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Original Articles

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TURKISH JOURNAL OF
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Original Article

Evaluation of the Consistency of Two Interproximal Reduction Methods in Clear Aligner Therapy: A Preliminary Study

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Main Points

- Motor-driven 3/4 oscillating segmental disks had better consistency.
- Hand-operated abrasive strips tended to result in inadequate interproximal reduction.
- This tendency was more pronounced in the maxillary central incisors and mandibular canines.

ABSTRACT

Objective: To compare the consistency of two interproximal reduction (IPR) methods in terms of the amount of planned and performed IPR during clear aligner therapy (CAT).

Methods: Thirty-four patients who received IPR using hand-operated abrasive strips (Group 1, 20 patients, 162 teeth) and motor-driven 3/4 oscillating segmental disks (Group 2, 14 patients, 134 teeth) during CAT were included in this preliminary study. The consistency between the planned and performed IPR amounts was evaluated within and between groups for teeth and quadrants.

Results: In Group 1, the amount of IPR performed on teeth numbers 22 and 43 and in the upper left quadrant was found to be statistically less than that of planned. On the other hand, the amount of performed IPR was statistically higher on tooth number 44 and in the upper right quadrant, whereas it was statistically less on tooth number 33 when compared with the planned amount in Group 2. The inconsistency between the planned and performed IPR amounts were statistically significant only in Group 1 and for teeth numbers 11, 21, 32, 33, and 43. No significant difference was found when the same parameter was compared between the groups.

Conclusion: The consistency of IPR was found to be better with the motor-driven oscillating disk system than with the hand-operated IPR strip system.

Keywords: Abrasive strip, clear aligner treatment, consistency, oscillating disk stripping

INTRODUCTION

With the development of technology and the increase in patients' aesthetic perception, treatment options with minimal visibility have become a necessity in orthodontic practice. Ceramic, plastic, vinyl, zircon, or polycarbonate brackets combined with Teflon- coated wires have been used to meet the aesthetic demands for many years. However, these tooth-colored brackets also failed to satisfy the aesthetic demands and led clinicians to use even less visible orthodontic materials such as clear aligners.[1-4] Movement of teeth without the use of bands, brackets, and wires was first introduced in 1945 by Dr. Kesling[5], who performed orthodontic treatment using a flexible tooth positioning device. Then, in 1997, the Invisalign® system (Align Technology Inc, Santa Clara, CA,

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USA) took Kesling's[5] philosophy further and produced a range of transparent and removable devices using computer-aided design and manufacturing technology.[6,7] In this system, manual impressions or digital scans were converted into virtual models with stereolithographic technology and then processed with ClinCheck™ software (Align Technology Inc, Santa Clara, CA, USA) to simulate virtual tooth movements and decide where, when, and how much interproximal reduction (IPR) to make. A series of aligners were then produced to obtain the necessary corrections.[6,8,9] The advantages of these systems are improved esthetics, increased patient comfort and oral hygiene, and healthier periodontal tissues.[3,10,11]

Success in clear aligner therapy (CAT) depends on various patient-related factors, such as bone density and crown and root morphology of the teeth, as well as operator-related factors, such as an appropriate treatment plan, close follow-up of the treatment process, and accurate execution of the pre-planned IPR. Features such as the thickness and material of the clear aligners and the shape and position of the attachments also play an important role in the treatment success of clear aligners.[3]

IPR, also known as stripping, enamel re-proximation, slenderizing, interdental enamel re-proximation, and selective enamel reduction, is a clinical procedure commonly used in orthodontic practice to eliminate black triangles by reshaping two neighboring teeth, to treat mild to moderate crowding, to eliminate Bolton tooth size discrepancy and to stabilize dental arches.[12-17] The most preferred IPR techniques in clinical practice are hand- or motor-operated abrasive metal strips, thin diamond burs and diamond-coated discs used with a handpiece.[12,14] The hand-operated abrasive metal strips, attached to color-coded plastic frames, effectively follow the proximal contours of the teeth and bend without any deformation, while the frames provide safety for the lips and cheeks.[18] On the other hand, oscillating segmental disk systems consist of diamond-coated disks that are one-sixth (60°) the size of a standard disk and a special handpiece. Unlike stripping disks that perform 360° rotation, they work by making oscillating movements with a 30° rotation angle, thereby eliminating the need for lip or cheek protectors.[19]

As the literature lacks reliable studies investigating the consistency of IPR in CAT, this study aims to compare the consistency of planned and performed IPR amounts during CAT using two different techniques, hand-operated diamond strips and motor-driven oscillating segmental disks with an *in vivo* study design.

METHODS

This prospective study was approved by Başkent University Institutional Review Board and Ethics Committee (project no: D-KA21/13, date: 28.04.2021) and supported by Başkent University Research Fund. Patients treated with clear aligners (Invisalign®, Align Technology, California, USA) at Başkent University between June 2021 and May 2022 were included in the study. Inclusion criteria were as follows: (1) IPR being planned for one or both jaws, (2) non-extraction treatment, (3) patients receiving mild, moderate, or comprehensive treatment packages, (4) no previous history of orthodontic treatment, (5) absence of periodontal pathology, and (6) no conservative or prosthetic restorations performed during treatment.

To achieve standardization, records of patients who were treated by the same experienced orthodontist (A.A.Ö.) were included in the study. Digital scans were taken at the beginning of treatment (T0) and after the first set of aligners/at the end of treatment (T1) using an iTero Element 5 intraoral scanner (Align Technologies Inc, San Jose, CA, USA). To capture the true size and form of the crowns, patients were asked to brush their teeth before scanning, and the teeth were dried thoroughly during the procedure.

Sample size calculation performed with 80% power and 0.35 effect size with a 10% probability of dropout suggested that 112 teeth should be included per group.[3] IPR was performed with hand-operated abrasive strips (ContacEZ-Ortho Classic®, Vancouver, WA, USA) (Figure 1) in 20 patients (162 teeth) in Group 1 and with motor-driven 3/4 oscillating segmental discs (KOMET-Sterisafe® A6, Rock Hill, SC, USA) (Figure 2) in 14 patients (134 teeth) in Group 2. A metal interproximal gauge KOMET USA, Rock Hill, SC, USA) was used after each IPR to check whether the performed amount was even with the planned amount. We assumed that equal reduction (50%) was achieved in the mesial and distal surfaces of the adjacent teeth.

The mesiodistal widths of the teeth (measured from the widest part) except for the molars were recorded at T0 and T1 using the Bolton table of the ClinCheck™ software. The difference between T1-T0 values gave the amount of IPR performed. The mean difference between the planned and performed IPR amounts was calculated by subtracting the planned

Figure 1. Hand-operated abrasive strips (ContacEZ, Ortho Classic®, Vancouver, WA, USA)

Figure 2. Motor-driven oscillating segmental discs (KOMET, Sterisafe® A6, Rock Hill, SC, USA)

amount from the performed amount. The reliability of the Bolton function of the ClinCheck™ software was evaluated by calculating intraclass correlation coefficients (ICC) for the 282 teeth that were not subjected to IPR using T0 and T1 values for comparison.

Statistical Analysis

Statistical analyses were performed using the SPSS software package (SPSS for Windows 22.0, SPSS Inc, IL, USA). The Shapiro-Wilk test was used to test the normality of distributions. Due to the non-normal distribution of the data, the Mann-Whitney U test was used for comparisons between paired groups, and the Kruskal-Wallis H and Wilcoxon signed rank tests were used for comparisons between three or more groups.

Descriptive statistical methods (mean, median, standard deviation, and minimum-maximum) were used while evaluating the study data. The significance level was set at 0.05.

RESULTS

A total of 34 patients and 296 teeth were used for data analysis. The ICC value calculated to confirm the reliability of the Bolton function of the ClinCheck™ software was found to be 0.996 (mean difference= -0.09 mm, median= -0.07 mm), indicating that the measurement system was reliable with good repeatability.

Table 1 shows the difference between the amounts of planned and performed IPR within the groups. The overall amount of performed IPR was significantly less than the planned amount in Group 1 but similar in Group 2. Furthermore, the amount of IPR performed in Group 1 in the upper left quadrant and

Table 1. Comparison of the planned and performed amounts (mm) of interproximal reduction (IPR) on quadrant- and tooth-level

	Group 1 (ContacEZ)						Group 2 (KOMET)					
	n	Planned		Performed		p value†	n	Planned		Performed		p value†
Measurement		Mean	SD	Mean	SD			Mean	SD	Mean	SD	
Quadrant												
Upper right	33	0.24	0.10	0.20	0.13	0.074	24	0.19	0.07	0.27	0.18	0.021*
Upper left	37	0.28	0.13	0.23	0.15	0.023*	23	0.22	0.12	0.21	0.14	0.553
Lower right	46	0.22	0.08	0.20	0.12	0.115	41	0.24	0.11	0.24	0.16	0.638
Lower left	46	0.21	0.08	0.19	0.13	0.249	46	0.24	0.10	0.23	0.18	0.299
Tooth number												
11	12	0.26	0.11	0.21	0.15	0.209	10	0.21	0.07	0.32	0.25	0.139
12	10	0.25	0.10	0.23	0.10	0.444	7	0.21	0.07	0.23	0.08	0.553
13	8	0.21	0.12	0.16	0.14	0.080	6	0.14	0.06	0.21	0.08	0.092
21	12	0.30	0.13	0.23	0.16	0.158	10	0.23	0.10	0.22	0.15	0.799
22	11	0.32	0.15	0.25	0.16	0.004*	7	0.26	0.15	0.28	0.14	0.307
23	9	0.27	0.14	0.26	0.16	0.889	5	0.19	0.12	0.14	0.06	0.501
31	14	0.25	0.07	0.24	0.12	0.850	13	0.27	0.10	0.30	0.15	0.289
32	13	0.23	0.06	0.22	0.14	0.753	13	0.27	0.10	0.28	0.17	1
33	11	0.21	0.07	0.13	0.11	0.068	12	0.23	0.10	0.11	0.11	0.021*
34	8	0.12	0.03	0.13	0.10	1	7	0.17	0.10	0.11	0.13	0.091
41	14	0.24	0.08	0.21	0.11	0.177	12	0.27	0.11	0.26	0.14	0.635
42	12	0.24	0.05	0.25	0.10	0.844	10	0.29	0.09	0.35	0.15	0.213
43	11	0.21	0.08	0.12	0.08	0.041*	11	0.21	0.10	0.12	0.11	0.068
44	8	0.14	0.07	0.21	0.18	0.260	7	0.16	0.11	0.22	0.16	0.027*
Overall	162	0.23	0.10	0.20	0.13	0.001*	134	0.23	0.10	0.24	0.16	0.713

*Indicates statistical significance p<0.05
†Wilcoxon signed rank test
SD, standard deviation

Table 2. Intragroup and intergroup comparisons of the mean difference between the planned and performed amounts (mm) of interproximal reduction (IPR) on quadrant- and tooth-level

	Group 1 (ContacEZ)				Group 2 (KOMET)				Between groups
Measurement	n	Mean	SD	p value†	n	Mean	SD	p value†	p value‡
Quadrant									
Upper right	33	0.09	0.07	0.786	24	0.12	0.15	0.877	0.621
Upper left	37	0.10	0.08		23	0.10	0.07		0.819
Lower right	46	0.09	0.09		41	0.09	0.08		0.664
Lower left	46	0.08	0.07		46	0.11	0.10		0.208
Tooth number									
11	**12**	**0.12**	**0.09**	**0.032***	10	0.18	0.22	0.534	0.692
12	10	0.07	0.04		7	0.05	0.05		0.522
13	8	0.06	0.03		6	0.09	0.04		0.132
21	**12**	**0.13**	**0.09**		10	0.11	0.07		0.716
22	11	0.07	0.07		7	0.06	0.06		0.926
23	9	0.08	0.07		5	0.11	0.07		0.349
31	14	0.05	0.04		13	0.09	0.06		0.223
32	**13**	**0.11**	**0.05**		13	0.10	0.06		0.797
33	**11**	**0.12**	**0.09**		12	0.13	0.11		1
34	8	0.05	0.06		7	0.08	0.05		0.288
41	14	0.06	0.06		12	0.07	0.08		0.140
42	12	0.06	0.06		10	0.11	0.08		0.274
43	**11**	**0.13**	**0.08**		11	0.12	0.07		0.598
44	8	0.09	0.15		7	0.07	0.06		0.815

*Indicates statistical significance $p<0.05$
†Kruskal-Wallis H test
‡Mann-Whitney U test
SD, standard deviation

on teeth numbers 22 and 43 was significantly less than that planned. The amount of IPR performed in Group 2 in the upper right quadrant and on tooth number 44 was significantly higher than that planned; however, it was significantly less in tooth number 33.

Table 2 shows intra- and inter-group comparisons of the mean differences between planned and performed amounts of IPR. Intra-group evaluations showed that the performed amount of IPR was similar to the planned amount at the quadrant level in both groups. When the mean differences were evaluated at the tooth level, the difference values of teeth numbers 11, 21, 32, 33, and 43 in Group 1 were significantly higher than the other teeth in the same group (p=0.032). Inter-group comparisons, on the other hand, showed that there was no statistically significant difference between the two methods in terms of quadrants and teeth.

DISCUSSION

This study was conducted to compare the consistency of two IPR techniques commonly used in clinical practice, hand-operated abrasive diamond strips and motor-driven oscillating segmental disks in CAT. The first important feature of the study was that all IPRs were performed by a single orthodontist with more than 20 years of clinical experience, ensuring standardization. The second important feature was the *in vivo* nature of the study, which is rare in the literature. In addition, the accuracy of the IPR was checked with an interproximal metal gauge after each IPR.

IPR is crucial for the full realization of planned tooth movements in CAT. The consistency between the planned and performed IPR amounts depends on dental characteristics such as enamel hardness, tooth position, and crown morphology, as well as technical factors such as pressure applied during IPR, particle size and hardness of the abrasive material, and operator's experience.[8,14,20,21] In addition, applying excessive pressure with the interproximal gauge may create false spaces, resulting in inadequate IPR.[20]

The results showed that the overall amount of IPR performed was similar to that planned with the motor-driven oscillating disk system; however, it was less with the hand-operated abrasive strip system. Consistent with theses findings, De Felice et al.[3] demonstrated that the amount of IPR performed with single-sided manual strips could not reach the prescribed amount; however, the oscillating disk system effectively executed it. However, their study included patients treated by 10 different orthodontists, whereas the current study offers the advantage of standardization in which IPRs were performed by a single experienced orthodontist. Laganà et al.[8] and Kalemaj and Levrini[13] also reported that oscillating segmental disks had better consistency. The findings of this study together with the existing literature indicate that mechanical and manual methods differ with consistency between the planned and performed amounts of IPR, and that mechanical methods have better consistency than manual methods. This may be attributed to the incremental use of manual strips, which may displace the teeth and lead to false readings on the interproximal gauge, making it clinically more tiring and time-consuming, especially for marked amounts of IPR. Furthermore, this technique is clinically more tiring and time consuming, especially when a marked amount of IPR is planned, which may give the clinician a false impression that the targeted amount is reached.

Mandibular canines received significantly less IPR than the planned amount. A similar finding was demonstrated by Kalemaj and Levrini[13] who used burs, single-sided abrasives, and contra-angle mounted strips for IPR. This is likely due to the position of the mandibular canines on the arch, which are usually proclaimed, crowded, and in tight interproximal contact with the adjacent teeth.

Johner et al.[22] tested the accuracy of two mechanical and one manual IPR methods (oscillating segmental disks, motor-driven abrasive strips and hand-operated strips) with an *in vitro* study design and found that the amount of IPR performed was less than that planned for all 3 methods. This contrasts with our findings, showing consistent IPR amounts performed with the mechanical method was consistent with the planned amount, whereas the manual method was not efficient enough to fully achieve the prescribed amount.

Based on the findings of this study, it may be advised to use an interproximal gauge with minimal pressure after each application and to perform slightly more IPR on mandibular canines and maxillary central incisors when using manual methods.

Study Limitations

One limitation of the study was the use of the Bolton function of the ClinCheck™ software which is claimed to be prone to measurement errors. However, our results showed that the ICC value was 0.996, proving that the repeatability was high and the outcomes were reliable.

CONCLUSION

The following conclusions are drawn from this clinical study:

• The consistency between the planned and performed amounts of IPR is high with the mechanical (motor-driven 3/4 oscillating segmental disks) method.

