue measurements ($P<0.01$). In maxillo-mandibular skeletal measurements, there was a significant decrease in the ANB value (-3.27°) and a significant increase in the GoGn/SN (2.31°) ($P<0.01$). Significant decreases in overjet (-5.11 mm; $P<0.01$) and overbite (-3.43 mm; $P<0.05$) values were detected. A significant increase was observed in the Hyoid Region (4.02 mm; $P<0.01$). Significant

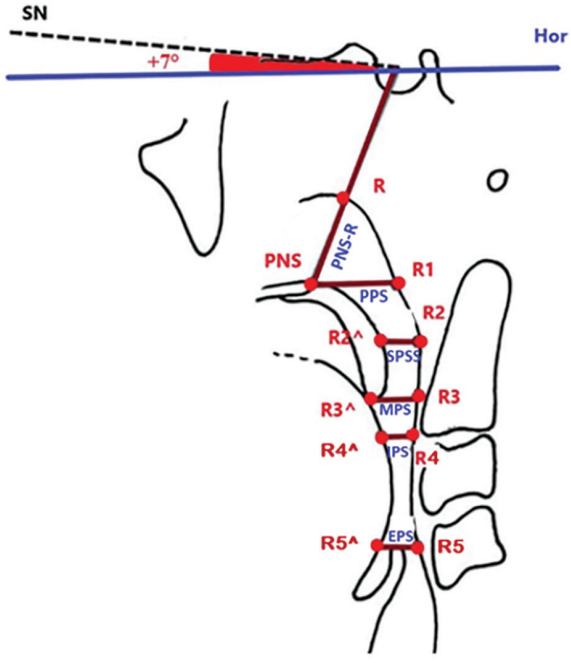

Figure 2. Pharyngeal Linear Measurements: PNS-R: distance between PNS and R points; PPS (PNS-R1): distance between PNS and R1 points (Palatal pharyngeal region). SPSS (R2-R2^): Superior posterior pharyngeal region MPS (R3-R3^): Middle pharyngeal region, IPS(R4-R4^): Inferior pharyngeal region, EPS (R5-R5^): Epiglottic pharyngeal region

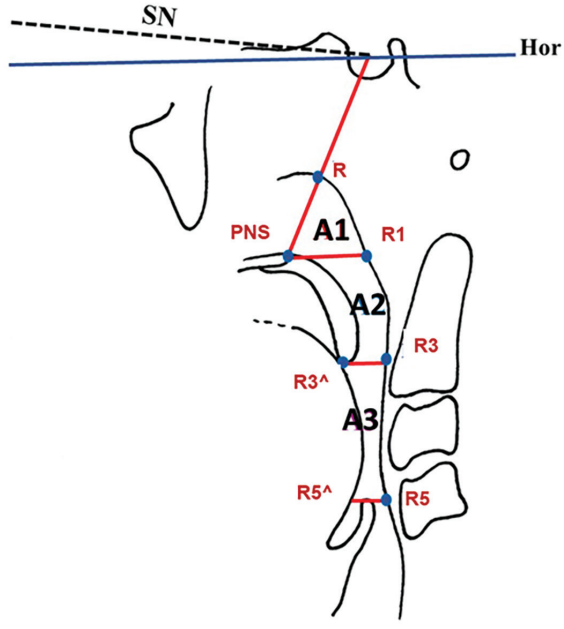

Figure 3. Pharyngeal Area Measurements: AREA 1 (A1): Nasopharyngeal Area; region bounded by the anterior and posterior pharyngeal walls between the PNS-R and PPS planes. AREA 2 (A2): Oropharyngeal area; region bounded by the anterior and posterior pharyngeal walls between the PPS and MPS planes. AREA 3 (A3): Hypopharyngeal Area; region bounded by the anterior and posterior pharyngeal walls between the MPS and EPS planes

Table 1. Comparison of the cephalometric measurements in pre-treatment (T1) periods between groups

Parameters	MA Group T1					2-JS Group T1					P value
	Mean	±SD	Median	Min.	Max.	Mean	±SD	Median	Min.	Max.	
Maxillary skeletal measurements											
SNA	77.46	3.74	79.50	70.4	81.2	78.58	3.78	77.95	73.8	87.1	0.887
A-Ver	61.17	5.25	61.50	52.3	68.7	60.63	4.90	61.40	52.2	68.7	0.815
A-Hor	51.43	2.98	52.00	44.7	55.3	51.72	3.12	52.05	45.8	58.1	0.962
Maxillary dental measurements											
U1i-Ver	63.88	5.24	64.90	55.8	69.6	61.83	5.48	61.45	53.9	72.0	0.289
U6t-Ver	33.86	5.10	33.70	23.0	40.9	33.29	4.92	33.25	24.6	39.8	0.873
U1i-Hor	73.88	5.28	74.70	60.8	81.1	75.16	4.22	75.00	68.4	82.0	0.131
U6t-Hor	65.19	4.36	64.60	56.1	71.7	66.87	3.48	67.15	61.5	72.8	0.441
Mandibular skeletal measurements											
SNB	70.30	3.77	71.50	64.6	75.8	69.11	3.19	68.35	65.2	76.5	0.203
B-Ver	45.68	7.64	47.70	33.4	57.9	39.90	7.13	38.15	31.0	53.0	0.055
B-Hor	86.59	7.17	85.40	73.1	99.7	91.20	4.19	90.50	86.0	99.5	0.032*
Pg-Ver	46.86	8.32	48.90	34.5	61.1	38.68	7.26	36.00	29.0	51.5	0.019*
Co-Gn	101.98	7.49	103.40	91.4	116.5	101.49	8.82	101.55	88.1	115.1	0.984
Go-Gn	66.39	3.68	64.80	61.4	72.7	64.20	6.05	65.65	53.0	72.3	0.872
Mandibular dental measurements											
L1i-Ver	55.88	5.68	56.60	47.6	63.5	53.97	7.51	52.8	42.7	67.0	0.257
L1i – Hor	67.81	6.68	67.70	54.6	79.9	70.13	7.19	71.05	50.4	78.4	0.138
Maxillo-mandibular skeletal measurements											
ANB	7.15	1.57	7.10	4.8	9.1	9.29	2.38	9.00	5.6	14.1	0.013*
GoGn/SN	34.52	7.57	34.30	22.8	45.5	41.94	6.87	43.10	27.1	50.8	0.032*
Maxillo-mandibular dental measurements											
Overjet	8.42	2.73	8.90	2.7	11.5	8.34	3.59	8.45	3.6	13.8	0.891
Overbite	6.10	3.44	6.90	-3.2	9.3	2.72	4.14	4.25	-9.1	5.6	0.003**
Soft tissue measurements											
Nasolabial angle	97.29	8.58	98.30	75.9	108.2	102.47	10.03	101.00	89.1	119.3	0.364
ULA-Ver	76.34	4.23	76.20	70.6	81.7	74.50	5.48	74.75	66.6	82.7	0.439
LLA-Ver	67.14	6.00	68.70	60.1	75.9	64.62	6.11	63.40	55.8	76.6	0.537
Pg'-Ver	59.64	8.59	63.10	48.5	74.0	53.01	6.85	52.50	43.5	65.3	0.086
Hyoidal measurements											
Hyoid-Ver	2.75	7.38	2.30	-10.7	14.4	-0.81	7.46	-0.80	-10.6	13.0	0.054
Hyoid-Hor	101.23	11.50	98.50	82.5	124.0	98.73	8.17	97.60	86.5	113.5	0.102
PAS linear measurements											
PNS-P	18.15	2.73	18.20	13.1	24.2	18.79	2.02	19.35	14.5	21.6	0.858
PPS	25.05	2.33	25.40	21.9	29.0	24.77	2.86	25.35	18.9	28.8	0.861
SPSS	9.30	3.41	8.90	3.3	14.8	11.10	2.47	11.95	6.0	13.7	0.476
MPS	9.96	2.70	10.10	5.4	14.2	9.55	1.55	9.75	7.0	12.0	0.983
IPS	8.67	2.96	7.90	4.1	13.7	9.28	3.67	9.75	2.9	14.0	0.791
EPS	9.22	2.57	9.10	4.8	13.4	11.72	3.00	10.90	7.2	17.0	0.279
PAS area measurements											
Area 1	306.20	65.10	291.05	202.51	430.17	350.43	68.15	349.97	236.55	440.12	0.052
Area 2	284.84	86.77	260.71	181.98	448.05	281.27	65.63	291.43	155.50	381.76	0.764
Area 3	208.46	34.80	216.14	148.96	277.03	238.46	98.87	206.07	112.33	427.20	0.173

SD indicates standard deviation; min., minimum value; and max., maximum value.
Mann-Whitney U test; P≤0.05*, P≤0.01**, P≤0.001***.
MA, mandibular advancement group; 2-JS, two-jaw surgery group; Ver, vertical reference plane; Hor, horizontal reference plane; Co, condylion; U1i, upper central incisor; U6t, upper first molar; L1i, lower central incisor; ULA, upper lip anterior; LLA, lower lip anterior; H, Hyoidale; PAS, pharyngeal airway space

Table 2. Pre- (T1) and post-treatment (T2) changes in cephalometric variables in the single-jaw mandibular advancement group

MA Group																
Parameters	T1					T2					T2-T1					P value
	Mean	±SD	Median	Min.	Max.	Mean	±SD	Median	Min.	Max.	Mean	±SD	Median	Min.	Max.	
Maxillary skeletal measurements																
SNA	77.46	3.74	79.50	70.4	81.2	77.53	3.78	79.90	70.0	81.5	0.07	0.45	0.20	-0.50	0.90	0.289[a]
A-Ver	61.17	5.25	61.50	52.3	68.7	62.07	6.51	63.40	53.5	76.3	0.90	2.79	1.00	-3.20	7.60	0.920
A-Hor	51.43	2.98	52.00	44.7	55.3	51.67	4.26	53.00	41.7	56.4	0.24	2.85	0.70	-7.10	5.40	0.635
Maxillary dental measurements																
U1i – Ver	63.88	5.24	64.90	55.8	69.6	64.58	7.05	67.00	54.4	79.2	0.70	3.65	0.20	-3.70	9.70	0.667
U6t-Ver	33.86	5.10	33.70	23.0	40.9	35.70	5.38	35.10	28.1	47.4	1.84	2.67	1.40	-2.00	6.50	0.299
U1i-Hor	73.88	5.28	74.70	60.8	81.1	75.70	5.60	74.50	62.7	81.9	1.81	2.61	1.60	-1.20	8.90	0.028*
U6t-Hor	65.19	4.36	64.60	56.1	71.7	66.20	4.93	65.50	56.1	73.3	1.01	2.21	0.50	-1.70	7.20	0.416
Mandibular skeletal measurements																
SNB	70.30	3.77	71.50	64.6	75.8	73.88	3.64	74.00	68.2	79.2	3.57	1.08	3.60	1.90	5.30	0.008**
B-Ver	45.68	7.64	47.70	33.4	57.9	51.42	8.09	52.00	42.4	66.7	5.74	4.52	4.40	0.80	14.90	0.004**
B-Hor	86.59	7.17	85.40	73.1	99.7	91.36	7.73	91.40	76.1	104.5	4.77	3.78	4.20	0.60	15.20	0.003**
Pg-Ver	46.86	8.32	48.90	34.5	61.1	52.19	9.49	52.70	41.2	67.8	5.32	4.59	3.80	-0.10	13.90	0.004**
Co-Gn	101.98	7.49	103.40	91.4	116.5	108.69	9.49	108.80	93.2	121.5	7.71	6.12	5.50	1.80	5.00	0.003**
Go-Gn	66.39	3.68	64.80	61.4	72.7	70.92	5.44	71.00	62.0	80.1	4.53	2.52	5.30	-0.60	7.40	0.007**
Mandibular dental measurements																
L1i-Ver	55.88	5.68	56.60	47.6	63.5	61.74	7.00	63.60	52.2	76.5	5.86	4.03	4.60	1.30	15.30	0.002**
L1i-Hor	67.81	6.68	67.70	54.6	79.9	72.89	5.64	74.40	59.8	79.4	5.08	3.43	-0.40	-9.2	13.9	0.006**
Maxillo-mandibular skeletal measurements																
ANB	7.15	1.57	7.10	4.8	9.1	3.61	2.18	3.90	-0.8	6.5	-3.27	1.47	3.50	-5.50	-2.50	0.002**
GoGn/SN	34.52	7.57	34.30	22.8	45.5	36.88	7.78	36.80	25.0	45.9	2.31	1.56	2.00	0.50	4.50	0.009**
Maxillo-mandibular dental measurements																
Overjet	8.42	2.73	8.90	2.7	11.5	3.31	0.92	0.92	3.50	2.0	-5.11	2.72	-5.40	-8.90	0.20	0.003**
Overbite	6.10	3.44	6.90	-3.2	9.3	2.67	1.03	1.03	2.50	0.6	-3.43	3.39	-4.60	-6.80	4.70	0.011*
Soft tissue measurements																
Nasolabial angle	97.29	8.58	98.30	75.9	108.2	97.73	9.49	99.70	85.3	111.8	0.44	9.11	0.8	-13.8	12.0	0.082[a]
ULA-Ver	76.34	4.23	76.20	70.6	81.7	78.01	7.15	79.70	68.0	94.4	1.67	4.38	0.3	-2.6	12.7	0.093
LLA-Ver	67.14	6.00	68.70	60.1	75.9	72.63	7.76	73.50	62.4	88.0	5.49	4.41	3.9	1.2	15.0	0.007**
Pg'-Ver	59.64	8.59	63.10	48.5	74.0	65.86	9.20	66.20	54.7	80.8	6.21	4.93	4.2	0.7	15.3	0.006**

Table 2. Continued

MA Group														
Parameters	T1					T2					T2-T1				P value
	Mean	±SD	Median	Min.	Max.	Mean	±SD	Median	Min.	Max.	Mean	±SD	Median	Min.	Max.	
Hyoidal measurements																
Hyoid-Ver	2.75	7.38	2.30	-10.7	14.4	6.78	6.93	6.60	-2.3	21.6	4.02	3.45	4.60	-2.3	9.9	0.005**
Hyoid-Hor	101.23	11.50	98.50	82.5	124.0	101.73	11.25	95.50	88.0	119.9	0.50	5.26	0.80	-9.6	9.8	0.645
PAS linear measurements																
PNS-P	18.15	2.73	18.20	13.1	24.2	18.38	2.96	17.70	13.1	24.4	0.22	1.07	0.20	-1.60	2.20	0.843
PPS	25.05	2.33	25.40	21.9	29.0	25.85	2.85	26.00	21.7	31.1	0.80	1.27	0.80	-1.00	2.10	0.786
SPSS	9.30	3.41	8.90	3.3	14.8	12.32	3.04	11.90	7.4	17.9	3.01	1.85	2.60	0.60	6.50	0.008**
MPS	9.96	2.70	10.10	5.4	14.2	13.50	2.10	13.90	9.7	16.6	3.53	1.90	3.80	0.40	6.70	0.009**
IPS	8.67	2.96	7.90	4.1	13.7	11.46	2.07	12.30	6.8	14.1	2.79	2.09	2.00	0.40	7.20	0.006**
EPS	9.22	2.57	9.10	4.8	13.4	12.59	2.13	13.60	8.6	14.9	3.36	1.66	3.50	0.90	6.20	0.007**
PAS area measurements																
Area 1	306.20	65.10	291.05	202.51	430.17	317.67	67.90	308.42	222.70	428.73	11.46	2.73	2.88	-27.88	77.63	0.028*
Area 2	284.84	86.77	260.71	181.98	448.05	367.09	97.21	314.18	265.29	556.92	82.24	52.41	67.89	36.21	226.55	0.004**
Area 3	208.46	34.80	216.14	148.96	277.03	276.28	54.16	278.65	162.65	394.48	67.81	42.55	66.93	8.19	168.04	0.006**

SD indicates standard deviation; min., minimum value; and max., maximum value. P≤0.05*, P≤0.01**, P≤0.001***
Paired t-tests were performed to compare the changes in posttreatment (T2) and pretreatment (T1), with the exception of a, which showed the results of the Wilcoxon signed-rank test
MA, mandibular advancement group; Ver, vertical reference plane; Hor, horizontal reference plane; Co, Condylion; U1i, upper central incisor; U6t, upper first molar; L1i, lower central incisor; ULA, upper lip anterior; LLA, lower lip anterior; H, hyoidale; PAS, pharyngeal airway space

increases were found in all linear measurements of the oropharyngeal and hypopharyngeal airway (P<0.01). A significant increase was found in all pharyngeal airway area measurements (A1, P<0.05; A2, P<0.01; A3, P<0.01) (Table 2).