• The manual method (hand-operated abrasive strips) failed to fully realize the planned amount of IPR, especially on the maxillary central incisors and mandibular canines.

Ethics

Ethics Committee Approval: This prospective study was approved by Başkent University Institutional Review Board and Ethics Committee (project no: D-KA21/13, date: 28.04.2021).

Informed Consent: Written informed consent was obtained from all individual participants included in the study.

Author Contributions: Concept - P.G.E., A.A.Ö., A.A.K., N.İ.T.; Design - P.G.E., A.A.Ö., A.A.K., N.İ.T.; Supervision - A.A.Ö., A.A.K., N.İ.T.; Fundings - P.G.E.; Materials - A.A.K.; Analysis and/or Interpretation - P.G.E., A.A.Ö., A.A.K., N.İ.T.; Literature Review - P.G.E.; Writing - P.G.E.; Critical Review - A.A.Ö., A.A.K., N.İ.T.

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

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References

1. Ghafari J. Problems associated with ceramic brackets suggest limiting use to selected teeth. *Angle Orthod.* 1992;62(2):145-152. [CrossRef]
2. Jeremiah HG, Bister D, Newton JT. Social perceptions of adults wearing orthodontic appliances: a cross-sectional study. *Eur J Orthod.* 2011;33(5):476-482. [CrossRef]
3. De Felice ME, Nucci L, Fiori A, Flores-Mir C, Perillo L, Grassia V. Accuracy of interproximal enamel reduction during clear aligner treatment. *Prog Orthod.* 2020;21(1):28. [CrossRef]
4. Grünheid T, Loh C, Larson BE. How accurate is Invisalign in nonextraction cases? Are predicted tooth positions achieved? *Angle Orthod.* 2017;87(6):809-815. [CrossRef]
5. Kesling HD. The philosophy of the tooth positioning appliance. *Am J Orthod Oral Surg.* 1945;31(6):297-304. [CrossRef]
6. Kravitz ND, Kusnoto B, BeGole E, Obrez A, Agran B. How well does Invisalign work? A prospective clinical study evaluating the efficacy of tooth movement with Invisalign. *Am J Orthod Dentofacial Orthop.* 2009;135(1):27-35. [CrossRef]
7. Kuo E, Miller RJ. Automated custom-manufacturing technology in orthodontics. *Am J Orthod Dentofacial Orthop.* 2003;123(5):578-581. [CrossRef]
8. Laganà G, Malara A, Lione R, Danesi C, Meuli S, Cozza P. Enamel interproximal reduction during treatment with clear aligners: digital planning versus OrthoCAD analysis. *BMC Oral Health.* 2021;21(1):199. [CrossRef]
9. Lanteri V, Farronato G, Lanteri C, Caravita R, Cossellu G. The efficacy of orthodontic treatments for anterior crowding with Invisalign compared with fixed appliances using the Peer Assessment Rating Index. *Quintessence Int.* 2018;49(7):581-587. [CrossRef]
10. Rossini G, Parrini S, Castroflorio T, Deregibus A, Debernardi CL. Periodontal health during clear aligners treatment: a systematic review. *Eur J Orthod.* 2015;37(5):539-543. [CrossRef]
11. Tepedino M, Paoloni V, Cozza P, Chimenti C. Movement of anterior teeth using clear aligners: a three-dimensional, retrospective evaluation. *Prog Orthod.* 2018;19(1):9. [CrossRef]

12. Kalai SV, Amudha, Kannan MS. A Review On Inter Proximal Enamel Reduction-An Adjunct In Orthodontics. *Eur J Mol Clin Med.* 2020;7(8):1747-1752. [CrossRef]
13. Kalemaj Z, Levrini L. Quantitative evaluation of implemented interproximal enamel reduction during aligner therapy. *Angle Orthod.* 2021;91(1):61-66. [CrossRef]
14. Gazzani F, Lione R, Pavoni C, Mampieri G, Cozza P. Comparison of the abrasive properties of two different systems for interproximal enamel reduction: oscillating versus manual strips. *BMC Oral Health.* 2019;19(1):247. [CrossRef]
15. Buschang PH, Ross M, Shaw SG, Crosby D, Campbell PM. Predicted and actual end-of-treatment occlusion produced with aligner therapy. *Angle Orthod.* 2015;85(5):723-727. [CrossRef]
16. Arman A, Cehreli SB, Ozel E, Arhun N, Cetinşahin A, Soyman M. Qualitative and quantitative evaluation of enamel after various stripping methods. *Am J Orthod Dentofacial Orthop.* 2006;130(2):131.e7-131.e14. [CrossRef]
17. Hellak A, Schmidt N, Schauseil M, Stein S, Drechsler T, Korbmacher-Steiner HM. Influence on interradicular bone volume of Invisalign treatment for adult crowding with interproximal enamel reduction: a retrospective three-dimensional cone-beam computed tomography study. *BMC Oral Health.* 2018;18(1):103. [CrossRef]
18. Kaaouara Y, Mohind HB, Azaroual MF, Zaoui F, Bahije L, Benyahia H. In vivo enamel stripping: A macroscopic and microscopic analytical study. *Int Orthod.* 2019;17(2):235-242. [CrossRef]
19. Zhong M, Jost-Brinkmann PG, Zellmann M, Zellmann S, Radlanski RJ. Clinical evaluation of a new technique for interdental enamel reduction. *J Orofac Orthop.* 2000;61(6):432-439. [CrossRef]
20. Danesh G, Hellak A, Lippold C, Ziebura T, Schafer E. Enamel surfaces following interproximal reduction with different methods. *Angle Orthod.* 2007;77(6):1004-1010. [CrossRef]
21. Piacentini C, Sfondrini G. A scanning electron microscopy comparison of enamel polishing methods after air-rotor stripping. *Am J Orthod Dentofacial Orthop.* 1996;109(1):57-63. [CrossRef]
22. Johner AM, Pandis N, Dudic A, Kiliaridis S. Quantitative comparison of 3 enamel-stripping devices in vitro: how precisely can we strip teeth? *Am J Orthod Dentofacial Orthop.* 2013;143(4 Suppl):S168-S172. [CrossRef]

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Original Article

Third Molar Comparison in Class I and II Extraction and Non-extraction Orthodontic Treatment: A Retrospective Longitudinal Study

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Main Points

- Premolar extractions in Class I and II patients favored third molar angulation and eruption.
- The third molars showed a more upright position after treatment, regardless of the malocclusion type or extraction protocol.
- Third molar angulation can influence posterior eruption.

ABSTRACT

Objective: This study compared third molar angulation and eruption status in Class I and II malocclusions after orthodontic treatment with and without first premolar extractions.

Methods: The sample comprised 93 patients divided into four groups: Group 1, Class I malocclusion treated with first premolar extractions; Group 2, Class I malocclusion treated without extractions; Group 3, Class II malocclusion treated with first premolar extractions; and Group 4, Class II malocclusion treated without extractions. Panoramic radiographs were used to evaluate the third molar mesiodistal angulations at T1 (pretreatment), T2 (posttreatment), and T3 (long-term posttreatment). Third molar eruption status was assessed in dental casts. Intergroup angulations and eruption status comparisons were performed using one-way analysis of variance (ANOVA), followed by Tukey's test and Kruskal-Wallis test, respectively.

Results: Significantly greater mesial angulation and percentage of erupted right maxillary third molars were observed in the Class I extraction group. Significantly greater eruption status of the right mandibular third molars was observed in the Class I and Class II malocclusion extraction groups.

Conclusion: Class I and II malocclusion extraction treatment exhibited more favorable angulations and a greater number of erupted third molars than non-extraction treatment. The non-extraction groups exhibited a greater percentage of unerupted third molars.

Keywords: Molar, tooth, unerupted, tooth eruption, ectopic

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INTRODUCTION

Third molars are the teeth with the highest rate of impaction, therefore causing various complications frequently found in dental practice.[1,2] Many factors are involved in their impaction, such as morphology, growth, retromolar space, anatomy, and position.[3] Numerous factors have been researched to predict its future impaction.[4] It has been established that some of these factors can be modified to favor third molar eruption. Consequently, orthodontic treatment, mainly in extraction therapy, has been suggested to help to prevent their impaction by providing extra retromolar space.

Some researchers have proposed that forward movement of the posterior teeth might improve the position of the third molar by allowing them to develop further and consequently in a more upright position.[5] To prove or deny the influence of orthodontic treatment on third molar eruption, many authors have assessed the third molars before and after treatment. Some of them have compared extraction and no extraction groups to assess retromolar space gain.[6] The results of those studies have shown significant gains in retromolar space; however, this was not translated into later third molar eruption.[7]

Moreover, some authors have proposed that in addition to additional space, significant angulation changes should occur to avoid impaction.[8] Recent studies evaluating third molar angulation changes have shown significant differences in third molar position, especially after extraction therapy.[3,9] However, some researchers have not found that these changes were sufficient to avoid impaction, while others state that eruption does occur.[10,11] Despite the existing literature, it has been reported that the available evidence is still limited to confirm whether orthodontic treatment with premolar extractions can favor the angulation and subsequent eruption of the third molars; however, it highlights the possibility of a potential benefit.[12] Therefore, based on the need for more scientific evidence on the subject, the purpose of this study was to compare third molar angulation and eruption statuses in Class I and II malocclusions treated with and without first premolar extractions.

METHODS

This project was approved by the Ethics in Research Committee of University of São Paulo Bauru Dental School (approval no: 466/12, date: 12.18.2018).

Sample Characteristics

Sample size calculation was performed based on an alpha level of 5% and beta test power of 80% to detect a minimum intergroup difference of 6 degrees, with a standard deviation of 6 degrees.[13] The results showed that a minimum of 21 patients was necessary for each group. The sample comprised 93 patient records with Class I and II malocclusion treated with fixed appliances (standard or preadjusted edgewise mechanotherapy) with moderate anchorage (extraoral headgear in the maxillary teeth in extraction treatments and Class II non-extraction treatment), with and without first premolar extractions, and with unerupted third molars. The records were retrospectively selected from the files of the Orthodontic Department at University of São Paulo Bauru Dental School. The inclusion criteria for sample selection were patients with unerupted third molars visible panoramic radiographs at the initial stage, without dental anomalies of number and form, and the presence of all permanent teeth, excluding the first premolars in the extraction cases. All participants' records should have the initial, final, and last follow-up panoramic radiographs and dental casts with the presence of the third molar in a 1-to 5-year interval after debonding. Patients with erupted third molars at the initial stage, Class III malocclusion, previous orthodontic treatment, or asymmetric extractions were not included in the study.

The sample was divided into four groups according to the malocclusion type and the orthodontic treatment performed, with or without first premolar extractions: Group 1 consisted of 23 records of patients with Class I malocclusion treated with first premolar extractions, comprising 12 females and 11 males. The mean treatment and follow-up time was 2.72 years (±1.15) and 4.55 years (±1.58), respectively. The group exhibited a mean age of 13.18 years (±1.00) at the initial stage, 15.90 years (±1.50) at the end of treatment, and 20.45 years (±1.85) at the last follow-up examination.

Group 2 comprised 23 records of patients with Class I malocclusion treated without extractions, consisting of 14 females and 9 males. The mean treatment time was 2.29 years (±0.85) with a follow-up time of 4.37 years (±1.85). The initial mean age was 13.36 years (±1.35), 15.65 years (±1.58) at the final stage, and 20.03 years (±2.37) at the last follow-up examination stage.

Twenty-four Class II malocclusion patients treated with first premolar extractions comprised group 3 with 11 females and 13 males. The group had a mean treatment time of 2.61 years (±0.90) and a mean follow-up time of 3.93 years (±1.66). The initial, final, and last follow-up mean ages were 12.84 years (±1.29), 15.46 years (±1.59), and 19.39 years (±1.00), respectively. Class II malocclusion patients treated without extractions comprised group 4, with 23 records (11 females and 12 males). The mean treatment time was 2.28 years (±0.48) and the follow-up time was 4.15 years (±1.52). The mean age was 12.47 years (±1.23) at the initial stage, 14.75 years (±1.17) at the final stage, and 18.90 years (±1.85) at the last follow-up examination.

To assess third molar angulation changes, angular measurements were performed on panoramic radiographs at the initial (T1) and final stages (T2) of treatment and at the last follow-up stage (T3) after a mean posttreatment period of 4.24 years (±1.64). To assess the third molar eruption status, dental casts were used at T3. They were designated as the right maxillary third molar (18), left maxillary third molar (28), left mandibular third molar (38), and right mandibular third molar (48), according to the International Numbering System.[14]

Panoramic Radiographs

Panoramic radiographs were digitized using a Microtek ScanMaker i800'den sonrası parantez ici olacak. (Microtek International, Carson, USA) scanner and saved in TIFF format. Subsequently, the radiographs were digitally traced using Dolphin Imaging Software Version 11.5 (Dolphin® Imaging and Management Solutions, Patterson Dental Supply, Inc., Chatsworth, California, USA).

Third Molar Angulation

Third molar mesiodistal angulation was assessed using angular measurements traced on panoramic radiographs. The nasal septum, anterior nasal spine, hard palate, and maxillary and mandibular third molars were used as anatomical reference structures. The reference lines were as follows: (A) the midline reference plane (MRP), a vertical line traced outlining the nasal septum and anterior nasal spine; (B) a horizontal reference plane (HRP), constructed as a line perpendicular to the MRP extending through the palatal shadow[13,15,16] (Figure 1). Thus, the long axes of the maxillary and mandibular third molars were traced as lines bisecting the middle of the crown and root furcation. To determine the third molar angulations, the outer angles formed between the third molar axes and HRP were measured (Figures 1 and 2). Increases in the angular measurements denoted mesial angulations of the maxillary molars and distal angulations of the mandibular molars, indicating a more upright position of the third molars.

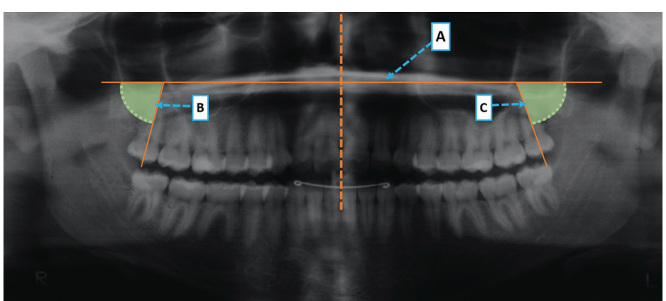

Figure 1. Third molar angulation measurements. **A)** Horizontal reference plane (HRP), **B)** HRP and right maxillary third molar long axis angle, **C)** HRP and left maxillary third molar long axis angle

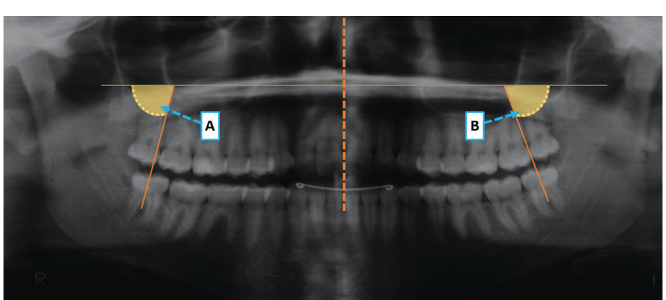

Figure 2. A) Horizontal reference plane (HRP) and right mandibular third molar long axis angle and **B)** HRP and left mandibular third molar long axis angle

Third Molar Eruption

Third molar eruption was assessed in the last follow-up dental casts with the presence of third molars.

The eruption stage was classified according to the third molar clinical crown position.[17] It was classified as unerupted when the clinical crown could not be seen in the dental casts; partially erupted when the crown was partially visible; or erupted when the clinical crown could be fully seen. Thus, the eruption stages were scored on an ascending scale from one to three, assigning a score of one when unerupted, two when partially erupted, and three when erupted.

Error Study

Thirty panoramic radiographs were randomly selected and re-measured at an interval of 30 days from the first measurement by the same examiner (D.P.R.). Random errors were assessed using the formula [$Se^2 = S (d^2 / 2n)^2$], proposed by Dahlberg.[18] To calculate the systematic errors, dependent t-tests were performed at $p<0.05$.[19] Thirty dental casts were also randomly selected and re-evaluated after a 30-day interval to assess the reproducibility of the eruption status evaluation. The intra-examiner agreement was then calculated using Kappa statistics.[20]

Statistical Analysis

The normal distribution of the variables was assessed using Kolmogorov-Smirnov normality tests. Intergroup comparability regarding sex distribution was evaluated using the chi-square test. One-way analysis of variance (ANOVA), followed by Tukey's test, was used for intergroup comparability regarding initial, final, and follow-up ages, treatment, and follow-up times.

Intergroup comparisons of third molar angulations at T1, T2, and T3 were performed using ANOVA, followed by Tukey tests, when necessary.

Descriptive statistics were performed to assess the third molar eruption status score frequency at T3. Intergroup comparisons for third molar eruption status were performed using Kruskal-Wallis tests. All statistical tests were performed using Statistica software (Statistica for Windows, version 7.0, StatSoft Inc., Tulsa, Okla, USA) at $p<0.05$.

RESULTS

The random errors ranged from 1.92° (right mandibular third molar angulation) to 2.52° (left maxillary third molar angulation) and were within acceptable limits.[21] None of the variables showed significant systematic errors. Intraexaminer reproducibility of the eruption status assessment showed perfect and substantial agreement between the first and second evaluations.

The groups were comparable in terms of sex distribution, initial, final, and follow-up ages, treatment and follow-up times, and third molar angulations at T1 (Tables 1 and 2). Intergroup comparisons in each stage showed significantly

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greater angulation of the right maxillary third molar in the Class I extraction group at T2 and T3 than in the Class II non-extraction group, and at T3 in the other groups. The left maxillary third molar in the Class I extraction group at T2 showed significantly greater angulation than the other groups (Table 2).

Descriptive statistics for the third molar eruption status score showed a frequency of erupted maxillary third molars of 60.87% in the Class I extraction group, 54.35% unerupted in the Class I non-extraction group, and 45.83% and 63.04% unerupted in the Class II extraction and non-extraction groups, respectively. For the mandibular third molars, the erupted frequency was 45.65% in the Class I extraction group and 47.83% in the Class I non-extraction group. In the Class II extraction group, 58.33% erupted, and 56.52% unerupted in the Class II non-extraction group (Table 3).

Intergroup comparisons of third molar eruption status showed a significantly greater percentage of erupted maxillary third molars in the Class I extraction group than in the Class II non-extraction group. A significantly greater percentage of erupted right mandibular third molars was also found in the Class I and II extraction groups than in the Class I and II non-extraction groups (Table 4).

Table 1. Intergroup comparison of sex distribution, initial and final ages, treatment and follow up times (chi-square and one-way ANOVA tests)

Variables	Group 1, Class I Ex n=23	Group 2, Class I Non-Ex n=23	Group 3, Class II Ex n=24	Group 4, Class II Non-Ex n=23	p value
Sex	n (%)	n (%)	n (%)	n (%)	
Female	12 (52.17)	14 (60.87)	11 (45.83)	11 (47.17)	0.742†
Male	11 (47.83)	9 (39.13)	13 (54.17)	12 (52.83)	
	Mean (SD)	Mean (SD)	Mean (SD)	Mean (SD)	
Initial age	13.18 (1.00)	13.36 (1.35)	12.84 (1.29)	12.47 (1.23)	0.079††
Final age	15.90 (1.50)	15.65 (1.58)	15.46 (1.59)	14.75 (1.17)	0.057††
Follow-up age	20.45 (1.85)	20.03 (2.37)	19.39 (1.00)	18.90 (1.85)	0.051††
Treatment time	2.72 (1.15)	2.29 (0.85)	2.61 (0.90)	2.28 (0.48)	0.215††
Follow-up time	4.55 (1.58)	4.37 (1.85)	3.93 (1.66)	4.15 (1.52)	0.604††

Statistically significant at p<0.05
†Chi-square test
††One-Way ANOVA
SD, standard deviation

Table 2. Intergroup comparisons for the third molars angulations at T1, T2 and T3 (one-way ANOVA and Tukey tests)

Variables	Stage	Class I, Ex n=23	Class I, Non-Ex n=23	Class II, Ex n=24	Class II, Non-Ex n=23	p value
Angulation comparisons						
		Mean (SD)	Mean (SD)	Mean (SD)	Mean (SD)	
18	T1	55.64 (15.70)	53.72 (16.53)	51.12 (12.50)	51.75 (11.13)	0.689
	T2	64.97 (15.64)^{A}	56.94 (13.34)^{AB}	56.72 (13.15)^{AB}	51.79 (15.04)^{B}	0.022*
	T3	70.36 (13.24)^{A}	58.96 (10.59)^{B}	59.84 (14.59)^{B}	58.78 (19.37)^{B}	0.023*
28	T1	47.61 (11.48)	48.35 (15.70)	44.60 (12.20)	50.91 (13.94)	0.453
	T2	62.04 (17.48)^{A}	52.91 (13.96)^{B}	54.97 (14.50)^{B}	49.90 (13.76)^{B}	0.048*
	T3	65.13 (17.38)	56.75 (13.89)	59.77 (15.45)	56.09 (16.87)	0.210
38	T1	36.04 (9.20)	37.36 (8.22)	37.44 (9.85)	38.11 (11.93)	0.912
	T2	39.53 (9.21)	41.68 (14.00)	35.78 (13.50)	39.93 (10.24)	0.387
	T3	41.60 (22.43)	49.71 (23.10)	50.97 (22.18)	44.64 (20.28)	0.433
48	T1	38.36 (9.03)	38.67 (8.08)	36.20 (12.10)	36.04 (10.39)	0.722
	T2	41.93 (11.47)	39.85 (12.84)	40.97 (12.61)	37.05 (9.64)	0.525
	T3	44.30 (18.39)	45.97 (25.54)	56.04 (18.10)	39.62 (23.06)	0.068

*Statistically significant at p<0.05
Different letters in a row indicate the presence of a statistically significant difference among the groups, indicated by the Tukey test.
$^{A, B}$: They indicate statistically significant differences between the groups.
SD, standard deviation

DISCUSSION

Third molar angulation was measured on panoramic radiographs, a method preferred over lateral cephalograms, due to reduced bias from superimposed images.[11,13] Previous studies have supported the reliability and accuracy of angular measurements in panoramic radiographs, which present less angular distortion even with changes in head position.[15,22] Many studies have used the occlusal plane, mandibular plane, and second molar long axis as anatomical references to measure third molar angulation, which are susceptible to growth and treatment changes.[9,12] In the present study, the hard palate and anterior nasal spine were used as references.[13,23] for angulation measurements due to their stability and minimal susceptibility to growth or treatment changes. Initial third molar angulation measurements may face criticism due to incomplete crown formation at younger ages. However, measurements based on the dental crown can still be conducted, despite incomplete root development.[21]

Class I patients treated with first premolar extractions exhibited a more upright position in their right maxillary third molars at T2 and T3 compared to Class II non-extraction cases. At T3, they also exhibited greater upright positioning compared to the non-extraction Class I group. The left maxillary third molar at T2 was more upright than the other groups (Table 2). Artun et al.[24] found a similar trend in their assessment of posttreatment angulation of maxillary third molars in extraction groups, aligning with our findings. Artun et al.[24] found a similar trend in their assessment of posttreatment angulation of maxillary third molars in extraction groups, aligning with our findings.

This was expected given the more mesial positioning of maxillary posterior teeth in Class II patients compared to in Class I patients.[10] Therefore, in most Class II non-extraction cases, restricting anterior movement of the posterior teeth is imperative to correct the sagittal discrepancy.[25] In Class I cases, distalization of the maxillary posterior teeth is not

Table 3. Descriptive statistics of the eruption status of the maxillary and mandibular third molars at T3

Eruption status						
Third molars	Score	Class I, Ex n=23	Class I, Non-Ex n=23	Class II, Ex n=24	Class II, Non-Ex n=23	Total
		N (%)	N (%)	N (%)	N (%)	
Maxillary	1	10 (21.74)	25 (54.35)	22 (45.83)	29 (63.04)	86
	2	8 (17.39)	8 (17.39)	11 (22.92)	9 (19.57)	36
	3	28 (60.87)	13 (28.26)	15 (31.25)	8 (17.39)	64
Mandibular	1	13 (28.26)	22 (47.83)	12 (25)	26 (56.52)	73
	2	12 (26.09)	9 (19.57)	8 (16.67)	7 (15.22)	36
	3	21 (45.65)	15 (32.60)	28 (58.33)	13 (28.26)	77
Total number of teeth		92	92	96	92	372
Total number of patients (n=93)		23	23	24	23	93

Eruption score: (1) unerupted, (2) partially erupted, (3) erupted

Table 4. Intergroup eruption status comparisons (Kruskal-Wallis tests)

Eruption status						
Tooth number	Score	Class I, Ex (n=23)	Class I, Non-Ex (n=23)	Class II, Ex (n=24)	Class II, Non-Ex (n=23)	p value
		n (%)	n (%)	n (%)	n (%)	
18	1 2 3	5 (21.74) 5 (21.74) 13 (56.52)^{A}	13 (56.52) 4 (17.39) 6 (26.09)^{AB}	11 (45.83) 6 (25) 7 (29.17)^{AB}	15 (65.22) 4 (17.39) 4 (17.39)^{B}	0.010*
28	1 2 3	5 (21.74) 3 (13.04) 15 (65.22)^{A}	12 (52.17) 4 (17.39) 7 (30.43)^{AB}	11 (45.84) 5 (20.83) 8 (33.33)^{AB}	14 (60.87) 5 (21.74) 4 (17.39)^{B}	0.009*
38	1 2 3	7 (30.44) 8 (34.78) 8 (34.78)	11 (47.83) 4 (17.39) 8 (34.78)	6 (25) 5 (20.83) 13 (54.17)	13 (56.52) 3 (13.04) 7 (30.43)	0.164
48	1 2 3	6 (26.09) 4 (17.39) 13 (56.52)^{A}	11 (47.82) 5 (21.74) 7 (30.43)^{B}	6 (25) 3 (12.5) 15 (62.5)^{A}	13 (56.52) 4 (17.39) 6 (26.09)^{B}	0.021*

Eruption score: (1) unerupted, (2) partially erupted, (3) erupted.
*Statistically significant at $p<0.05$
Different letters in a row indicate the presence of a statistically significant difference among the groups.
$^{A, B}$: They indicate statistically significant differences between the groups.

necessary; therefore, extraction in Class I cases may allow some mesialization of the posterior providing more space and improving third molar angulation.[26] This is particularly evident at T3, where the extractions in Class I malocclusions provided more space compared to non-extraction Class I cases and Class II non-extraction cases. The difference observed in Class II extraction cases may be attributed to the need for maxillary molars to maintain their position or undergo some degree of distalization.[9,27] The left maxillary third molar at T2 showed similar results to the right maxillary molar at T3; thus explaining the similarity in explanations. However, at T3, no more intergroup significant differences were found. These results show that all maxillary third molars tend to be come more upright over time, although the degree of uprighting may vary in different malocclusions.

Among the groups, the Class I extraction group had the highest frequency of erupted maxillary third molars (60.87%). Regarding mandibular third molars, eruption frequencies were 45.65% and 58.33% in the Class I and II extraction groups, respectively. A significantly greater percentage of erupted maxillary third molars was observed in the Class I extraction group compared to the Class II non-extraction group. Similarly, a greater percentage was found for the right mandibular third molars in the Class I and II extraction groups compared to the Class II non-extraction group. These results confirm that extraction treatment facilitates the eruption of third molars by providing additional space in the retromolar area after space closure, particularly in the maxilla for Class I and in the mandible for Class II treatments.

Mandibular third molar angulation comparisons showed no significant differences, as reported in previous studies.[28] Many studies have also shown that, mandibular third molars exhibit similar angulations after orthodontic treatment, regardless of extraction and non-extraction therapy.[11] Tarazona,[26] stated that independent of extraction or non-extraction therapy, third molar angulations will improve over time. These results also contradict previous studies, which showed smaller upright positions, indicated by mesial angulations of the mandibular molars, which are unfavorable for eruption.[2,29]

Therefore, this study cannot conclusively state that non-extraction treatment increases mandibular third molar impaction. The Class I extraction group had the highest frequency of erupted maxillary third molars (60.87%). Concerning the mandibular third molars, eruption frequencies were 45.65% and 58.33% in the Class I and II extraction groups, respectively (Table 3). A significantly greater percentage of erupted maxillary third molars was observed in the Class I extraction group than in the Class II non-extraction group (Table 4). A greater percentage was also found for the right mandibular third molars in the Class I and II extraction groups than in the Class II non-extraction group. These results confirm that the extraction treatment favors the eruption of the third molars due to a greater space gain in the retromolar space after space closure, especially in the maxilla, in Class I, and in the mandible, in Class II treatments.[30]

The significantly more upright position of the maxillary and right mandibular third molars in Class I and II extraction groups, respectively, as demonstrated in our results, likely influenced their eruption. This suggests a cause-effect relationship between third molar angulation and posterior eruption. Some authors have even proposed that the angulation of the third molar, rather than retromolar space, is the primary factor for impaction.[8] Similar findings were reported by Kim et al.[1], where over 50% of the maxillary and mandibular third molars had erupted in the extraction group. In contrast, Gungormus[17] showed that only 15% of the mandibular third molars had erupted in the extraction group, with none unerupted in the non-extraction group.

The findings of the current study differ from previous studies, where only 24% of mandibular third molars in the extraction group erupted.[8] This might be due to sample differences, as previous studies included non-growing patients. It is noted that in growing patients, the third molar is still developing and pre-eruptive movements can occur, facilitating its eruption.[13]

Clinical Implications

Assessing the position of unerupted third molars is crucial for accurate diagnosis, considering factors like angulation and root development to avoid overdiagnosis or underdiagnosis of potential impaction. Additionally, treatment planning should account for the impact of extraction or non-extraction therapy on third molar eruption. While extraction therapy may assist third molar eruption in some cases, other factors must be considered to ensure success. Moreover, incomplete root development precludes accurate prediction of impaction.

Evaluation of the unerupted third molar position is crucial for accurate diagnosis, considering factors like angulation and root development to avoid overdiagnosis or underdiagnosis of its potential impaction.[8] Furthermore, the effect of an extraction or non-extraction therapy on third molar eruption should be considered during treatment planning. While extraction therapy may assist third molar eruption in some cases, other factors must be considered to ensure success.[7] In addition, incomplete root development precludes accurate prediction of.[8]

Although this study did not find worsening of third molar angulation with non-extraction therapy, the frequency of non-erupted third molars in these treatments should be considered. Therefore, it is important to recognize that a "non-extraction treatment" may necessitate third molar extraction in some cases. The authors advocate an evaluation of the third molar angulation before and after orthodontic treatment and monitoring eruption until root development is complete, thereby mitigating unnecessary extractions or future complications.

CONCLUSION

Based on the results of this study, it can be concluded that:

- Premolar extractions in Class I malocclusion treatment positively influenced maxillary third molar angulation and eruption, with 60.87% of maxillary third molars erupted.

- Class II extraction treatment positively effected mandibular third molar posterior eruption, with 58.33% of mandibular third molars erupted.
- Less than 32.60% of the third molars erupted in the Class I non-extraction group.
- Third molars showed a more upright position after treatment, regardless of the malocclusion type or extraction protocol.
- These results suggest that third molar angulation can influence posterior eruption.

Ethics

Ethics Committee Approval: This project was approved by the Ethics in Research Committee of University of São Paulo Bauru Dental School (approval no: 466/12, date: 12.18.2018).

Informed Consent: A retrospective longitudinal study.

Author Contributions: Concept - D.P.-R.; Supervision - M.R.F.; Materials - K.M.S.F.; Analysis and/or Interpretation - A.A.-D.C.; Writing - J.Q.F., S.A.B.-P.; Critical Review - G.J.