Changes in the craniofacial and hyoid position and PAS measurements from T1 to T2 in 2-JS are presented in Table 3. A significant decrease was observed in A-Hor and U6t-Hor (P<0.01); however, the decrease in GoGn/SN value was not significant (P>0.05). Significant increases were detected in all measurements, including sagittal mandibular skeletal, dental, and soft tissue changes (P<0.01; P<0.05). Significant decreases were found in ANB (-2.13°) and overjet (-4.91 mm) values (P<0.01). A significant increase was found in the Hyoid Vertex (3.55 mm; P<0.05), whereas a significant decrease was detected in Hyoid-Hor (-4.43 mm; P<0.01). A significant decrease (P<0.01) was observed in PNS-P, one of the linear measurements of PAS, whereas significant increases were observed in all other linear measurements (P<0.01; P<0.05). A significant decrease was found in A1 (-52.25 mm^2; P<0.01), whereas significant increases were found in A2 (81.58 mm^2; P<0.01) and A3 (54.30 mm^2; P<0.05) (Table 3).

The comparison of differences from T1 to T2 between groups is presented in Table 4. The increase in A-Hor (P<0.01), U1i-Hor (P<0.05), U6t-Hor (P<0.001), B-Hor (P<0.001), L1i-Hor (P<0.001) and GoGn/SN (P<0.01), which are the parameters used in the vertical direction evaluation, increased in the MA group and the decrease in the 2-JS group was found to be significant in the comparison between groups. On the contrary, the decrease in the overbite value in the MA group and the increase in the 2-JS group were statistically significant compared with the time-dependent comparison of the groups (P<0.01). Increases in Hyoid-Hor (P<0.05) in MA and decreases in 2-JS showed significant differences between groups. In addition, the increase in PNS-P and A1 values from T1 to T2 in the MA group (P<0.01) and the decrease in the 2-JS group (P<0.001) were statistically significant in the comparison between groups (Table 4).

DISCUSSION

Although orthognathic surgery is known to improve the quality of life of patients with severe skeletal Class II malocclusion, there are still concerns regarding its treatment.[12] In addition to complaints of pain in the orofacial region, these patients had the highest rates of functional problems and a

Table 3. Pre- (T1) and post-treatment (T2) changes in cephalometric variables in the two-jaw surgery group.

2-JS Group																
Parameters	T1					T2					T2-T1					P value
	Mean	±SD	Median	Min.	Max.	Mean	±SD	Median	Min.	Max.	Mean	±SD	Median	Min.	Max.	
Maxillary skeletal measurements																
SNA	78.58	3.78	77.95	73.8	87.1	79.22	3.81	78.70	74.9	88.0	0.64	0.30	0.60	0.20	1.10	0.009**
A-Ver	60.63	4.90	61.40	52.2	68.7	61.69	5.45	61.00	53.5	76.3	1.19	1.25	1.30	-1.00	3.30	0.028*
A-Hor	51.72	3.12	52.05	45.8	58.1	49.84	2.65	49.70	45.4	54.3	-1.88	1.43	-1.25	-4.50	-0.40	0.003a**
Maxillary dental measurements																
U1i-Ver	61.83	5.48	61.45	53.9	72.0	61.79	6.35	60.80	52.0	71.6	-0.04	3.01	-0.30	-6.50	4.10	0.454
U6t-Ver	33.29	4.92	33.25	24.6	39.8	35.05	4.94	34.50	27.0	41.4	1.76	3.18	2.05	-3.50	9.00	0.536
U1i-Hor	75.16	4.22	75.00	68.4	82.0	74.22	3.44	73.55	68.1	79.0	-0.94	2.06	-0.60	-4.50	2.30	0.513
U6t-Hor	66.87	3.48	67.15	61.5	72.8	64.05	3.75	64.85	56.5	70.1	-2.82	1.46	-3.00	-5.00	-0.50	0.008**
Mandibular skeletal measurements																
SNB	69.11	3.19	68.35	65.2	76.5	72.06	3.04	71.05	68.9	79.8	2.95	0.72	2.95	1.9	4.2	0.002**
B-Ver	39.90	7.13	38.15	31.0	53.0	45.16	6.08	43.60	38.0	55.5	5.26	2.09	6.25	1.50	7.20	0.002**
B-Hor	91.20	4.19	90.50	86.0	99.5	90.05	3.17	89.80	84.5	97.6	-1.14	2.76	-0.50	-6.60	3.30	0.762
Pg-Ver	38.68	7.26	36.00	29.0	51.5	44.76	6.95	42.85	36.5	56.0	6.08	3.18	6.80	0.50	11.90	0.002**
Co-Gn	101.49	8.82	101.55	88.1	115.1	104.90	8.26	105.40	89.6	120.8	3.54	3.21	2.50	-1.00	9.00	0.004**
Go-Gn	64.20	6.05	65.65	53.0	72.3	66.47	6.58	67.25	52.7	75.9	2.27	1.90	1.75	-0.30	5.40	0.003**
Mandibular dental measurements																
L1i-Ver	53.97	7.51	52.8	42.7	67	58.86	6.41	57.80	50.0	70.0	4.89	3.21	4.20	0.30	10.70	0.002**
L1i-Hor	70.13	7.19	71.05	50.4	78.4	69.78	6.68	70.50	51.4	77.4	-0.35	1.86	-1.20	-2.40	3.5	0.051a
Maxillo-mandibular skeletal measurements																
ANB	9.37	2.38	9.00	5.6	14.1	7.15	2.09	7.10	4.2	11.8	-2.13	0.80	-2.1	-3.4	-0.9	0.009**
GoGn/SN	41.94	6.87	43.10	27.1	50.8	40.90	7.59	40.35	28.1	55.1	-1.04	2.90	-1.35	-5.20	5.80	0.970
Maxillo-mandibular dental measurements																
Overjet	8.34	3.59	8.45	3.6	13.8	3.42	1.41	3.25	1.2	6.0	-4.91	3.23	-4.60	-10.20	0.30	0.004**
Overbite	2.72	4.14	4.25	-9.1	5.6	3.00	1.03	3.00	1.0	5.1	0.28	3.52	-1.50	-2.20	10.10	0.270a
Soft tissue measurements																
Nasolabial angle	102.47	10.03	101.00	89.1	119.3	103.70	8.79	104.25	90.7	123.3	1.23	11.31	4.65	-14.1	14.7	0.092
ULA-Ver	74.50	5.48	66.6	82.7	75.90	75.90	5.47	74.10	70.0	85.2	1.40	4.60	0.35	-3.8	11.6	0.993
LLA-Ver	64.62	6.11	63.40	55.8	76.6	67.46	5.32	66.60	59.0	78.0	2.84	4.37	3.50	-4.40	8.00	0.016*
Pg'-Ver	53.01	6.85	52.50	43.5	65.3	58.91	7.32	57.80	49.0	69.6	5.90	3.09	5.80	0.50	11.70	0.007**