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REFERENCES

1. Kim TW, Artun J, Behbehani F, Artese F. Prevalence of third molar impaction in orthodontic patients treated nonextraction and with extraction of 4 premolars. *Am J Orthod Dentofacial Orthop*. 2003;123(2):138-145. [CrossRef]
2. Saysel MY, Meral GD, Kocadereli I, Tasar F. The effects of first premolar extractions on third molar angulations. *Angle Orthod*. 2005;75(5):719-722. [CrossRef]
3. Miclotte A, Grommen B, Cadenas de Llano-Perula M, Verdonck A, Jacobs R, Willems G. The effect of first and second premolar extractions on third molars: A retrospective longitudinal study. *J Dent*. 2017;61:55-66. [CrossRef]
4. Björk A, Jensen E, Palling M. Mandibular growth and third molar impaction. *Acta Odont Scandinav*. 1957:231-272. [CrossRef]
5. Tait RV. Mesial migration and lower third molar tilt. *Br J Orthod*. 1982;9(1):41-47. [CrossRef]
6. Richardson ME. The effect of mandibular first premolar extraction on third molar space. *Angle Orthod*. 1989;59(4):291-294. [CrossRef]
7. Behbehani F, Artun J, Thalib L. Prediction of mandibular third-molar impaction in adolescent orthodontic patients. *Am J Orthod Dentofacial Orthop*. 2006;130(1):47-55. [CrossRef]
8. Turköz C, Ulusoy C. Effect of premolar extraction on mandibular third molar impaction in young adults. *Angle Orthod*. 2013;83(4):572-577. [CrossRef]
9. Gohilot A, Pradhan T, Keluskar KM. Effects of first premolar extraction on maxillary and mandibular third molar angulation after orthodontic therapy. *J Oral Biol Craniofac Res*. 2012;2(2):97-104. [CrossRef]
10. Staggers JA, Germane N, Fortson WM. A comparison of the effects of first premolar extractions on third molar angulation. *Angle Orthod*. 1992;62(2):135-138. [CrossRef]
11. Artun J, Thalib L, Little RM. Third molar angulation during and after treatment of adolescent orthodontic patients. *Eur J Orthod*. 2005;27(6):590-596. [CrossRef]
12. Durgesh BH, Gowda KH, AlShahrani OA, et al. Influence of premolar extraction or non-extraction orthodontic therapy on the angular changes of mandibular third molars. *Saudi J Biol Sci*. 2016;23(6):736-740. [CrossRef]
13. Jain S, Valiathan A. Influence of first premolar extraction on mandibular third molar angulation. *Angle Orthod*. 2009;79(6):1143-1148. [CrossRef]
14. ICS SC -. ISO 3950:1984 Dentistry-Designation system for teeth and areas of the oral cavity. Standards Catalogue - ICS; 1984: p. 2. [CrossRef]
15. Elsey MJ, Rock WP. Influence of orthodontic treatment on development of third molars. *Br J Oral Maxillofac Surg*. 2000;38(4):350-353. [CrossRef]
16. You TM, Ban BH, Jeong JS, Huh J, Doh RM, Park W. Effect of premolar extraction and presence of the lower third molar on lower second molar angulation in orthodontic treatment. *Oral Surg Oral Med Oral Pathol Oral Radiol*. 2014;118(3):278-283. [CrossRef]
17. Güngörmüs M. Pathologic status and changes in mandibular third molar position during orthodontic treatment. *J Contemp Dent Pract*. 2002;3(2):11-22. [CrossRef]
18. Dahlberg G. Statistical methods for medical and biological students. *Br Med J*. 1940;2(4158):358-359. [CrossRef]
19. Houston WJ. The analysis of errors in orthodontic measurements. *Am J Orthod*. 1983;83(5):382-390. [CrossRef]
20. Landis JR, Koch GG. The measurement of observer agreement for categorical data. *Biometrics*. 1977;33(1):159-174. [CrossRef]
21. Janson G, Putrick LM, Henriques JF, de Freitas MR, Henriques RP. Maxillary third molar position in Class II malocclusions: the effect of treatment with and without maxillary premolar extractions. *Eur J Orthod*. 2006;28(6):573-579. [CrossRef]
22. Nikneshan S, Sharafi M, Emadi N. Evaluation of the accuracy of linear and angular measurements on panoramic radiographs taken at different positions. *Imaging Sci Dent*. 2013;43(3):191-196. [CrossRef]
23. Nanda RS. Reappraising “Wits”. *Am J Orthod Dentofacial Orthop*. 2004;125(2):18A. [CrossRef]
24. Artun J, Behbehani F, Thalib L. Prediction of maxillary third molar impaction in adolescent orthodontic patients. *Angle Orthod*. 2005;75(6):904-911. [CrossRef]
25. Miclotte A, Grommen B, Lauwereins S, et al. The effect of headgear on upper third molars: a retrospective longitudinal study. *Eur J Orthod*. 2017;39(4):426-432. [CrossRef]
26. Tarazona B, Paredes V, Llamas JM, Cibrian R, Gandia JL. Influence of first and second premolar extraction or non-extraction treatments on mandibular third molar angulation and position. A comparative study. *Med Oral Patol Oral Cir Bucal*. 2010;15(5):e760-766. [CrossRef]
27. Janson G, Brambilla Ada C, Henriques JF, de Freitas MR, Neves LS. Class II treatment success rate in 2- and 4-premolar extraction protocols. *Am J Orthod Dentofacial Orthop*. 2004;125(4):472-479. [CrossRef]
28. Dierkes DD. An investigation of the mandibular third molars in orthodontic cases. *Angle Orthod*. 1975;45(3):207-212. [CrossRef]
29. Staggers JA. A comparison of results of second molar and first premolar extraction treatment. *Am J Orthod Dentofacial Orthop*. 1990;98(5):430-436. [CrossRef]
30. Mihai AM, Lulache IR, Grigore R, Sanabil AS, Boiangiu S, Ionescu E. Positional changes of the third molar in orthodontically treated patients. *J Med Life*. 2013;6(2):171-175. [CrossRef]

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Original Article

Orthodontists on Social Media: Instagram's Influence

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Main Points

- Public Instagram accounts have more marketing purposes than private ones, as evidenced by more posts and followers.
- The numbers of followers, followings, and daily posts are higher for accounts with a company name compared with those without one.
- While the leading categories in orthodontic sharing are awareness and before-after posts, the most commonly shared treatment option is fixed mechanics.

ABSTRACT

Objective: The aim of this study was to determine how orthodontists utilize the social media application Instagram for health communication.

Methods: Four Turkish keywords were manually searched on the Instagram platform on February 12, 2022: "orthodontist" (*ortodontist*), "orthodontics" (*ortodonti*), "orthodontic specialist" (*ortodonti uzmanı*), and "doctor of orthodontist" (*ortodonti doktoru*). A total of 195 orthodontist accounts matching the inclusion criteria were divided into two groups: public and private. Profile information analyses were performed, and the results for public and private accounts were compared. Public accounts were further divided by gender and whether they shared a company name in their profiles. Groups were compared according to post content and type of patient photo. Statistical analysis involved the Shapiro-Wilk test, an Independent Samples t-test, the Mann-Whitney U test, and chi-square and Kappa tests.

Results: The number of posts (96.06±149.30 vs. 195.36±248.51) and followers (1,250.56±2,347.47 vs. 4,071.43±6,557.63) were higher for public accounts. The number of followers (3,171.62±4,645.08 vs. 5,472.57±8,595.99) and daily posts (0.17±0.37 vs. 0.23±0.43) were higher for accounts with a company name. In the content analysis, posts on clear aligners (1.51±4.74 vs. 6.60±18.60, $p<0.05$) and patient and company advertisements were more common (0.49±1.85 vs. 3.70±10.70, $p<0.05$) for accounts with a company name.

Conclusion: While public orthodontist accounts commonly promote fixed mechanics as a treatment option, accounts with a company name adopt a different approach, emphasizing the sharing of information about clear aligners.

Keywords: Orthodontics, social media, Instagram

Introduction

Health professionals use social media to browse or discover medical information, exchange information with colleagues, and share professional problems and clinical experiences, and some of these professionals contribute to social media with new information on a daily basis.[1,2] Within the healthcare sector, social media posts appear to be useful in improving the loyalty of current patients and enabling potential patients to gain insights into orthodontists' clinical practice.[3] Social media serves as an educational tool for patients undergoing orthodontic treatment.[4]

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As dentistry transitions into the digital age in dentistry, an upsurge in orthodontists' use of digital technologies, including social media, is anticipated.[5] The increased use of social media in medicine and dentistry is accompanied by some risks and ethical problems. In particular, the concerns of specialist physicians and internet users about the quality and intelligibility of health information for the public have come to the fore.[6,7] It can often be difficult for patients to distinguish good, sound medical information obtained from electronic sources from circulating false information.[8] At the same time, the mixing of patients and physicians both online and in public areas in the social media environment may result in imprudent speculation and misunderstanding.[9]

Before the advent of the internet and social media, orthodontists found potential patients through social means or referrals from other colleagues. However, today, many patients find their physicians by using the internet, either through websites or social media.[10] Recently, the use of social media, which can be an effective marketing and communication tool for orthodontists and patients, has become widespread.[11] Parmar et al.[12] analyzed the role of social media in dentistry and reported that more than one-third of patients search for their dentists on social media. Instagram use has become quite popular among orthodontists and related companies for information sharing with colleagues and the general public.[13] As of May 2022, with 1.28 billion active users, Instagram was the fourth most popular social media platform, and it continues to grow rapidly in terms of users.[14,15] This application provides the opportunity to upload not only photos but also videos using hashtags on social networking platforms.[16] Instagram, which has grown so much in a short time, has attracted the attention of not only individuals but also physicians who want to communicate with their potential patients within the framework of health communication.[17] Alkadhimi et al.[13] noted that advertisements on Instagram are common and can be used to impress "followers" with clinical and scientific claims. Nelson[10] also reported that social media is an effective marketing and communication tool in orthodontic practice. Instagram, which has grown so much in a short time, has attracted the attention of not only individuals but also physicians who want to communicate with their potential patients within the framework of health communication.[17] Therefore, the aim of the present study was to determine how Instagram, a social media application, is used by orthodontists in the context of health communication.

METHODS

Ethics committee approval was not required before conducting this cross-sectional study because it used only publicly available data. Four keywords were manually searched on Instagram using its "Search" filter (www.instagram.com) by one of the authors on February 12, 2022: "orthodontist" (*orthodontist*), "orthodontics" (*ortodonti*), "orthodontic specialist" (*ortodonti uzmanı*), and "doctor of orthodontics" (*ortodonti doktoru*). Among the five different categories (Top, Accounts, Audio, Tags, and Places) that appear in the search filter, only the Accounts category was searched. The search language used was Turkish. Following the search, 205 accounts were recorded in Microsoft Excel. For inclusion in the study, accounts had to belong to individuals, display a full name, and match the public orthodontist registry of the Turkish Orthodontic Society. Accounts belonging to health institutions and multiple accounts belonging to the same individual were excluded from the study. Only public accounts of orthodontists with more than one account were considered, resulting in the inclusion of a total of 195 orthodontist accounts matching these

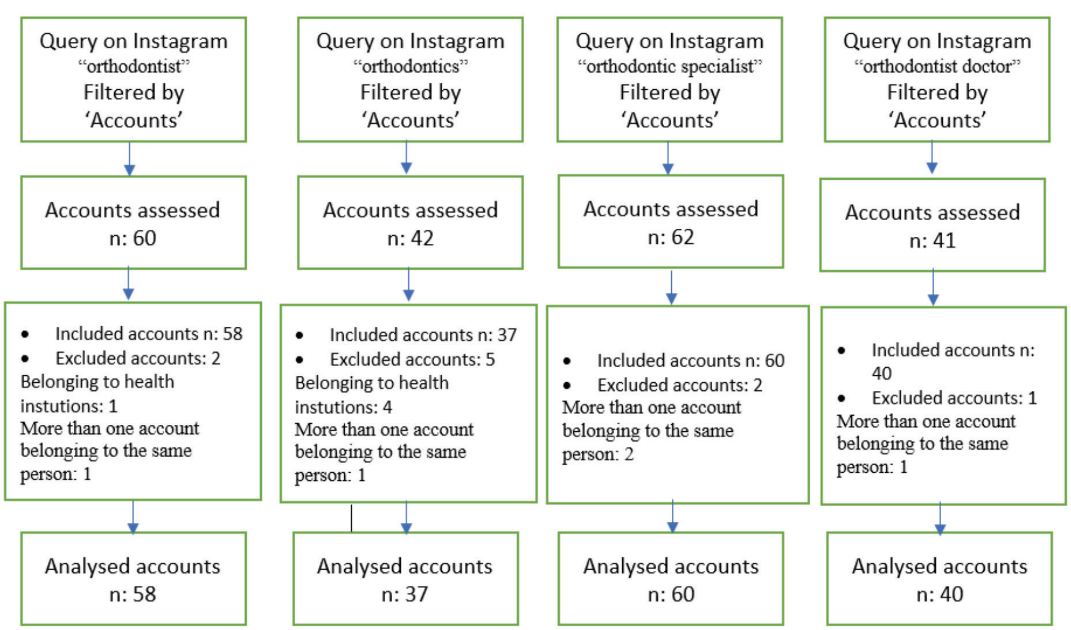

Figure 1. Inclusion criteria for orthodontist accounts

criteria (Figure 1). Due to the large difference in the number of posts in public accounts and to evaluate the current posts of orthodontists, the most recent 100 posts were evaluated. Each orthodontist's contributions were assigned sequential numbers. The texts and images of the posts were recorded. Beginning with the first post in the account, the average daily post count was calculated by dividing the total number of posts by the number of days passed.

Profile Analysis

In the analysis of profile information, the number of followers in the account profile, the number of people followed, the number of posts, gender, phone number, whether the address was written, and whether the name of any orthodontic company was written were recorded. Instagram accounts were divided into two groups: public and private, depending on whether the posts were public or not. Public account features were analyzed according to whether a company name was mentioned in their profiles.

Post Analysis

Content analysis

The posts were categorized based on their content as follows:

- Personal: Posts unrelated to orthodontics, were categorized as personal.

- Awareness: Posts without any visual or content depicting patients but providing information or raising awareness about orthodontic treatment, were recorded as awareness.

- Before-after: Posts displaying treatment stages of orthodontic patients, including photographic records, were categorized as before-after.

- Fixed mechanics: Posts containing descriptions or photographs of the orthodontic patient treated with fixed mechanics were categorized as, fixed mechanics.

- Clear aligners: Posts mentioning treatment with clear aligners or featuring images of clear aligner treatment were categorized as clear aligners.

- Functional appliances: Posts containing descriptions or photographs of the orthodontic patients treated with functional appliances were recorded as functional appliances

- Orthodontic face mask: Posts including descriptions or photographs of the orthodontic patients treated with orthodontic face masks were categorized as such.

- Orthognathic surgery: Posts featuring descriptions or photographs of orthodontic patients treated with orthognathic surgery, were categorized as orthognathic surgery.

Photo analysis

The posts shared by the orthodontists were recorded according:

- Partial patient's face: Posts showing a portion of the patient's face

- Full patient's face: Posts displaying the patient's entire face.

- Patient and company name: Posts containing both the patient's name and the name of the orthodontic company.

Statistical Analysis

Statistical analysis was performed using SPSS 22.0 for Windows (IBM Corp, Armonk, NY, USA). Descriptive information was expressed as minimum, maximum, frequency, ratio, mean, and standard deviation. The normality of the data was evaluated with the Shapiro-Wilk test. The statistical analysis of normally distributed continuous variables was done with an Independent Samples t-test, and the evaluation of non-distributed variables was done with Mann-Whitney U test. Chi-square test was used to compare categorical variables between groups. The Kappa test was used to evaluate the intra- and interrater agreement of categorical measures, and the interclass correlation coefficient was used to evaluate continuous variables. $p<0.05$ was considered as statistically significant.

RESULTS

Table 1 presents the description of profile information of orthodontic accounts and a comparison according to whether the account is private or public. The number of posts was 96.06±149.30 in private accounts and 195.36±248.51 in public accounts, and the difference between these two accounts was found to be statistically significant ($p<0.05$). Furthermore, there was a statistical difference between the two types of Instagram accounts in terms of the number of followers ($p<0.05$). 12.5% of private accounts and 71.5% of public accounts had a phone number ($p<0.05$). Additionally, address information was provided in 6.3% of private accounts and 74.3% of public accounts.

The results of content analysis of public orthodontist accounts are shown in Table 2. The number of days after the first post sharing in the accounts is 1358.72±817.61. Besides, the average number of posts per day was 0.20±0.40. It has been observed that the number of personal posts in account content is quite high with 22.68±23.30. This was followed by before and after photos, fixed mechanics, awareness, clear aligners, functional appliances, orthognathic surgery, and face mask. Moreover, 10.62±22.75 of the patient photos in the accounts included partial face, 8.01±18.80 full face, and 1.74±6.99 patient, doctor and company name.