Table 3. Continued

2-JS Group														
Parameters	T1					T2					T2-T1				P value
	Mean	±SD	Median	Min.	Max.	Mean	±SD	Median	Min.	Max.	Mean	±SD	Median	Min.	Max.	
Hyoidal measurements																
Hyoid-Ver	-0.81	7.46	-0.80	-10.6	13.0	2.74	7.44	3.30	-7.0	19.5	3.55	3.94	3.80	-4.60	11.50	0.021*
Hyoid-Hor	98.73	8.17	97.60	86.5	113.5	94.30	8.51	94.55	80.6	110.0	-4.43	4.43	-3.55	-13.80	0.00	0.006**
PAS linear measurements																
PNS-P	18.79	2.02	19.35	14.5	21.6	16.95	2.88	17.60	11.1	21.6	-1.83	1.97	-1.60	-5.10	1.90	0.009**
PPS	24.77	2.86	25.35	18.9	28.8	26.13	3.19	26.50	20.5	31.8	1.35	1.66	1.20	-0.60	5.10	0.014*
SPSS	11.10	2.47	11.95	6.0	13.7	13.59	2.70	12.85	9.0	18.8	2.48	2.12	2.50	-1.10	6.20	0.008**
MPS	9.55	1.55	9.75	7.0	12.0	12.00	2.68	11.75	8.0	16.9	2.44	1.65	1.95	0.00	5.60	0.006**
IPS	9.28	3.67	9.75	2.9	14.0	12.55	3.69	12.75	6.5	20.0	3.26	2.39	3.40	0.00	6.90	0.006**
EPS	11.72	3.00	10.90	7.2	17.0	14.23	2.91	15.10	9.0	18.0	2.50	2.04	2.35	-0.20	5.70	0.005a**
PAS area measurements																
Area 1	350.43	68.15	349.97	236.55	440.12	298.18	86.10	300.18	149.70	414.43	-52.25	33.59	-49.31	-126.33	-8.34	0.036**
Area 2	281.27	65.63	291.43	155.50	381.76	362.85	79.54	361.56	232.11	494.41	81.58	59.03	64.24	-26.00	188.70	0.003**
Area 3	238.46	98.87	206.07	112.33	427.20	292.76	117.83	299.06	128.92	494.22	54.30	65.85	28.48	-48.01	176.33	0.014*

SD indicates standard deviation; min, minimum value; and max, maximum value. P≤0.05*, P≤0.01**, P≤0.001***
Paired t-tests were performed to compare the changes in post-treatment (T2) and pre-treatment (T1), with the exception of [a], which showed the results of the Wilcoxon signed-rank test.
2-JS, Two-jaw surgery group; Ver, Vertical Reference Plane; Hor, Horizontal Reference Plane; Co, Condylion; U1i, Upper cental incisor; U6t, Upper first molar; L1i, Lower central incisor; ULA, Upper lip anterior; LLA, Lower lip anterior; H, Hyoidale; PAS, Pharyngeal airway space

history of TMD compared with other types of malocclusion.[13,14] Therefore, the expectations of these patients regarding treatment are quite high. Although patients with severe skeletal Class III malocclusion require orthognathic surgery due to aesthetic complaints, this demand may not be valid for individuals with skeletal Class II malocclusion.[15]

Although 3D computed tomography imaging is considered the gold standard for the evaluation of PAS, it is not ethical to obtain multiple tomography images from patients. For this reason, two-dimensional (2D) lateral cephalometric radiographs were used in our study. Moreover, in this study, in which we examined the changes that occur as a result of the treatment of skeletal Class II malocclusion with orthognathic surgery, we decided to evaluate the area of the pharyngeal airway. For this purpose, as in previous studies, digital planimeter was used.[16,17]

Establishing cranial base references and coordinate systems is of great importance in the evaluation of changes in the maxillofacial system. The Sella-Nasion (SN) plane is often used as a reference for lateral cephalometric radiograph analysis. However, using the S-N reference plane may cause some measurement errors. Proffit et al.[18] introduced the horizontal reference plane, which is the horizontal plane below the SN plane and drawn at an angulation of 6° with the SN plane. At the same time, a plane perpendicular to the horizontal reference plane was drawn from the Sella Point, and this plane was accepted as the vertical reference plane. In this study, as in previous studies, the horizontal reference plane obtained at an angulation of 7° with the SN plane and the vertical reference plane drawn perpendicularly to the horizontal reference plane from the Sella point were created.[17,19]

According to this study, the 2-JS group had increased vertical dimensions (GoGn/SN, 41.94°; B-Hor, 91.20 mm) and more severe skeletal Class II malocclusion (ANB, 9.29°) than the MA group in T1. The combination of orthodontic treatment and bimaxillary orthognathic surgery is usually indicated for the treatment of adults with high-angle skeletal Class II malocclusion.[20] Maxillary impaction with Le Fort I osteotomy provides good skeletal stability in high angle patients with skeletal open bite. Therefore, intrusion of the maxilla with Lef Fort I osteotomy and counterclockwise rotation of the mandible in patients with Class II skeletal malocclusion who have increased facial height is expected to be advantageous in terms of treatment.[21,22] In summary, it can be said that the main difference between groups is due to

Table 4. Comparison of T2–T1 changes in cephalometric variables between groups

Parameters	MA Group T2-T1		2-JS Group T2-T1		P value
	Mean	±SD	Mean	±SD	
Maxillary skeletal measurements					
SNA	0.07	0.45	0.64	0.30	0.003**
A-Ver	0.90	2.79	1.19	1.25	0.405
A-Hor	0.24	2.85	-1.88	1.43	0.004**
Maxillary dental measurements					
U1i-Ver	0.70	3.65	-0.04	3.01	0.054
U6t-Ver	1.84	2.67	1.76	3.18	0.901
U1i-Hor	1.81	2.61	-0.94	2.06	0.011*
U6t-Hor	1.01	2.21	-2.82	1.46	0.000***
Mandibular skeletal measurements					
SNB	3.57	1.08	2.95	0.72	0.513
B-Ver	5.74	4.52	5.26	2.09	0.736
B-Hor	4,77	3,78	-1,14	2,76	0.000***
Pg-Ver	5.32	4.59	6.08	3.18	0.133
Co-Gn	7.71	6.12	3.54	3.21	0.064
Go-Gn	4.53	2.52	2.27	1.90	0.023*
Mandibular dental measurements					
L1i-Ver	5.86	4.03	4.89	3.21	0.204
L1i-Hor	5.08	3.43	-0.35	1.86	0.007**
Maxillo-mandibular skeletal measurements					
ANB	-3.27	1.47	-2.13	0.80	0.748
GoGn/SN	2.31	1.56	-1.04	2.90	0.002**
Maxillo-mandibular dental measurements					
Overjet	-5.11	2.72	-4.91	3.23	0.559
Overbite	-3.43	3.39	0.28	3.52	0.004**
Soft tissue measurements					
Nasolabial angle	0.44	9.11	1.23	11.31	0.788
ULA-Ver	1.67	4.38	1.40	4.60	0.958
LLA-Ver	5.49	4.41	2.84	4.37	0.116
Pg'-Ver	6.21	4.93	5.90	3.09	0.766
Hyoidal measurements					
Hyoid-Ver	4.02	3.45	3.55	3.94	0.763
Hyoid-Hor	0.50	5.26	-4.43	4.43	0.013*
PAS linear measurements					
PNS-P	0.22	1.07	-1.83	1.97	0.004**
PPS	0.80	1.27	1.35	1.66	0.673
SPSS	3.01	1.85	2.48	2.12	0.741
MPS	3.53	1.90	2.44	1.65	0.702
IPS	2.79	2.09	3.26	2.39	0.574
EPS	3.36	1.66	2.50	2.04	0.559
PAS area measurements					
Area 1	11.46	25.73	-52.25	33.59	0.000***
Area 2	82.24	52.41	81.58	59.03	0.833
Area 3	67.81	42.55	54.30	65.85	0.353

Data presented as mean ± standard deviation, P≤0.05*, P≤0.01**, P≤0.001*** Mann Whitney-U test
MA, Mandibular advancement group; 2-JS, Two-jaw surgery group; Ver, Vertical Reference Plane; Hor, Horizontal Reference Plane; Co, Condylion; U1i, Upper central incisor; U6t, Upper first molar; L1i, Lower central incisor; ULA, Upper lip anterior; LLA, Lower lip anterior; H, Hyoidale; PAS, Pharyngeal airway space

the inclusion of a vertical component in addition to sagittal malocclusion in the 2-JS group.

In the current study, due to MA, the hyoid bone moved significantly anteriorly by approximately 4.02 mm, and this finding was similar to previous study results.[23-26] At the same time, as in a previous study, significant increases were observed in all linear measurements below the level of the soft palate in the MA group. [27] These increases can be associated with anterior movement of the mandible and hyoid bone and anterior stretching of the muscles forming the anterior pharyngeal wall and posterior tongue muscles. Similar to the findings of many studies after MA, increases were observed in all areas, including the nasopharyngeal airway area.[26,28] Although there was no maxillary surgery, the risk of upper airway collapse was reduced with anterior movement of the tongue as a result of the surgery.

In the 2-JS group, after Le Fort I maxillary impaction and MA surgery, the hyoid bone was displaced anteriorly and superiorly following the movement of the mandible in the anterior and superior directions, similar to previous studies.[4,29] Additionally, statistically significant increases were observed in the oropharyngeal and hypopharyngeal areas as well as all dimensional measurements below the PNS in the 2-JS group.[27,29] Therefore, it should not be forgotten that the mandible and hyoid bone are not structures independent of the pharyngeal airway. Thus, it can be concluded that these increases are related to the anterior movement of the mandible and hyoid bones and their associated muscles. Moreover, decreases in the PNS-P value and nasopharyngeal area were also detected due to maxillary impaction surgery, similar to the finding of Vijayakumar Jain et al. [30] The reason for the decrease in nasopharyngeal area as a result of maxillary impaction can be explained by the impaction of the posterior region of the maxilla onto the upper and posterior parts of the pharyngeal walls, resulting in a more limited area in PAS, as well as the decrease in A-Hor.

In the comparison of the T2-T1 periods between groups, significant differences occurred due to the decrease in A-Hor, B-Hor, GoGn-SN, which are skeletal parameters, and U1-iHor, U6t-Hor, and L1i-Hor values, which are dental measurements, as a result of the superior movement of the maxilla and the anterior rotation of the mandible after the maxillary impaction surgery performed in the 2-JS group. In addition, the significant difference in the H-Hor value in the time-dependent comparison between the groups can be interpreted as the counterclockwise rotation of the mandible as a result of the impaction of the maxilla in the 2-JS group and, accordingly, superior follow-up of the hyoid bone.[4,29] In the comparison of the changes in the T2-T1 periods of both surgical approaches, a significant difference was found between the groups as a result of the decrease in the PNS-P value and nasopharyngeal area due to the superior movement of the maxilla after maxillary impaction surgery in 2-JS.[30]

Study Limitations

One of the main shortcomings of this study was the absence of a control group. The second limitation was the lack of long-term follow-up of the study groups. More studies, including a control group and long-term follow-up, are needed to examine the airway with 3D imaging. However, for ethical reasons, we preferred 2D analysis in this study.

CONCLUSION

Our findings indicated that single MA and combined Le Fort I maxillary impaction and MA surgery were viable options for widening the oropharyngeal and hypopharyngeal airway spaces in Class II skeletal patients. However, the decrease in linear and area measurements of the nasopharyngeal airway after 2J-S was noteworthy, which is generally preferred in patients with increased facial height and more severe skeletal Class II malocclusion. Although the hyoid bone was clearly displaced forward in both groups, the hyoid bone was positioned superiorly in the 2J-S group.

Ethics

Ethics Committee Approval: The study was approved by the Ankara University Faculty of Dentistry Clinical Research Ethics Committee (approval no.: 36290600/70, date: 07.07.2017).

Informed Consent: This retrospective study was conducted using data obtained from patients at Ankara University Faculty of Dentistry, Department of Orthodontics and Maxillofacial Surgery.

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Conflict of Interest: The authors have no conflicts of interest to declare.

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Original Article

Bibliometric Analysis of Maxillary Expansion Publications Trends

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Main Points

- Maxillary expansion is associated with orthodontics and many other disciplines.
- Maxillary expansion studies have remained popular over the years and have been published in many high-impact journals.

ABSTRACT

Objective: Maxillary expansion is a common treatment in clinical orthodontics and can be performed in a wide age range using different methods. This bibliometric analysis aims to provide an overview of research on maxillary expansion.

Methods: A literature search was performed in the Web of Science database, and publications related to maxillary expansion between 1970 and 2023 were included. Data, including titles, abstracts, keywords, countries, regions, and references, were exported and analyzed within the scope of the bibliometric indicators.

Results: The study was conducted on 2633 publications. Between 1970 and 2023, research on maxillary expansion showed a general upward trend in the number of publications. From the analyzed publications, we observed that rapid maxillary expansion (RME) was the most common type of maxillary expansion, accounting for 78% of all publications. Most publications originated from the United States (24.3%), and these articles were also the most cited (17180). Lorenzo Franchi contributed the most publications (85, 3.2%) and was cited 2830 times for maxillary expansion. The highest number of publications was from the University of Sao Paolo (119), and the most cited institution was the University of Florence (3287).

Conclusion: The bibliometric indicators showed a rapid increase in the number of published works on the topic of maxillary expansion, particularly in recent years. Advances in patient evaluation (3D imaging, modeling) and application methods (mini-screws, clear aligners) appear to have helped to maintain the popularity of maxillary expansion. We also observed that maxillary expansion is associated with several other specialties in addition to dentistry.

Keywords: Bibliometric analysis, maxillary expansion, rapid maxillary expansion

INTRODUCTION

Posterior crossbite, the prevalence of which is reported to vary between 8% and 22%, is one of the most common malocclusions in deciduous and early mixed dentition.[1-5] Studies have shown that this problem does not correct spontaneously, and orthodontic intervention is needed.[1] Maxillary expansion is an effective orthodontic treatment for correcting malocclusion caused by transverse maxillary deficiency or posterior crossbite occurs.[6-8] In maxillary expansion treatment initiated in the early mixed dentition stage, the desired effect can be achieved

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with lower forces because the mid-palatal suture has not yet been fused. However, for older children (12 years and older), greater forces may be required to achieve maxillary expansion in the early permanent dentition.[7] Maxillary expansion treatment can be performed in rapidly, semi-rapidly, or slowly using fixed or removable appliances.[7,9] When the expansion occurs at a rate of 0.5 mm/day, it is referred to as "rapid"; when expansion is achieved at a rate of 1 mm/week, it is referred to as "semi-rapid". When expansion occurs at a rate of 0.5 mm/week, it is named as "slow".[7,10] Beyond orthodontic purposes, some studies have shown that maxillary expansion therapy has positive effects on nocturnal enuresis, conductive hearing loss, nasal airway width, and resistance.[11-13]

Bibliometric analysis is an important statistical tool for mapping state-of-the-art research areas and it comprehensively describes the relationship between data by creating an information map.[14-16] Bibliometric analysis provides the opportunity to statistically evaluate the entire literature body according to specific criteria.[17,18] Bibliometric studies also allow comparisons between countries, institutions, and authors. The main objectives of such studies are to identify the analyzed subject's chronological trends, show the number of citations, and highlight evidence-based studies.[19,20] By creating a relationship map between the data from the maxillary expansion procedure, which is a fundamental orthodontic treatment method, we can obtain summarized and precise information about the studies, authors, and countries.

Although there have been many studies on maxillary expansion over the years, no bibliometric analysis of this topic has been performed. In this study, we aimed to provide an overview of the subject and give researchers an idea about future study priorities by identifying the most frequently used keywords, most preferred journals, most cited publications, researchers, institutions, countries, and collaborations in publications related to maxillary expansion.

METHODS

The search was conducted in the Web of Science (WoS) database, initially hosted by the Institute for Scientific Information and later maintained by Clarivate Analytics. The literature search was conducted in February 2023. Articles published before February 27, 2023, were screened, and pilot searches were conducted to develop the search strategy. The electronic search was limited to "topics" including titles, abstracts, and keywords. Filtering was performed to enhance and limit the search. During filtering, "article", "proceeding paper", "review", and "early access" were selected as document types. In the screening process, the article language was set to English, and only articles published in this language were included in the study.

By using the "analyze results" option in the WoS database, it was possible to access information on which authors had the most articles and citations on this topic, as well as which countries and universities conducted more research. In addition, graphical representations of these data were accessed from the "analyze results" option, and these graphs were added to the study.