Table 3 shows a comparison of the contents of public orthodontist accounts between genders. 63.3% of males and 78.0% of females shared phone numbers on their profiles ($p<0.05$). In content analysis, a significant difference was found between genders only in the number of personal posts ($p<0.05$). This value was 18.67±21.41 for males, whereas it was 25.85±24.33 for females.

Table 4 displays a comparison of the contents of public orthodontist accounts with and without a company name on their profiles. Public orthodontist accounts with or without a company name on their profiles were similar in terms of gender, having a telephone number and address information (p>0.05). However, the number of followers (5472.57±8595.99), number of following (950.55±792.00), and number of posts per day (0.23±0.43) were found to be statistically higher in accounts with a company name. In the content analysis, clear aligners played a more significant role in accounts with a company name than in accounts without a company name (p<0.05). There were also some differences between the two accounts in terms of patient photos. Patient and company advertisements were more common in accounts with company names (p<0.05).

DISCUSSION

Recently, social media, especially Instagram, has become a significant tool for both patients and professionals in the field of healthcare.[18,19] Instagram has become a dominant channel for orthodontists' relationships with active and potential patients, both as a marketing tool and for providing educational information.[3,4,11] The current study aimed to evaluate the posts and information shared by orthodontists in their public accounts on Instagram. The results indicated that orthodontists' private or public Instagram accounts differ in terms of the number of followers, following and shared posts. Public accounts naturally attract more followers than private accounts. This distinction understandable because while you can follow public accounts on Instagram at any time, private accounts have to be approved by the users.

Today, with the increasing time customers spend online, social media marketing is a cost-effective and more effective solution to promote services and products than traditional methods.[20] Notably, in public accounts, the prevalence of phone number, address information, and significantly higher volume of posts may suggest that these accounts were primarily created for

Table 1. Profile information descriptives of orthodontic accounts and a comparison based on the account is private or public

Parameters		Private account	Public account	p value
Number of posts (mean ± SD)		96.06±149.30	195.36±248.51	**0.002**[†]
Number of followers (mean ± SD)		1250.56±2347.47	4071.43±6557.63	**0.000**[†]
Number of followings (mean ± SD)		620.06±656.27	789.08±651.55	0.207[†]
Gender	Male (n, %)	11 (68.8%)	79 (44.1%)	0.058[a]
	Female (n, %)	5 (31.3%)	100 (55.9%)	
Phone number	Not available (n, %)	14 (87.5%)	51 (28.5%)	**0.000**[a]
	Available (n, %)	2 (12.5%)	128 (71.5%)	
Address	Not available (n, %)	15 (93.8%)	46 (25.7%)	**0.000**[a]
	Available (n, %)	1 (6.3%)	133 (74.3%)	
Company name	Not available (n, %)	13 (81.3%)	109 (60.9%)	0.107[a]
	Available (n, %)	3 (18.8%)	70 (18.8%)	

Statistical significance at p<0.05
[†]: Mann-Whitney U test, [a]: Chi-square test, p: significance
SD, standard deviation

Table 2. Content analysis of public orthodontist accounts

Parameters			N (mean ± SD)
Profile analysis	**Number of days since first post (mean ± SD)**		1358.72±817.61
	Number of posts per day (mean ± SD)		0.20±0.40
Post analysis	**Content analysis**	Personal post (mean ± SD)	22.68±23.30
		Awareness (mean ± SD)	16.48±20.50
		Before-after (mean ± SD)	21.78±34.09
		Fixed mechanics (mean ± SD)	18.50±29.73
		Clear aligners (mean ± SD)	3.50±12.41
		Functional appliances (mean ± SD)	2.17±9.78
		Face mask (mean ± SD)	0.33±0.86
		Orthognathic surgery (mean ± SD)	0.69±4.61
	Photo analysis	Partial face (mean ± SD)	10.62±22.75
		Full face (mean ± SD)	8.01±18.80
		Patient and company advertisement (mean ± SD)	1.74±6.99

N, number; SD, standard deviation

marketing purposes. This study revealed that orthodontists share an average of one post every five days in their open accounts, indicating their active engagement. This trend highlights the increasing prominence of social media, alongside with other marketing tools, within the field of orthodontics in recent years. The fact that the posts were orthodontic-themed rather than personal posts reveals the marketing motivation of these accounts.[21,22]

Studies have reported that patients use social media platforms as sources of information regarding orthodontic treatments, with Instagram being is the most frequently used program for this purpose.[23-25] Treatment modalities are one of the most sought-after topics by orthodontic patients on social media.[26] For this reason, our study also investigated the diversity of the content of Instagram accounts that orthodontists use as an information tool. Our findings frequently identified before-and-after images, and orthodontic posts aimed at increasing awareness. Supporting our findings, Meira et al.[23] showed that the categories of "being a teacher" and "before and after treatment" had a higher effect on the reliability perception of the participants. Among treatment modalities, fixed mechanics were the most prominently featured, consistent with our expectations. Graf et al.[27] similarly found that on Instagram and Twitter commonly discussed the application, removal, and limitations of brackets in their study. Our study found that orthodontists also shared cases involving clear aligner cases. Olson et al.[28] showed that patients with the highest interest in orthodontic treatment with clear aligners tended to prefer orthodontists. In addition, they also reported that clear aligner treatments had a high effect on the patient perceptions of reliability. In our study, the least treatment options shared by orthodontists were functional appliances, orthodontic face masks, and orthognathic surgical treatment cases, respectively. Buyuk and Imamoglu[29] in their examination of orthognathic surgery posts on Instagram in 2019 using hashtags, reported that Instagram was not an adequate source of information. This highlights the importance of orthodontists sharing these options that require sensitive information for informative purposes.

Although physicians' use of social media provides significant benefits to both patients and medical professionals, it also brings ethical problems. In the orthodontist accounts analyzed in this study, the fact that the faces of orthodontic patients are shared openly in most of the posts may give an idea about possible ethical violations in social media in the coming years. These ethical considerations present significant problems for physicians as they engage in online interactions with patients, society, and colleagues.[30]

Table 3. Comparison of the contents of public orthodontist accounts between genders

Parameters			Male	Female	p value
Profile analysis	**Telephone number**	Not available (n, %)	29 (36.7%)	22 (22.0%)	**0.030**[a]
		Available (n, %)	50 (63.3%)	78 (78.0%)	
	Address	Not available (n, %)	23 (29.1%)	23 (23.0%)	0.353[a]
		Available (n, %)	56 (70.9%)	77 (77.0%)	
	Company name	Not available (n, %)	54 (68.4%)	55 (55.0%)	0.069[a]
		Available (n, %)	25 (31.6%)	45 (45.0%)	
	Number of days since first post (mean ± SD)		1457.24±815.31	1279.30±814.94	0.151[b]
	Number of followers (mean ± SD)		4504.79±7227.95	3729.08±5990.65	0.783[†]
	Number of followings (mean ± SD)		708.74±643.77	852.55±653.18	0.053[†]
	Number of posts (mean ± SD)		174.65±184.27	211.72±289.26	0.816[†]
	Number of posts per day (mean ± SD)		0.13±0.16	0.24±0.51	0.097[†]
Post analysis	**Content analysis**	Personal post (mean ± SD)	18.67±21.41	25.85±24.33	**0.040**[b]
		Awareness (mean ± SD)	19.22±24.75	14.32±16.20	0.676[†]
		Before-after (mean ± SD)	27.25±44.44	17.47±22.16	0.365[†]
		Fixed mechanics (mean ± SD)	23.01±38.73	14.95±19.46	0.269[†]
		Clear aligners (mean ± SD)	4.16±17.66	2.98±5.53	0.052[†]
		Functional appliances (mean ± SD)	3.64±14.35	1.01±2.54	0.494[†]
		Face mask (mean ± SD)	0.34±1.03	0.33±0.71	0.384[†]
		Orthognathic surgery (mean ± SD)	1.17±6.83	0.31±1.07	0.606[†]
	Photo analysis	Partial face (mean ± SD)	12.77±30.55	8.93±13.75	0.518[†]
		Full face (mean ± SD)	10.44±25.18	6.10±11.29	0.274[†]
		Patient and company advertisement (mean ± SD)	1.44±4.31	1.99±8.55	0.215[†]

Statistical significance at p<0.05
[†]: Mann-Whitney U test, [a]: Chi square test, [b]: Independent Samples t-test, p: Significance
SD, standard deviation

Table 4. Comparison of the content of public orthodontist accounts with and without a company name in their profile

Parameters			Company name not available	Company name available	p value
Profile analysis	Gender	Male (n, %)	54 (49.5%)	25 (35.7%)	0.069[a]
		Female (n, %)	55 (50.5%)	45 (64.3%)	
	Telephone number	Not available (n, %)	34 (31.2%)	17 (24.3%)	0.318[a]
		Available (n, %)	75 (68.8%)	53 (75.7%)	
	Address	Not available (n, %)	33 (30.3%)	13 (18.6%)	0.080[a]
		Available (n, %)	76 (69.7%)	57 (81.4%)	
	Number of days since first post (mean ± SD)		1394.85±842.47	1303.48±780.82	0.693[b]
	Number of followers (mean ± SD)		3171.62±4645.08	5472.57±8595.99	**0.003**[†]
	Number of followings (mean ± SD)		685.38±519.95	950.55±792.00	**0.023**[†]
	Number of posts (mean ± SD)		179.68±245.23	219.77±253.36	0.114[†]
	Number of posts per day (mean ± SD)		0.17±0.37	0.23±0.43	**0.028**[†]
Post analysis	Content analysis	Personal post (mean ± SD)	21.52±24.70	24.48±20.98	0.292[b]
		Awareness (mean ± SD)	14.66±20.01	19.32±21.06	0.036[†]
		Before-after (mean ± SD)	22.92±37.23	20.01±28.70	0.957[†]
		Fixed mechanics (mean ± SD)	21.33±35.81	14.10±15.52	0.798[†]
		Clear aligners (mean ± SD)	1.51±4.74	6.60±18.60	**0.000**[†]
		Functional appliances (mean ± SD)	2.22±10.97	2.10±7.62	0.201[†]
		Face mask (mean ± SD)	0.25±0.72	0.45±1.04	0.440[†]
		Orthognathic surgery (mean ± SD)	0.82±5.82	0.48±1.33	0.312[†]
	Photo analysis	Partial face (mean ± SD)	10.40±25.75	10.97±17.25	0.499[†]
		Full face (mean ± SD)	7.71±19.00	8.48±18.60	0.204[†]
		Patient and company advertisement (mean ± SD)	0.49±1.85	3.70±10.70	**0.000**[†]

Statistical significance at p<0.05
[†]: Mann-Whitney U test, [a]: Chi-square test, [b]: Independent Samples t-test, p: Significance
SD, standard deviation

Confidentiality and privacy are the most important digital professional problems in physicians' use of social media. If a physician shares a patient's information to a third party without the consent of the patient, it will be a violation of privacy. For this reason, physicians should secure patients' permission before disseminating their medical information online, even if it serves medical purposes.[31] In the literature, there are many studies on the effect of gender on social media usage. Nelson et al.[10] reported that orthodontists actively utilized social media, with a higher prevalence of usage among females. Another study conducted by Brenner[31] stated that the utilization rate of social media use was 79% among women and 69% among men. In the current study, it was seen that female orthodontists added their phone numbers to their profiles more frequently possibly as a means to connect with patients. The possible verbal abilities of women compared to men as a marketing strategy may explain this result.[32] Another difference was observed in the frequency of sharing personal posts. Female orthodontists were more willing to present slices of life visually, which is the main purpose of Instagram.

In our study, the Instagram accounts of orthodontists with or without a company name in their profiles were compared. In the analysis of the profile information and shared posts, it was seen that a significant number of orthodontists identified themselves as "Invisalign providers" in their profiles, signifying their association with the clear aligner company. The use of this marketing method by a considerable proportion of orthodontists (39.1%) prompted a comparison between submissions from orthodontists who used and did not use this method. Clear aligner treatment, prominently represented by the Invisalign appliance, was introduced in 1997 and started to be used by orthodontists in 1999.[26] This relatively recent treatment approach has since been adopted by various companies across different countries. Invisalign (Align Technology, San Jose, California, USA) is the most widely used of these systems, although similar systems under different commercial names are also available in the market.[33] The Invisalign system serves as both a brand and a treatment methodology. Invisalign's leadership in this regard may have led to the perception of clear aligner equals Invisalign among patients. Using a well-known clear aligner company like Invisalign in the profile description can be considered a sensible marketing strategy, given that social media relies heavily on visual content and clear aligners are often preferred for their aesthetic benefits. However, it can also be misleading when considering ethical violations and the limitations of clear aligner treatment. The results of this study indicate that orthodontic accounts using this marketing method tend to attract a larger number of followers. When the content analysis between the two groups was analyzed, the only difference was found that the orthodontists who incorporated the company name in their profiles as a marketing method posted more content about clear aligners– a result that aligns with expectations.

Another review made on accounts with or without a company name, focusing on the photos in the posts. It was observed that the number of photographs in which the patient and the company name were in the frame together was significantly higher in the group containing the company name. It seems that this group uses a common marketing method, both the treatment method they apply and the company. Both the contribution of such shares to the awareness of the company and the fact that orthodontists attract patients who desire this treatment can please both parties.[6] However, the possibility of these posts increasing the prejudices of patients about fixed treatments or against other companies raises the possibility that this method may cause problems for orthodontists in the long term.

Study Limitations

A limitation of this study was that it was based on the assessment of the most recent posts shared in a specific period and community on the Instagram platform. Secondly, the data extracted from the Instagram platform may not be consistently stable and could undergo frequent changes. Because this study was conducted in a single population, the generalizability of its results can be limited. The outcomes of this study highlight important information that can be used by orthodontists to navigate social media with greater professionalism and have a greater impact on recruiting potential patients.

CONCLUSION

Instagram is a social network widely used among orthodontists. Based on the findings of the current study, the following conclusions could be drawn:

- Public Instagram accounts have more marketing purposes with more posts and followers.

- Public accounts are more prone to share contact information such as phone numbers and addresses.

- Accounts that incorporate a company name tend to exhibit a larger larger follower counts, a higher number of accounts followed, and a heightened frequency of daily posts.

- While the leading categories for orthodontic content sharing are centered around rasing awareness and showcasing before and after transformations. Among treatment options, fixed mechanics emerged as the most frequently shared approach.

Ethics

Ethics Committee Approval: Because this study comprised only the data available in the public domain, it did not require approval from an ethics committee.

Informed Consent: Not applicable.

Author Contributions

Concept - M.A.Y., G.G.K.; Design - M.A.Y., G.G.K.; Supervision - M.A.Y.; Materials - M.A.Y., G.G.K.; Data Collection and/or Processing - M.A.Y., G.G.K.; Analysis and/or Interpretation - M.A.Y., G.G.K.; Literature Review - M.A.Y.; Writing - M.A.Y.; Critical Review - G.G.K.

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References

1. Avcı K, Çelikden SG, Eren S, Aydenizöz D. Assessment of medical students' attitudes on social media use in medicine: a cross-sectional study. *BMC Med Educ.* 2015;15:18. [CrossRef]
2. Mansfield SJ, Morrison SG, Stephens HO, et al. Social media and the medical profession. *Med J Aust.* 2011;194(12):642-644. [CrossRef]
3. Jorgensen G. Attracting orthodontic patients via the Internet: A 20-year evolution. *Am J Orthod Dentofacial Orthop.* 2015;148(6):939-942. [CrossRef]
4. Al-Silwadi FM, Gill DS, Petrie A, Cunningham SJ. Effect of social media in improving knowledge among patients having fixed appliance orthodontic treatment: A single-center randomized controlled trial. *Am J Orthod Dentofacial Orthop.* 2015;148(2):231-237. [CrossRef]
5. Papadimitriou A, Kakali L, Pazera P, Doulis I, Kloukos D. Social media and orthodontic treatment from the patient's perspective: a systematic review. *Eur J Orthod.* 2020;42(3):231-241. [CrossRef]
6. Berland GK, Elliott MN, Morales LS, Algazy JI, Kravitz RL, Broder MS, et al. Health information on the Internet: accessibility, quality, and readability in English and Spanish. *JAMA.* 2001;285(20):2612-2621. [CrossRef]
7. Cline RJ, Haynes KM. Consumer health information seeking on the Internet: the state of the art. *Health Educ Res.* 2001;16(6):671-692. [CrossRef]
8. Lehmann BA, Ruiter RA, Kok G. A qualitative study of the coverage of influenza vaccination on Dutch news sites and social media websites. *BMC Public Health.* 2013;13:547. [CrossRef]
9. Hyman JL, Luks HJ, Sechrest R. Online professional networks for physicians: risk management. *Clin Orthop Relat Res.* 2012;470(5):1386-1392. [CrossRef]
10. Nelson KL, Shroff B, Best AM, Lindauer SJ. Orthodontic marketing through social media networks: the patient and practitioner's perspective. *Angle Orthod.* 2015;85(6):1035-1041. [CrossRef]
11. Stephen AT, Galak J. The effects of traditional and social earned media on sales: a study of a microlending marketplace. *J Mark Res.* 2012;49(5):624-639. [CrossRef]
12. Parmar N, Dong L, Eisingerich AB. Connecting With Your Dentist on Facebook: Patients' and Dentists' Attitudes Towards Social Media Usage in Dentistry. *J Med Internet Res.* 2018;20(6):e10109. [CrossRef]
13. Alkadhimi A, Al-Moghrabi D, Fleming PS. The nature and accuracy of Instagram posts concerning marketed orthodontic products. *Angle Orthod.* 2022;92(2):247-254. [CrossRef]

14. Statista. Number of Instagram users worldwide from 2020 to 2025. [CrossRef]
15. Peng R, Sun D, Tsai WT. Success factors in mobile social networking application development: case study of instagram. In Proceedings of the 29th Annual ACM Symposium on Applied Computing. 2014;1072-1079. [CrossRef]
16. Oliveira LM, da Silva Pilecco K, de Souza DF, de Oliveira CA, Zanatta FB. Main uses of Instagram in oral health research: A scoping review. *Health Policy Technol.* 2022;11(1):100605. [CrossRef]
17. Zhou J, Bercovitch L. Instagram and the dermatologist: An ethical analysis. *J Am Acad Dermatol.* 2018;78(6):1226-1228. [CrossRef]
18. Kılınç DD. Is the information about orthodontics on Youtube and TikTok reliable for the oral health of the public? A cross sectional comparative study. *J Stomatol Oral Maxillofac Surg.* 2022;123(5):e349-e354. [CrossRef]
19. Kılınç DD, Sayar G. Assessment of Reliability of YouTube Videos on Orthodontics. *Turk J Orthod.* 2019;32(3):145-150. [CrossRef]
20. Henzell M, Knight A, Antoun JS, Farella M. Social media use by orthodontic patients. N Z Dent J. 2013;109(4):130-133. [CrossRef]
21. Chretien KC, Tuck MG. Online professionalism: A synthetic review. *Int Rev Psychiatry*. 2015;27(2):106-117. [CrossRef]
22. Farnan JM, Snyder Sulmasy L, Worster BK, Chaudhry HJ, Rhyne JA, Arora VM; American College of Physicians Ethics, Professionalism and Human Rights Committee; American College of Physicians Council of Associates; Federation of State Medical Boards Special Committee on Ethics and Professionalism*. Online medical professionalism: patient and public relationships: policy statement from the American College of Physicians and the Federation of State Medical Boards. *Ann Intern Med.* 2013;158:620-7. [CrossRef]
23. Meira TM, Prestes J, Gasparello GG, Antelo OM, Pithon MM, Tanaka OM. The effects of images posted to social media by orthodontists on public perception of professional credibility and willingness to become a client. *Prog Orthod.* 2021;22:7. [CrossRef]
24. Alslakhi MH, Öz U, Sin Ç. The powerful effects of social media platforms on orthodontic patient knowledge's improving, attitude management and it is influence on financial income of the orthodontic clinic. *Appl Nanosci.* 2022;13:1-6. [CrossRef]
25. Siddiqui N, Chia M, Sharif MO. Social media and orthodontics: Are our patients scrolling? *J Orthod.* 2022;49(2):179-184. [CrossRef]
26. Al-Gunaid TH, Ibrahim AM, Alhazmi KM, Aljohani AA, Eshky RT, Althagafi N. Impact of social media on patient's decision-making toward orthodontic treatment. *Saudi J Health Sci*. 2021;10(2):132-137. [CrossRef]
27. Graf I, Gerwing H, Hoefer K, Ehlebracht D, Christ H, Braumann B. Social media and orthodontics: A mixed-methods analysis of orthodontic-related posts on Twitter and Instagram. *Am J Orthod Dentofacial Orthop.* 2020;158(2):221-228. [CrossRef]
28. Olson JC, Shroff B, Carrico C, Boyle J, Lindauer SJ. Comparison of patient factors influencing the selection of an orthodontist, general dentist, or direct-to-consumer aligners. *Am J Orthod Dentofacial Orthop.* 2020;157(4):526-532. [CrossRef]
29. Buyuk SK, Imamoglu T. Instagram as a social media tool about orthognathic surgery. *Health Promot Perspect.* 2019;9(4):319-322. [CrossRef]
30. Hamm MP, Chisholm A, Shulhan J, et al. Social media use among patients and caregivers: a scoping review. *BMJ Open.* 2013;3(5):e002819. [CrossRef]
31. Brenner J. Pew Internet: Social Networking Fact Sheet. Pew Research Center. [CrossRef]
32. Phan X, Ling PH. Clinical limitations of Invisalign. *J Can Dent Assoc.* 2007;73(3):263-266. [CrossRef]
33. Kim TW, Echarri P. Clear aligner: an efficient, esthetic, and comfortable option for an adult patient. *World J Orthod.* 2007;8(1):13-18. [CrossRef]

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Original Article

The Common Retention Practices Among Orthodontists from Different Countries

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Main Points

- Pre-treatment spacing, degree of rotation and pre-treatment crowding were the most influencing malocclusion-related factors on the choice of retainers.
- A thermoplastic retainer was the most prescribed retention appliance for the maxillary arch.
- The bonded retainer was the most prescribed retention appliance for the mandibular arch.

ABSTRACT

Objective: To investigate the most common retention practices, factors influencing the retention protocol, and the differences among orthodontists regarding retention practices.

Methods: An online validated questionnaire was anonymously sent to 3,000 orthodontic residents and clinicians. The survey consisted of 19 questions regarding the participants' demographics, prescribed retention appliances, factors affecting retention appliance choices, and adjunctive retention procedures. Descriptive statistics, Chi2 and Kendall's Tau-b tests were applied.

Results: Five hundred fifty-five orthodontic residents and clinicians, 53.3% males and 46.7% females, completed the survey, indicating a response rate of 18.5%. Although participants' demographics, type of treatment and pre-treatment malocclusion influence the choice of retention protocols, thermoplastic retainers (TR) were the most popular retention regime for the maxillary arch for both adults (47.4%) and adolescents (42.3%). Bonded retainers (BR) were the favored option for the mandibular arch (44.9% of adults and 40.7% of adolescents). The degree of arch expansion (64.1%) and the degree of interdigitation (50.1%) after treatment were the most influential factors for the choice of the preferred type of retainers by the respondents. 68.6% of the participants thought professional retention guidelines would be useful.

Conclusion: Thermoplastic retainers were the most common retention appliances for adults and adolescents in the maxilla. At the same time, BR was the most favored retainer in the mandibular arch, with clinical experience, practice setting, and malocclusion- and treatment-related factors influencing the type of the chosen appliance. The demographic differences and the uneven participation in the survey need to be considered while interpreting the findings of this study.

Keywords: Survey, retention, online, orthodontic

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INTRODUCTION

The most challenging part of orthodontic treatment is the retention phase. The term retention refers to the procedure of holding teeth in an ideal aesthetic and functional position after orthodontic treatment.[1] Retention permits the reorganization of bone and supragingival/transseptal fibers and neuromuscular and soft tissue adaptation. Static and dynamic occlusal stability, an appropriate retention plan, soft tissue balance, active growth, and patient cooperation are vital parameters to avoid potential post-orthodontic relapse.[2]

Several researchers have concluded that a certain degree of change is inevitable after active orthodontic treatment. Thilander[3] showed that most patients (40% to 90%) reported unacceptable outcomes ten years after treatment. However, orthodontists in clinical practice require an understanding of the etiologies of relapse. The etiologies of relapse include age- and orthodontic-related factors.[4] Knowledge of different types of retainers and retention protocols can help minimize relapse. Though several types of removable or fixed retention appliances have been proposed with varying protocols to minimize relapse,[5,6] there is no consensus regarding the optimal appliance and/or ideal protocol. The type of retention choice and protocol depends on many factors, including but not limited to clinician preference and experience, occlusal outcomes, the type of orthodontic movement achieved, and patients age and preferences.[4]

Several studies have reviewed retention protocols, covering a broad spectrum of the types of prescribed retainers and retention protocols adopted by clinicians in different countries.[7,8] For instance, clinicians in the UK[9] and Australia[10] preferred removable retainers as the retention protocol for the maxillary arch. A study that involved clinicians from The Netherlands showed that the most commonly used retainer was a fixed retention appliance.[8] Norwegian orthodontists preferred using a combination of removable and fixed retainers.[11] However, it is essential to acknowledge that the selection of retainers and protocol is temporal. For instance, in the USA, the selection of Hawley retainers declined in the period from 1986 to 1996, while the use of spring aligners, clear thermoplastic retainers, and canine-to-canine fixed retainers became more popular.[12] This trend is due to the lack of conclusive findings about the optimal choice of retention appliance and protocol.[13] Many clinicians justify their choice based on their clinical experience and interpretation of the evidence.

The objective of this global study was first to investigate the most common retention practices and, secondly, to assess the associated rationale and reasoning that affected the retention practices, and to inspect the differences among clinicians regarding their retention practices with a primary focus on age, experience, and practice settings.

METHODS

Sample Population

Orthodontic residents and specialists who subscribed to virtual orthodontic learning sessions hosted by the Orthodontic Mastery Facebook group were eligible to participate in the study. There was no restriction on the country of residence. The participants who opted for a choice of general practitioner were excluded from the survey.

Survey Validity

Initially, 29 questions were designed and agreed upon by the authors. These questions were consistent with contemporary literature and guidelines.[4,14] For content validity (CV), 20 specialist orthodontists were emailed via SurveyMonkey, and were asked to rate each question as "essential", "useful but not essential", or "not necessary".[15] The CV ratio (CVR) was calculated for each item using Lawshe's[16] method. Questions with a CVR higher than 0.51 were selected for the final survey. Hence, 23 questions remained and were included in the construct face validity (CFV) phase. For the CFV phase, 100 participants (50 residents and 50 specialist orthodontists) were emailed via SurveyMonkey to anonymously rate the remaining 23 questions as "favorable" or "unfavorable". An analysis of the responses using Kappa statistics was undertaken to test the agreement for every question. Questions with a low level of agreement were excluded. In summary, 16 experts and 28 orthodontic specialists and residents participated in the CV and CFV phases, respectively. Expert feedback at the CV phase led us to drop 7, retain 22, revise 5, and add 1 new question to the survey. At the CFV phase, 4 items were dropped, 19 were retained, 2 were revised, and no new questions were added. The final set of 19 questions was used in the final survey.

The Validated Survey

The validated online survey consisted of 19 questions divided into five main domains (Appendix 1):

- Demographic information for participants, including gender, age, years of experience, country of residency, and clinical practice setting.
- The prescribed retention appliances for different age groups and their reasoning.
- Patient and clinician-related factors.
- Malocclusion and treatment factors.
- The adjunctive procedures and the benefit of guidelines.

In the final survey and when necessary, a logical option was implemented in which respondents could skip from certain pages to specific destination pages further ahead, based on their answer to a previous question. To avoid the partial response error, the whole questionnaire was constructed as mandatory. (https://www.surveymonkey.co.uk/r/Orthodontic1).

Data Collection

The approval was granted by the Ethical Committee of ITTEFAQ Hospital (registration number: RCDD-IHT-04-2020, date: 21.09.2020).

The anonymous survey link was shared with 3,000 residents and orthodontists. At the commencement of the survey, details about the study objectives and the research team were provided to the participants. Reminders were sent after two weeks to those who failed to participate. The survey remained open for four months until the sample size was met.

Data Analysis and Sample Size

A sample size calculation was performed using the SurveyMonkey calculator (www.surveymonkey.co.uk). Considering that there are 25,000 residents and orthodontists who are actively engaged in virtual learning, to detect a 95% confidence interval with a margin error of 4% and statistical power of 80%, the required sample size was 550 orthodontists.

Statistical analysis consisted of general descriptive analyses for all categorical variables using absolute and relative frequencies. The chi^2 test assessed the association or dependence between categorical variables. Kendall's Tau-b test was conducted in the ordinal scale measurement case. The significance level used in the analysis was set at 5% (α=0.05).

All statistical analyses were performed using SPSS software (SPSS Inc., version 25.0 for Windows, Chicago, IL, USA).

RESULTS

Demographic Information of Participants

In total, 555 participants completed the survey (18.5% response rate), of whom 53.3% were males and 46.7% were females. More than half (50.2%) were from Asia, followed by Europe (27.6%) and Africa (14%) (Figure 1).

The majority (43.4%) of the respondents were 30-39 years old. Respondents aged 40-49 years and 50-59 years represented 22.7% and 11% of the total cohort, respectively. The minority of the participants were either younger than 30 years (18.4%) or older than 60 years (4.5%).

Almost one out of three respondents (34.6%) were novices in clinical orthodontics (less than 5 years), and one out of four (27%) had 5-10 years of clinical experience. In contrast, seasoned clinicians with more than 20 years of clinical orthodontic experience represented 14.6% of the cohort. At the time of the study, most of the participants were certified orthodontists working either in private (46.1%) or mixed settings (29%). In comparison, the remainder (24.9%) were postgraduate students or residents in orthodontics (Figure 2).

Retention Appliances of Choice

1. Based on the age groups of patients

The thermoplastic retainer was the most prescribed retention appliance for the maxillary arch for adults (47.4%) and adolescents (42.3%). However, in the mandibular arch, bonded retainers were the favored retention appliances in both adults (44.9%) and adolescents (40.7%).

2. Based on the gender of the clinician

The results showed that there were no statistically significant differences (p>0.05) between genders in the choice of the retention protocol for adult and adolescent patients, except that females clinicians were more likely to prescribe Hawley retainers for adolescents in the maxillary arch (37.8%, p=0.044), and to combine this with bonded retainers in the maxillary arch for adult patients (18.5%, p=0.049) in comparison with their male peers (Table 1).

3. Based on the clinical settings

The results showed that there was no significant influence (p>0.05) of practice setting on the use of combined Hawley and bonded retainers in the maxillary and mandibular arch for both adults and adolescents (Table 1). In private practices, certified orthodontists significantly favoured the uses of the combined thermoplastic and bonded retainers for adolescent patients. However, the difference was not significant among participants from other settings regarding using this protocol in adults

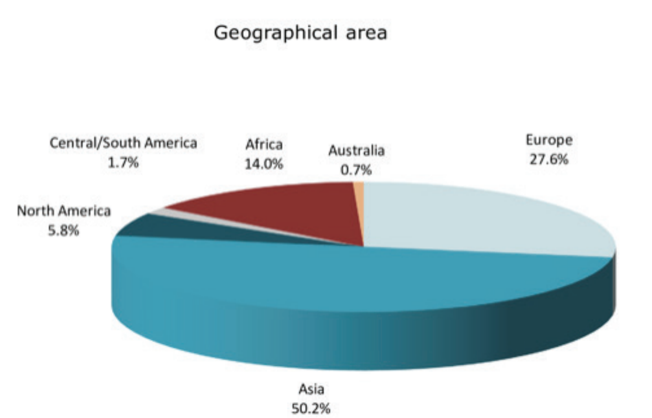

Figure 1. Global distribution of the respondents

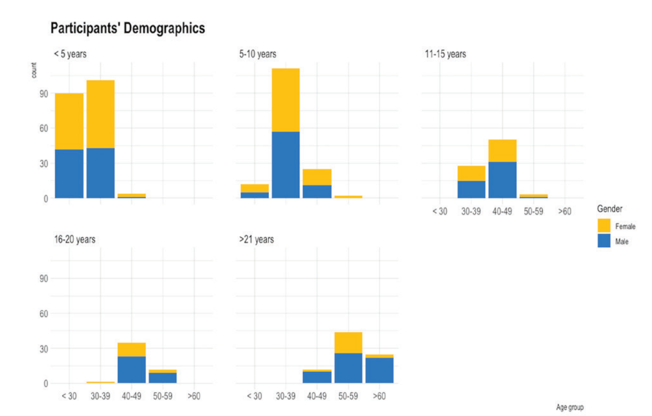

Figure 2. Bar plot depicts the participants demographics; gender (male, female), age group (<30, 30-39, 40-49, 50-59, >60 years), and years of experience (<5, 5-10, 11-15, 16-20, >21 years)

(maxillary and mandibular arch). Hawley retainer was the least favored retention appliance to be used by orthodontists in a private practice setting compared to other practice settings, the differences being statistically significant (p<0.001).