Statistical Analysis

The VOSviewer (Center for Science and Technology Studies, Leiden University, Holland) bibliometric analysis program was used to analyze the data obtained.[21,22] VOSviewer version 1.6.18, released on January 24, 2022, was downloaded free of charge from the program's official site.[19] Data in ".txt" and ".xls" types, which were previously exported, transferred to the VOSviewer program and processed.[22-24] The number of collaborations and citations was visualized by network type or overlap with the help of VOSviewer software. For the co-authors, a network-type visualization was presented in which bubbles of the same color formed clusters, indicating the close collaborations made due to the research. In this visual map, the size of the bubble reflected the number of publications, the distance between the bubbles reflected the relationship between the two items, and the color of each dot has different meanings in different visual maps.

RESULTS

A total of 2711 articles were found when "palat* expan*" OR "maxill* expan*" OR "midpalatal suture*" was typed into the search bar. In the first search, the titles and abstracts of the articles were scanned by a single author, and only articles related to maxillary expansion were included. Then, the full texts of the articles suspected to be relevant to the topic were opened and examined in detail. A total of 78 articles were found to be irrelevant and eliminated. After all these screening and filtering procedures, the study was conducted on 2633 publications, which were published from 1970 to 2023 according to the WoS database. When a separate investigation was made of these publications as "RME" OR "rapid maxil* exp*" OR "rapid pal* exp*", it was seen that 2033 out of 2633 publications were related to RME. It was observed that the number of published articles increased each year compared with the previous year. Publications on maxillary expansion received 47794 citations; 21981 citations were from authors other than the authors themselves. The average number of citations per article was 18.15, and the H index was 88. A large proportion (87.771%) of the publications on maxillary expansion were "article" type documents. Information on specific topics, such as title, author, journal, publication date, total number of citations, and annual average, was obtained from the database, and tables were created. The most cited 20 articles on "maxillary expansion" are shown in Table 1. Since 1970, the annual number of articles and citations is shown in Figure 1. The distribution of network structures resulting from bibliometric analyses according to authors, institutions, and countries are shown in Figures 2-4, respectively). Lorenzo Franchi seems to have been the most active author on maxillary expansion (85 articles, 2830 citations). Data related to authors, countries, and institutions regarding maxillary expansion are presented in Tables 2-4.

Table 1. Most cited 20 articles

Titles	Authors	Journals	Publication year	Total citations	Average per year	The type of study
Diagnosis And Management Of Childhood Obstructive Sleep Apnea Syndrome	Marcus CL, Brooks LJ, Draper KA, Gozal D, Halbower AC, Jones J, Schechter MS, Ward SD, Sheldon SH, Shiffman RN, Lehmann C, Spruyt K; American Academy of Pediatrics	Pediatrics	2012	867	72.25	Article
Palatal Expansion: The Just Beginning Of Dentofacial Orthopedics	Haas AJ	American Journal Of Orthodontics	1970	471	8.72	Article
Skeletal And Dental Changes Accompanying Rapid Midpalatal Suture Opening	Wertz RA	American Journal Of Orthodontics	1970	445	8.24	Review
Obstructive Sleep Disordered Breathing in 2- to 18-year-old Children: Diagnosis And Management	Kaditis AG, Alvarez MLA, Boudewyns A, Alexopoulos EI, Ersu R, Joosten K, Larramona H, Miano S.	European Respiratory Journal	2016	371	46.38	Article
Maxillary Expansion: Clinical implications	Bishara SE, Staley RN	American Journal Of Orthodontics And Dentofacial Orthopedics	1987	292	7.89	Article
Long-Term Post-Treatment Evaluation Of Rapid Palatal Expansion	Haas, AJ	Angle Orthodontist	1980	247	5.61	Article
Treatment Timing For Rapid Maxillary Expansion	Baccetti T, Franchi L, Cameron CG, Mcnamara JA Jr	Angle Orthodontist	2001	241	10.48	Article
Skeletal Effects Of Early Treatment for Class Iii Malocclusion With Maxillary Expansion and Face Mask Therapy	Baccetti T, Mcgill JS, Franchi L, Mcnamara JA, Tollaro I	American Journal Of Orthodontics And Dentofacial Orthopedics	1998	236	9.08	Article
Stimulatory Effects Of Low-Power Laser Irradiation On Bone Regeneration in Midpalatal Sutures during Expansion in Rats	Saito S, Shimizu N	American Journal Of Orthodontics And Dentofacial Orthopedics	1997	228	2.44	Article
Practice Parameters for Respiratory Indications For Polysomnography In Children	Aurora RN, Zak RS, Karippot A, Lamm CI, Morgenthaler TI, Auerbach SH, Bista SR, Casey KR, Kristo DA, Ramar K	Sleep	2011	194	17.64	Article
A Review Of Maxillary Expansion in Relation to the Rate of Expansion and Patient Age	Bell RA	American Journal Of Orthodontics And Dentofacial Orthopedics	1982	195	4.64	Article
Clinical Recommendations Regarding the Use of Cone Beam Computed Tomography In Orthodontics. Position Statement of the American Academy Of Oral And Maxillofacial Radiology	Evans CA, Scarfe WC, ; Ahmad M, Cevidanes LHS, Ludlow JB, Palomo JM, Simmons KE, White SC Group Author: Amer Acad Oral Maxillofacial Radiography	Oral Surgery, Oral Medicine, Oral Pathology, Oral Radiology	2013	194	17.64	Article
Effectiveness of Protraction Face Mask Therapy: A Meta-Analysis	Kim JH, Viana MAG, Graber TM, Omerza FF, Begole EA	American Journal Of Orthodontics And Dentofacial Orthopedics	1999	188	7.52	Meta Analysis
Long-Term Effects Of Class Iii Treatment With Rapid Maxillary Expansion And Facemask Therapy Following Fixation	Westwood PV, McNamara JA Jr, Baccetti T, Franchi L, Sarver DM	American Journal Of Orthodontics And Dentofacial Orthopedics	2003	184	8.76	Article
Rapid Maxillary Expansion-Tooth Tissue-Borne Versus Tooth-Borne Expanders: A Computed Tomography Evaluation Of Dentoskeletal Effects	Garib DG, Henriques JFC, Janson G, Freitas MR, Coelho RA.	Angle Orthodontist	2005	182	9.58	Article

Table 1. Continued

Title	Author	Journals	Publication year	Total citations	Average per year	The type of study
Cytokine Expression Patterns on the Compression and Tension Sides Of The Periodontal Ligament During Orthodontic Tooth Movement In Humans	Garlet TP, Coelho U, Silva JS, Garlet GP	European Journal Of Oral Sciences	2007	178	10,47	Article
Surgically Assisted Rapid Palatal Expansion: A Literature Review	Suri L, Taneja P	American Journal Of Orthodontics And Dentofacial Orthopedics	2008	175	10,94	Article
Periodontal Effects Of Rapid Maxillary Expansion with Tooth-Tissue- and Tooth-Borne Expanders: A Computed Tomography Evaluation	Garib DG, Henriques JFC, Janson G, Freitas MR, Fernandes AY	American Journal Of Orthodontics And Dentofacial Orthopedics	2006	175	9,72	Article
Transpalatal Distraction as a Method for Maxillary Expansion	Mommaerts MY	British Journal of Oral and Maxillofacial Surgery	1999	175	7	Article
Arch Perimeter Changes during Rapid Palatal Expansion	Adkins MD, Nanda RS, Currier GF	American Journal Of Orthodontics And Dentofacial Orthopedics	1990	175	5,15	Article

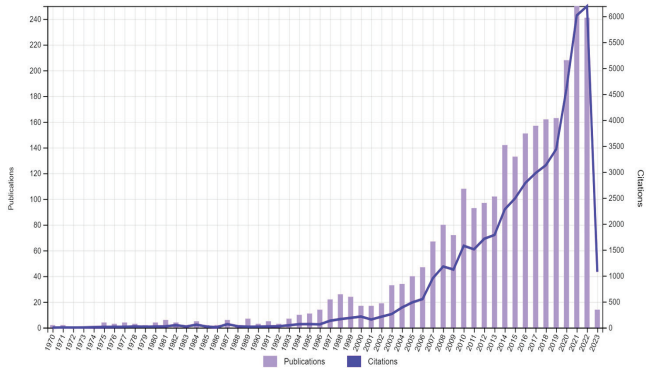

Figure 1. Annual number of published articles from 1970 to 2023 with maxillary expansion

The largest number of publications was from the United States (640), followed by Italy (443), Turkey (348), and Brazil (348). In terms of institutions, the University of Sao Paolo ranked first with 119 publications. Most RME studies were published in American Journal of Orthodontics and Dentofacial Orthopedics (AJO-DO), Angle Orthodontist, and European Journal of Orthodontics. The keywords most frequently used by the authors are listed in Table 5.