Those from mixed-setting practices significantly used lower thermoplastic retainers for adults in their daily practice (p=0.010) and prescribed bonded retainers in the maxillary arch (p=0.016) and in the mandibular arch (p=0.036) for adult patients, compared to different practice settings. However, the influence of practice setting on the use of bonded retainers in adolescents was insignificant (p>0.05).

4. Based on the clinicians' age and experience

The results (Table 2) showed that the age of participants had a negligible effect on the prescribed retention protocol (p>0.05), except that younger age groups (less than 30 years of age) were more likely to prescribe a combination of lower Hawley and bonded retainers for their adult patients (14.7%, p<0.01). Orthodontists aged 30-39 years were more likely to combine Hawley and bonded retainers in the mandibular arch for adolescent patients (14.1%, p=0.006) in comparison with older age groups. Moreover, participants older than 60 years preferred to use lower bonded retainers in adolescents (56%, p=0.026).

With regards to clinical experience, orthodontists having less than 5 years of clinical experience, highly preferred the use of a combined lower Hawley and bonded retainer for their adult and adolescent patients in comparison with other groups, p=0.011 and p=0.007 respectively (Table 2). On the other hand, the influence of clinical experience was not statistically significant for other retention protocols (p>0.05).

Patient and Clinician Related Factors

When the participants were asked to choose factors influencing their choice of a retainer, compliance of the patients (56.2%)

Table 1. Retention protocols in the maxilla and mandible in both adult and adolescents according to the gender and the practice setting

Patients	Type of retainer	Overall	Gender		Practice setting		
			Male n=296 (%)	Female n=256 (%)	Postgraduate students n=138 (%)	Private practice n=256 (%)	Mixed settings (university/hospital and private) n=161 (%)
Maxillary arch in adults	Bonded retainer	100 (18%)	56 (18.9%)	54 (20.8%)	30 (21.7%)	38 (14.8%)	42 (26.1%)*
	Hawley retainer	113 (20%)	56 (18.9%)	57 (22%)	36 (26.1%)	31 (12.1%)	46 (28.6%)***
	Thermoplastic retainer	263 (47%)	145 (49%)	118 (45.6%)	68 (49.3%)	114 (44.5%)	81 (50.3%)
	Thermoplastic and bonded retainer	220 (39.6%)	124 (41.9%)	96 (37.1%)	46 (33.3%)	109 (42.6%)	65 (40.4%)
	Hawley and bonded retainer	85 (15%)	37 (12.5%)	48 (18.5%)*	23 (16.7%)	35 (13.7%)	27 (16.8%)
Mandibular arch in adults	Bonded retainer	249 (45%)	131 (44.3%)	118 (45.6%)	64 (46.4%)	101 (39.5%)	84 (52.2%)*
	Hawley retainer	60 (11%)	33 (11.1%)	27 (10.4%)	15 (10.9%)	14 (5.5%)	31 (19.3%)***
	Thermoplastic retainer	172 (31%)	85 (28.7%)	87 (33.6)	49 (35.5%)	63 (24.6%)	60 (37.3%)*
	Thermoplastic and bonded retainer	241 (43%)	130 (43.9%)	111 (42.9%)	58 (42%)	122 (47.7%)	61 (37.9%)
	Hawley and bonded retainer	53 (9.5%)	24 (8.1%)	29 (11.2%)	16 (11.6%)	19 (7.4%)	18 (11.2%)
Maxillary arch in adolescents	Bonded retainer	78 (14%)	43 (14.5%)	35 (13.5%)	24 (17.4%)	27 (10.5%)	27 (16.8%)
	Hawley retainer	186 (33.5%)	88 (29.7%)	98 (37.8%)*	65 (47.1%)	54 (21.1%)	67 (41.6%)***
	Thermoplastic retainer	235 (42%)	132 (44.6%)	103 (39.8%)	55 (39.9%)	106 (41.4%)	74 (46%)
	Thermoplastic and bonded retainer	171 (31%)	93 (31.4%)	78 (30.1%)	34 (24.6%)	93 (36.3%)	44 (27.3%)*
	Hawley and bonded retainer	110 (19.8%)	54 (18.2%)	56 (21.6%)	29 (21%)	45 (17.6%)	36 (22.4%)
Mandibular arch in adolescents	Bonded retainer	226 (40.7%)	122 (41.2%)	104 (40.2%)	53 (38.4%)	95 (37.1%)	78 (48.4%)
	Hawley retainer	103 (18.5%)	50 (16.9%)	53 (20.5%)	39 (28.3%)	21 (8.2%)	43 (26.7%)***
	Thermoplastic retainer	149 (26.8%)	76 (25.7%)	73 (28.2%)	40 (29%)	58 (22.7%)	51 (31.7%)
	Thermoplastic and bonded retainer	183 (33%)	105 (35.5%)	78 (30.1%)	37 (26.8%)	105 (41%)	41 (25.5%)**
	Hawley and bonded retainer	61 (11%)	29 (9.8%)	32 (12.4%)	17 (12.3%)	25 (9.8%)	19 (11.8%)

Statistically significant: *p<0.05; **p<0.01; ***p<0.001
n, number of participants

Table 2. Retention protocols in the maxilla and mandible in both adult and adolescents according to the age and the clinical experience

Patients	Type of retainer	Age					Clinical experience				
		Less than 30 years	30-39 years	40-49 years	50-59 years	More than 60 years	Less than 5 years	5-10 years	11-15 years	16-20 years	More than 20 years
		n=102 (%)	n=241 (%)	n=126 (%)	n=61 (%)	n=25 (%)	n=192 (%)	n=150 (%)	n=83 (%)	n=49 (%)	n=81 (%)
Maxillary arch in adults	Bonded retainer	31 (30.4%)	37 (15.4%)	25 (19.8%)	12 (19.7%)	5 (20%)	43 (22.4%)	30 (20%)	11 (13.3%)	9 (18.4%)	17 (21%)
	Hawley retainer	27 (26.5%)	42 (17.4%)	23 (18.3%)	13 (21.3%)	8 (32%)	46 (24%)	28 (18.7%)	13 (15.7%)	2 (4.1%)	24 (29.6%)
	Thermoplastic retainer	49 (48%)	117 (48.5%)	57 (45.2%)	29 (47.5%)	11 (44%)	97 (50.5%)	64 (42.7%)	44 (53%)	23 (46.9%)	35 (43.2%)
	Thermoplastic and bonded retainer	36 (35.3%)	100 (41.5%)	56 (44.4%)	20 (32.8%)	8 (32%)	70 (36.5%)	66 (44%)	37 (44.6%)	20 (40.8%)	27 (33.3%)
	Hawley and bonded retainer	20 (19.6%)	32 (13.3%)	18 (14.3%)	9 (14.8%)	6 (24%)	31 (16.1%)	22 (14.7%)	9 (10.8%)	9 (18.4%)	14 (17.3%)
Mandibular arch in adults	Bonded retainer	53 (52%)	97 (40.2%)	54 (42.9%)	31 (50.8%)	14 (56%)	87 (45.3%)	63 (42%)	35 (42.2%)	20 (40.8%)	44 (54.3%)
	Hawley retainer	10 (9.8%)	22 (9.1%)	17 (13.5%)	6 (9.8%)	5 (20%)	22 (11.5%)	15 (10%)	9 (10.8%)	1 (2%)	13 (16%)
	Thermoplastic retainer	36 (35.3%)	73 (30.3%)	37 (29.4%)	19 (31.1%)	7 (28%)	65 (33.9%)	48 (32%)	22 (26.5%)	15 (30.6%)	22 (27.2%)
	Thermoplastic and bonded retainer	41 (40.2%)	115 (47.7%)	57 (45.2%)	21 (34.4%)	7 (28%)	80 (41.7%)	72 (48%)	38 (45.8%)	26 (53.1%)	25 (30.9%)
	Hawley and bonded retainer	**15 (14.7%)**	**26 (10.8%)**	**7 (5.6%)**	**3 (4.9%)**	**2 (8%)***	**26 (13.5%)**	**14 (9.3%)**	**6 (7.2%)**	**2 (4.1%)**	**5 (6.2%)***
Maxillary arch in adolescents	Bonded retainer	20 (19.6%)	24 (10%)	24 (19%)	6 (9.8%)	4 (6%)	29 (15.1%)	16 (10.7%)	10 (12%)	11 (22.4%)	12 (14.8%)
	Hawley retainer	40 (39.2%)	79 (32.8%)	37 (29.4%)	21 (34.4%)	9 (36%)	74 (38.5%)	48 (32%)	21 (25.3%)	10 (20.4%)	33 (40.7%)
	Thermoplastic retainer	36 (35.3%)	103 (42.7%)	53 (42.1%)	35 (57.4%)	8 (32%)	76 (39.6)	66 (44%)	33 (39.8%)	24 (49%)	36 (44.4%)
	Thermoplastic and bonded retainer	30 (29.4%)	83 (34.4%)	41 (32.5%)	11 (18%)	6 (24%)	54 (28.1%)	57 (38%)	27 (32.5)	17 (34.7%)	16 (19.8%)
	Hawley and bonded retainer	22 (21.6%)	49 (20.3%)	26 (20.6%)	9 (14.8%)	4 (16%)	47 (24.5%)	26 (17.3%)	18 (21.7%)	4 (8.2%)	15 (18.5%)
Mandibular arch in adolescents	Bonded retainer	**36 (35.3%)**	**93 (38.6%)**	**53 (42.1%)**	**30 (49.2%)**	**14 (56%)***	**71 (37%)**	**59 (39.3%)**	**36 (43.4%)**	**19 (38.8%)**	**41 (50.6%)**
	Hawley retainer	27 (26.5%)	40 (16.6%)	22 (17.5%)	9 (14.8%)	5 (20%)	45 (23.4%)	28 (18.7%)	8 (9.6%)	5 (10.2%)	17 (21%)
	Thermoplastic retainer	24 (23.5%)	65 (27%)	35 (27.8%)	20 (32.8%)	5 (20%)	52 (27.1%)	41 (27.3%)	19 (22.9%)	16 (32.7%)	21 (25.9%)
	Thermoplastic and bonded retainer	31 (30.4%)	91 (37.8%)	43 (34.1%)	13 (21.3%)	5 (20%)	59 (30.7%)	58 (38.7%)	32 (38.6%)	17 (34.7%)	17 (21%)
	Hawley and bonded retainer	**14 (13.7%)**	**34 (14.1%)**	**8 (6.3%)**	**4 (6.6%)**	**1 (4%)****	**31 (16.1%)**	**14 (9.3%)**	**7 (8.4%)**	**3 (6.1%)**	**6 (7.4%)****

Statistically significant: *p<0.05; **p<0.01; ***p<0.001
n, number of participants

and status of oral hygiene (54.2%) were the most influencing clinician and patient-related factors.

Malocclusion and Treatment Factors

Pre-treatment spacing, degree of rotation and pre-treatment crowding were the most influencing malocclusion related-factors on the choice of retainers, 77.7%, 73.5% and 70.8%, respectively. Notably, the influence of third molars received the lowest score (8.5%). With regards to treatment-related factors, 64.1% of the total sample thought the amount of expansion achieved during treatment was the most influential factor for their preferred choice of retainer type. The degree of interdigitation after treatment was chosen by half of the participants (50.1%) as being a factor. Only 18.6% of the cohort thought the amount of extrusion of posterior teeth would be an influencing factor on their choice of retainer after treatment. Appendix 2 shows a detailed report of the participants' responses.

The Adjunctive Procedures and the Benefit of Guidelines

46.4% of the respondents do not routinely use adjunctive retention procedures such as the circumferential supracrestal fiberotomy (CSF) or interproximal reduction (IPR) (Appendix 3). However, 39.7% of the cohort prescribe CSF to enhance retention of de-rotated teeth, while 31.3% of the participants considered IPR in the presence of pre-treatment labial segment crowding to optimise post-treatment retention. The results demonstrated that there is a consensus (92.8%) regarding the association between a thick labial frenum and a median diastema. Most respondents (94.2%) applied the blanching test for its diagnosis, while 39.5% relied on the radiographical assessment. Most participants believed in the thick labial frenum being an aetiological factor for a median diastema and recommended labial frenectomy to minimise relapse, either before commencing orthodontic treatment (7.7%), during treatment but before complete diastema closure (42%), or after active orthodontic treatment (44.5%). Furthermore, 84.7% of the participants recommended the use of a bonded retainer as a post-treatment retention protocol for maintaining diastema closure, but only 12.6% preferred a removable retainer (4.1% for the Hawley retainer and 8.5% for thermoplastic retainer).

Approximately, two-thirds (68.6%) of the participants agreed that professional guidelines on retention would be useful, 24.7% thought it would be partially helpful, and only 5% thought such guidelines would have no benefit.

DISCUSSION

The present survey has shed some light on the retention regimes employed by orthodontic clinicians worldwide, which may help orthodontists improve their retention protocols in the absence of uniform clinical guidelines. Despite their importance, existing guidelines are out of date, and their quality was rated inadequate, especially in terms of their development, editorial independence, stakeholder agreement, and record of applicability, as judged by the AGREE instrument (Appraisal of Guidelines, Research, and Evaluation).[17]

This study showed that thermoplastic retainers were the most commonly prescribed retainers in the maxillary arch in adult and adolescent patients, a finding similar to those of previous studies in the UK,[9] Australia/New Zealand,[10] Ireland,[19] Canada,[23] and Malaysia.[24] On the other hand, studies from other parts of the globe showed different outcomes. For instance, the Hawley retainer was the most common retention appliance in the maxillary arch in the USA[21,25] and Saudi Arabia,[20] while fixed retainers were commonly adopted by clinicians from the Netherlands,[18] and Norwegian and Danish clinicians[11,26] were in favor of a combination of removable and fixed retainers, indicating the influence of the training center on the choice of retention appliance. It is noteworthy that over recent years and in many countries, there has been a shift from Hawley to clear thermoplastic retainers.[8,18,21,27] Present evidence[28] shows that thermoplastic retainers are more cost-effective and well accepted by patients when compared with Hawley retainers. However, the effectiveness of thermoplastic retainers over Hawley retainers for maxillary arch stability is inconclusive.[29,30] Moreover, in this study, most clinicians favored bonded retainers in the mandibular arch, which is in agreement with most previous studies.[8,10,11,18,20,25] Additionally, some previous studies have reported using thermoplastic retainers[24] or a combination of removable and fixed retainers.[7]

In the present study, female clinicians were more inclined towards the use of Hawley retainers alone in the maxillary arch in adolescents (37.8%) or in combination with bonded retainers in adults (18.5%), similar to the findings of previous studies.[11,31] Clinicians in private practices favored thermoplastic retainers in the maxillary arch and a combination of thermoplastic and bonded retainers in the mandibular arch. These findings are consistent with UK[9] and Ireland[19] based retention surveys. For orthodontists working in mixed practice settings, the use of upper thermoplastic and lower bonded retainers were most common, in contrast with an Ireland-based survey[19] in which thermoplastic retainers were mostly used in both maxillary and mandibular arches. This discrepancy could be due to the fact that the latter study[19] included respondents from public practices as well as the influence of the orthodontic training background on the choice of retention appliance.