DISCUSSION

While studies on "maxillary expansion" have been increasing since the 1970s, it is noteworthy that the most studied expansion method is "rapid maxillary expansion (RME)". In addition to non-invasive RME methods, surgically assisted RME has been widely reported in the literature. When the studies were analyzed over 10-year periods, the dental and skeletal effects of maxillary expansion were extensively examined between 1970 and 1979, and many experimental studies were performed on monkeys.

Between 1980 and 1989, among other studies, publications on the effects of RME on the nasal airway were noteworthy. Studies investigating the health effects of maxillary expansion increased between 1990 and 1999. Between 2000 and 2009, the finite element method began to attract attention in the literature. Since 2010, a significant body of research has been examining the effects of maxillary expansion on medical conditions, particularly obstructive sleep apnea. As a result of the widespread use of cone-beam computed tomography in dentistry, studies evaluating the effects of maxillary expansion three-dimensionally were common during this period. Again, during this period, it was observed that mini-screw and mini-implant-supported maxillary expansion studies started to become widespread and reached their highest level in the last few years. From 2020 to the first quarter of 2023, there was a greater focus on reviews, systematic reviews, and meta-analyses. The fact that 24.8% of all reviews and meta-analyses on maxillary expansion were published during this period indicates that literature, data, and study analyses replaced clinical trials due to the coronavirus disease-2019 pandemic.

Maxillary narrowing requiring maxillary expansion, is a global problem. The worldwide distribution of data and high number of publications are attributed to the fact that maxillary expansion is a treatment of international interest. The total number of publications from the United States, Italy, Turkey, and Brazil was higher than that from the rest of the world.

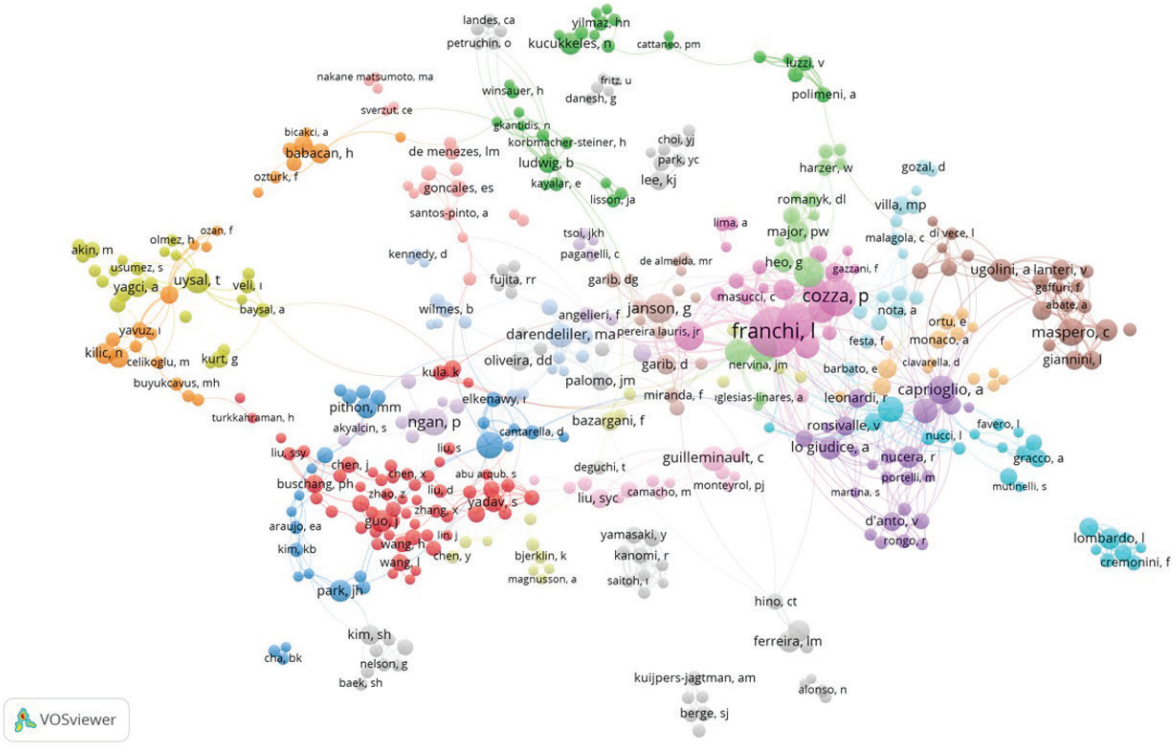

Figure 2. Collaboration networks between authors

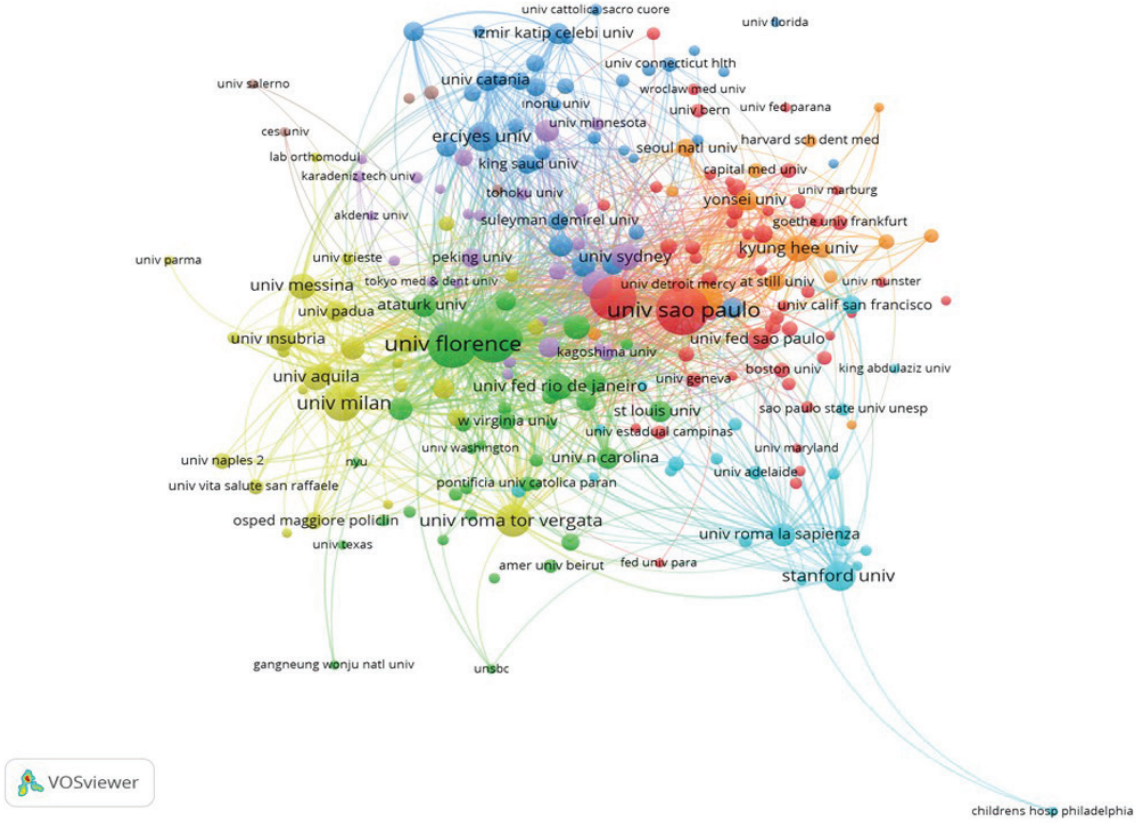

Figure 3. Collaboration networks between institutions

When countries were evaluated according to the number of citations, the USA, Italy, Turkey, and Brazil were ranked, respectively. In the present study, similar to the literature, the USA was the most cited country in the bibliometric studies.[25,26] The number of citations in the United States, which ranks first, is approximately the sum of the number of citations from Italy, Turkey, and Brazil. The high number of publications in the United States also accounts for the high number of citations.

The University of Sao Paulo has the highest number of publications on maxillary expansion. The literature review revealed that the same university also ranked highest in publications related to cleft palate.[27] Intense use of maxillary expansion in the treatment of cleft lip and palate patients may partially explain this finding.

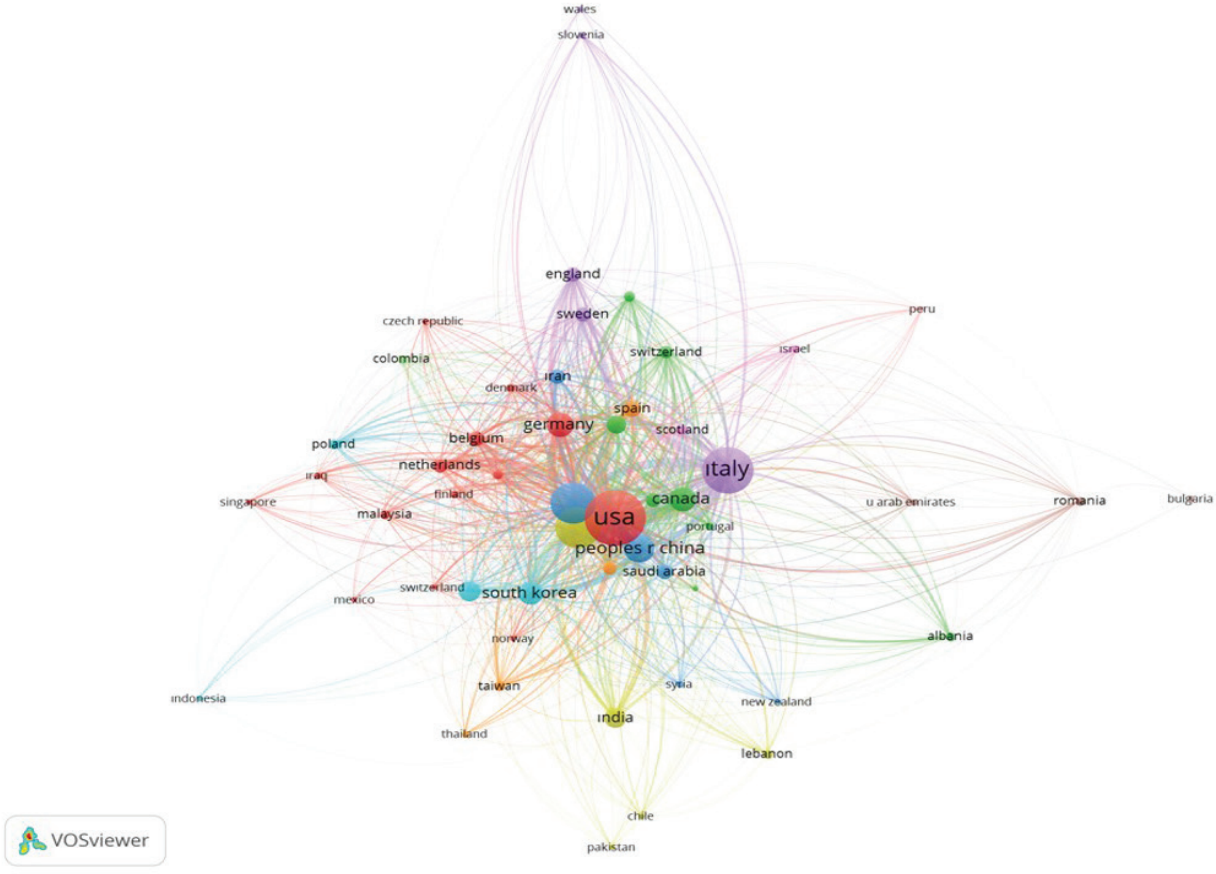

Figure 4. Collaboration networks between countries

Table 2. Top 10 authors

Authors	Institutions	Country or region	Number of citations	Number of articles
Franchi L	University of Florance	Italy	2830	85
Bacetti T	University of Florance	Italy	2495	47
Mcnamara JA	University of Michigan	USA	2448	51
Gozal D	University of Missouri	USA	1206	8
Lagravere MA	University of Alberta	Canada	1052	36
Guillerminaut C	Stanford University	USA	939	21
Cozza P	St. Camillus International University of Health and Medical Sciences	Italy	872	48
Villa MP	Sapienza University of Rome, Italy	Italy	825	12
Ngan P	West Virginia University	USA	752	25
Flores-Mir C	University of Alberta	Canada	607	25

Table 3. The 10 most contributing institutions

Institutions	Country or region	Number of articles	Number of citations
University of Florence	Italy	102	3287
University of Michigan	USA	97	3181
University of São Paulo	Brazil	119	1824
University of California, Los Angeles	USA	46	1319
University of Alberta	Canada	86	1292
Sapienza University of Rome, Italy	Italy	45	1254
Stanford University	USA	45	1250
University of Rome, Tor Vergata	Italy	57	1010
Carolina University	USA	25	791
University of Illinois	USA	29	777

Table 4. The ten most contributing countries or regions

Country or region	Number of articles	Number of citations
USA	640	17180
Italy	443	8085
Turkey	348	5305
Brazil	348	4647
Canada	127	2305
Germany	120	1941
South Korea	106	1883
China	163	1539
Belgium	44	1456
Netherlands	40	1355

Table 5. List of keywords with a total link strength greater than 10

Keywords	Occurrence
Rapid Maxillary Expansion	313
Maxillary Expansion	227
Orthodontics	147
Palatal Expansion	121
Obstructive Sleep Apnea	68
Rapid Palatal Expansion	68
Malocclusion	65
Orthognatic Surgery	64
Class III Malocclusion	64
Cone-beam Computed Tomography	58

Although most of the reviewed articles were published in journals in the orthodontic specialty, some were published in journals with high-impact factors in other disciplines, such as surgery and otorhinolaryngology. This indicates that maxillary expansion is not only a dental issue but also a multidisciplinary issue involving other fields.

In a bibliometric study, AJO-DO, Angle Orthodontist, and the European Journal of Orthodontics received the most citations.[20] According to the results of our study in the field of maxillary expansion, these journals received the most citations in support of the study. Again, most publications on this subject were published in these journals. The authors' choice was most likely based on the fact that these three scientific journals are popular, reputable, and have a high impact factor in the field of orthodontics. Another parameter to consider, is the frequency of publication of orthodontic journals (AJO-DO, 12 issues per year; The Angle Orthodontist and European Journal of Orthodontics, 6 issues per year). This may have resulted in a greater amount of content (number of articles).

When the top 20 most cited articles were individually examined, it was observed that only 4 of them were open access. It is a well-established fact in the literature that open access articles tend to receive more citations due to their ease of accessibility.[28,29] In fact, when we checked the number of citations received per year, these 4 open access studies reached their highest annual citation counts. On the other hand, the majority of the most cited articles in this study are not open access, which can be explained by these studies serving as fundamental studies in this field and often with earlier publication dates (Table 1).

CONCLUSION

- Based on the findings of this bibliometric analysis, the following conclusions were drawn:
- It has been observed that maxillary expansion is associated with orthodontics and many other disciplines.
- Maxillary expansion studies have remained popular over the years and have been published in many high-impact journals.
- Maxillary expansion is commonly performed over a wide age range using a variety of appliances and auxiliary units.
- It was determined that maxillary expansion was mainly performed using the rapid method (RME), and most research was conducted using this method.

Ethics

Ethics Committee Approval: Ethics committee approval is not required for this study.

Informed Consent: Not applicable.

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