In the current study, upper thermoplastic retainers in adults, Hawley retainers in adolescents, and lower bonded retainers, were preferred options for patients treated in mixed settings (university, hospital and private). Previous studies from Ireland and the UK[9,19] showed that thermoplastic retainers were most commonly used in both jaws in hospital-based practices. This trend can be explained by the fact that almost all of our participants in mixed-based practices were postgraduate students who were working under supervision.[7] The participants' age had negligible influence on retainer choice, with older orthodontists leaning more towards lower bonded retainers. Similar opinions were given by UK orthodontists in a previous study.[9]

It is well established that clinical experience of orthodontists is an important factor that can affect the retention protocol.[8] In our study, orthodontic clinicians with less than 5 years of clinical experience highly preferred using a combined lower Hawley retainer and bonded retainer. This could be due to the carry-over learning effect of their previous clinical training during residency.[7] However, a recent study showed no correlations between different retention modalities and orthodontic experience.[31]

In this study, malocclusion-related factors were more important than patient- and treatment-related factors. The spacing and de-crowding were equally important variables in selecting the retainers, while the influence of third molars was the least importance. Similar opinions were given by orthodontists in previous studies.[7,18,31] The most important patient-related factors for the choice of retainers were compliance of the patients and their oral hygiene status, similar to the findings of previous studies.[7,11,18] Expansion achieved during treatment and the degree of interdigitation at the end of treatment were the most important treatment-related factors that influenced retainer choice. In previous studies, interdigitation after treatment,[18] expansion and extraction,[7,18-20] and final occlusal outcomes[11,18] were opined to be the most important treatment factors in determining the retention plan.

Adjunct procedures like IPR and CSF are widely reported to prevent relapse.[4,32] In the present study, one third of the cohort prescribed CSF to enhance retention of de-rotated teeth, while a quarter of the participants considered IPR to be beneficial in preventing potential post-treatment lower labial segment relapse. In a Saudi Arabia-based survey,[20] 28% of orthodontists performed IPR, while 19.1% used CSF as an adjunct procedure to optimise post-treatment retention.

Since a thick labial frenum is one of the causative factors for a median diastema, it is an established fact that these patients are at high risk of post-treatment relapse.[33] In the present survey, most clinicians acknowledged this association and therefore recommended a labial frenectomy before complete diastema closure or after active orthodontic treatment, followed by placing a bonded retainer. This is in agreement with the findings of previous studies.[18,31] Regarding the need for retention guidelines, the majority of the participants agreed that such guidelines would be beneficial, which is in agreement with several previous studies.[7,11,18]

Some studies have reported a higher response rate in their survey studies mainly by implementing telephonic reminders[8,18] or paper-based postal services.[9,19] In the present study, the response rate was low, which is common in electronic-based surveys in the field of orthodontic retention.[20,21] As the present survey was global and conducted during the coronavirus disease-2019 pandemic, it was not practical for the authors to have pre-contacts and personalized contacts with most of the participants. Moreover, in survey-based studies, response representativeness is more important than response rate.[22] All previous survey studies on retention protocols[7,8,18,23] were mostly limited to specialist orthodontists, or were regional and thus lacking favorable representativeness of working orthodontic clinicians, in comparison with the present study. However, higher response rate from different continents may or may not change the significance of the results, but it may increase the generalizability of the findings.

Study Limitations

The strength of this survey lies in the fact that it involved validated questionnaires answered by orthodontists and residents of different ages and experience levels from across the globe, thus increasing representativeness rate and minimizing the level of bias. The authors acknowledge that the participation in this study was uneven, and therefore this factor needs to be taken into consideration when interpreting the findings.

CONCLUSION

This study showed that the most common retention appliance was thermoplastic retainer in the maxillary arch and bonded retainer in the mandibular arch for both adults and adolescents. This is similar to the adopted adolescent retention protocol in private practices except that the lower bonded retainer is usually combined with thermoplastic retainer. Female orthodontists commonly used Hawley retainer alone or combined with bonded retainer. The age of participants has negligible effect on the prescribed retention protocol except that younger age groups who are more likely to prescribe a combination of lower Hawley and bonder retainers for their adult. The pre-treatment spacing and crowding were the most influencing malocclusion-related factors. Moreover, the uneven participation in this survey should be taken into consideration during interpreting the results.

Ethics

Ethics Committee Approval: The approval was granted by the Ethical Committee of ITTEFAQ Hospital (registration number: RCDD-IHT-04-2020, date: 21.09.2020).

Informed Consent: At the commencement of the survey, details about the study objectives and the researcher team were provided to the participants.

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

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REFERENCES

1. Riedel R, Graber T, Swain B. Current orthodontic concepts and techniques. Philadelphia: WB Saunders Co; 1969. [CrossRef]
2. Fleming PS, Dibiase AT, Lee RT. Arch form and dimensional changes in orthodontics. *Prog Orthod.* 2008;9(2):66-73. [CrossRef]
3. Thilander B. Orthodontic relapse versus natural development. *Am J Orthod Dentofacial Orthop.* 2000;117(5):562-563. [CrossRef]
4. Littlewood SJ, Kandasamy S, Huang G. Retention and relapse in clinical practice. *Aust Dent J.* 2017;62(Suppl 1):51-57. [CrossRef]
5. Al-Moghrabi D, Johal A, O'Rourke N, et al. Effects of fixed vs removable orthodontic retainers on stability and periodontal health: 4-year follow-up of a randomized controlled trial. *Am J Orthod Dentofacial Orthop.* 2018;154(2):167-174.e1. [CrossRef]
6. Kaklamanos EG, Kourakou M, Kloukos D, Doulis I, Kavvadia S. Performance of clear vacuum-formed thermoplastic retainers depending on retention protocol: a systematic review. *Odontology.* 2017;105(2):237-247. [CrossRef]
7. Andriekute A, Vasiliauskas A, Sidlauskas A. A survey of protocols and trends in orthodontic retention. *Prog Orthod.* 2017;18(1):31. [CrossRef]
8. Padmos JAD, Fudalej PS, Renkema AM. Epidemiologic study of orthodontic retention procedures. *Am J Orthod Dentofacial Orthop.* 2018;153(4):496-504. [CrossRef]
9. Singh P, Grammati S, Kirschen R. Orthodontic retention patterns in the United Kingdom. *J Orthod.* 2009;36(2):115-121. [CrossRef]
10. Wong PM, Freer TJ. A comprehensive survey of retention procedures in Australia and New Zealand. *Aust Orthod J.* 2004;20(2):99-106. [CrossRef]
11. Vandevska-Radunovic V, Espeland L, Stenvik A. Retention: type, duration and need for common guidelines. A survey of Norwegian orthodontists. *Orthodontics (Chic.).* 2013;14(1):e110-117. [CrossRef]
12. Sheridan JJ, LeDoux W, McMinn R. Essix retainers: fabrication and supervision for permanent retention. *J Clin Orthod.* 1993;27(1):37-45. [CrossRef]
13. Littlewood SJ, Millett DT, Doubleday B, Bearn DR, Worthington HV. Retention procedures for stabilising tooth position after treatment with orthodontic braces. *Cochrane Database Syst Rev.* 2016;2016(1):CD002283. [CrossRef]
14. Johnston C, Burden D, Morris D. Clinical guidelines: Orthodontic retention. 2008. [CrossRef]
15. Lewis BR, Snyder CA, Rainer Jr RK. An empirical assessment of the information resource management construct. *JMIS.* 1995;12(1):199-223. [CrossRef]
16. Lawshe CH. A quantitative approach to content validity. *Pers Psychol.* 1975;28(4):563-575. [CrossRef]
17. Tejani T, Mubeen S, Seehra J, Cobourne MT. An exploratory quality assessment of orthodontic clinical guidelines using the AGREE II instrument. *Eur J Orthod.* 2017;39(6):654-659. [CrossRef]
18. Renkema AM, Sips ET, Bronkhorst E, Kuijpers-Jagtman AM. A survey on orthodontic retention procedures in The Netherlands. *Eur J Orthod.* 2009;31(4):432-437. [CrossRef]
19. Meade MJ, Millett D. Retention protocols and use of vacuum-formed retainers among specialist orthodontists. *J Orthod.* 2013;40(4):318-325. [CrossRef]
20. Al-Jewair TS, Hamidaddin MA, Alotaibi HM, et al. Retention practices and factors affecting retainer choice among orthodontists in Saudi Arabia. *Saudi Med J.* 2016;37(8):895-901. [CrossRef]
21. Pratt MC, Kluemper GT, Hartsfield JK Jr, Fardo D, Nash DA. Evaluation of retention protocols among members of the American Association of Orthodontists in the United States. *Am J Orthod Dentofacial Orthop.* 2011;140(4):520-526. [CrossRef]
22. Cook C, Heath F, Thompson RL. A meta-analysis of response rates in web- or internet-based surveys. *EPM.* 2000;60(6):821-836. [CrossRef]
23. Carneiro NCR, Nóbrega MTC, Meade MJ, Flores-Mir C. Retention decisions and protocols among orthodontists practicing in Canada: A cross-sectional survey. *Am J Orthod Dentofacial Orthop.* 2022;162(1):51-57. [CrossRef]
24. Ab Rahman N, Low TF, Idris NS. A survey on retention practice among orthodontists in Malaysia. *Korean J Orthod.* 2016;46(1):36-41. [CrossRef]
25. Valiathan M, Hughes E. Results of a survey-based study to identify common retention practices in the United States. *Am J Orthod Dentofacial Orthop.* 2010;137(2):170-177; discussion 7. [CrossRef]
26. Hamran T, Čirgić E, Aiyar A, Vandevska-Radunovic V. Survey on retention procedures and use of thermoplastic retainers among orthodontists in Norway, Sweden, and Denmark. *J World Fed Orthod.* 2022;11(4):114-119. [CrossRef]
27. Keim RG, Vogels Iii DS, Vogels PB. 2020 JCO study of orthodontic diagnosis and treatment procedures part 1: results and trends. *J Clin Orthod.* 2020;54(10):581-610. [CrossRef]
28. Mollov ND, Lindauer SJ, Best AM, Shroff B, Tufekci E. Patient attitudes toward retention and perceptions of treatment success. *Angle Orthod.* 2010;80(4):468-473. [CrossRef]
29. Rowland H, Hichens L, Williams A, et al. The effectiveness of Hawley and vacuum-formed retainers: a single-center randomized controlled trial. *Am J Orthod Dentofacial Orthop.* 2007;132(6):730-737. [CrossRef]
30. Barlin S, Smith R, Reed R, Sandy J, Ireland AJ. A retrospective randomized double-blind comparison study of the effectiveness of Hawley vs vacuum-formed retainers. *Angle Orthod.* 2011;81(3):404-409. [CrossRef]
31. Padmos J, Mei L, Wouters C, Renkema AM. Orthodontic retention procedures in New Zealand: A survey to benefit clinical practice guideline development. *J World Fed Orthod.* 2019;8(1):24-30. [CrossRef]
32. Edman Tynelius G, Bondemark L, Lilja-Karlander E. Evaluation of orthodontic treatment after 1 year of retention--a randomized controlled trial. *Eur J Orthod.* 2010;32(5):542-547. [CrossRef]
33. Rajani ER, Biswas PP, Emmatty R. Prevalence of variations in morphology and attachment of maxillary labial frenum in various skeletal patterns - A cross-sectional study. *J Indian Soc Periodontol.* 2018;22(3):257-262. [CrossRef]

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Original Article

Can a Self-etching Primer be Effective in Bonding Aligner Attachments to Different Types of Ceramics?

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Main Points

- Self-etch ceramic primer increases the bond strength of aligner attachments to lithium disilicate ceramics.
- Self-etch primer did not improve the bond strength of the aligner attachments for monolithic zirconia ceramics.
- The resin attachment remnant index can be used to determine the remnant amount of aligner attachment.

ABSTRACT

Objective: This *in vitro* study aimed to evaluate the effectiveness of pretreatment with a self-etching primer for bonding aligner attachments to lithium disilicate (LD) and monolithic zirconia (MZ) ceramics.

Methods: Forty ceramics, including LD (n=20) and MZ (n=20), were divided into four study groups according to the surface pretreatments: LD specimens pretreated with universal primer (Monobond Plus, MP) after hydrofluoric acid etching (Group 1); MZ ceramics pretreated with MP after sandblasting (Group 2); LD ceramics pretreated with self-etching ceramic primer (Monobond etch & prime, MEP) (Group 3); and MZ ceramics pretreated with MEP after sandblasting (Group 4). The aligner composite (GC Aligner Connect) and universal adhesive (GPremio Bond) were used to prepare the resin attachments. The bond strength was evaluated by micro-shear bond strength (SBS) testing (0.1 mm/min) after thermocycling, and the remnant adhesive was scored according to the resin attachment remnant index (RARI). The SBS data were analyzed using ANOVA and Tukey tests, and the RARI scores were analyzed using the chi-square test.

Results: Group 1 had the lowest SBS, and group 2 had the highest SBS. There were significant differences between the groups in terms of bond strength ($p<0.05$). The RARI scores showed no significant differences, regardless of the pretreatment and ceramic type.

Conclusion: The use of a self-etching primer increased the bond strength of resin attachments on LD ceramics. For zirconia ceramics, both ceramic primers are recommended for aligner attachment bonding.

Keywords: Aligner attachment, ceramic, self-etching primer, shear bond strength

INTRODUCTION

Clear aligner (CA) treatment has gained popularity due to increased esthetic concerns. Adult patients undergoing CA therapy have the highest quality-of-life scores compared with labial and lingual treatments.[1] Other advantages of CA therapy include shorter treatment duration and chair time in mild to moderate cases over traditional fixed orthodontic treatment.[2] Most available aligner systems require resin attachments to retain appliances and better three-dimensional (3D) control of tooth movements.[3] Therefore, the adhesion between

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the resin attachment and surfaces must be strong to withstand orthodontic and chewing forces under intraoral conditions.

Due to advancements in adhesive materials, it has become easier to provide adequate attachment bond strength on natural teeth.[4] However, the adhesion protocol for attaching aligner attachments to glass-based ceramics or zirconia remains uncertain in clinical practice. The primary goal of ceramic pretreatment is to create surface roughness, followed by primer application to facilitate the bonding process. The protocols vary depending on the chemical nature of the ceramics. For lithium disilicate (LD) glass-ceramics, the most common method involves hydrofluoric acid (HFA) etching followed by silanization.[5] On the other hand, sandblasting is commonly used for bonding orthodontic brackets to Y-TZP zirconia ceramics.[6] When the ceramic surfaces are pretreated, either mechanically by sandblasting or chemically by etching, a ceramic primer is used as a silane coupling agent.[5] Therefore, clinicians need to determine the appropriate pretreatment method for applying aligner attachments to different ceramic surfaces due to their dissimilar structures in the bracket-bonding procedure.

The self-etching ceramic primer (Monobond etch & prime) has been introduced as a single-component primer, especially for glass-based ceramics, and an alternative to pretreatment with HFA etching due to its adverse effects on systemic toxicity, eye injuries, inhalation, and ingestion-related symptoms.[7] In recent studies, this self-etching primer has demonstrated adequate bracket bonding strength with no damage on ceramic surfaces in the case of debonding.[8,9] This raises the question of whether the self-etching primer can serve as an alternative to conventional pretreatment when bonding aligner attachments to different ceramic surfaces. The aim of this study was to evaluate the effectiveness of pretreatment with a self-etching primer for bonding of aligner attachments to LD and monolithic zirconia (MZ) ceramics. Therefore, the null hypothesis was that there would be no difference in bond strength and remnant amount of aligner attachments between pretreatment with self-etching or universal ceramic primer, regardless of the ceramic type.

METHODS

Sample size calculations were performed using software based on a previous study.[10] The required sample size in each group was estimated to be 10, with an alpha-type error of 0.05, power of 0.80, and effect size of 0.577.

Specimen Preparation

Forty disk-shaped specimens (5 mm in diameter and 2 mm thick), including LD (n=20) and MZ (n=20), were fabricated using the milling method. LD specimens were then subjected to crystallization in a ceramic oven (Programat P300, Ivoclar Vivadent, Schaan, Liechtenstein) according to the manufacturer's guidelines (840 °C, 20-25 min). The MZ specimens were sintered in a furnace (inLab Profire, Dentsply Sirona, Germany) according to the manufacturer's instructions (1500 °C, 135 min). After glazing the ceramic surfaces, the specimens were individually embedded in self-cured acrylic resin, leaving the ceramic surfaces exposed. Four study groups (n=10) were created according to the surface pretreatment as follows:

- Group 1: LD pretreated with universal ceramic primer after HFA etching.
- Group 2: MZ pretreated with universal ceramic primer after sandblasting.
- Group 3: LD pretreated with self-etching ceramic primer.
- Group 4: MZ pretreated with self-etching ceramic primer after sandblasting.

Surface Treatments

The materials used and their compositions are shown in Table 1. The ceramic material was etched with 5% HFA (Condac porcelana, FGM, Joinville, Brasil) for 20 s, rinsed for 30 s, and finally air-dried in group 1. Sandblasting was conducted with 50 µm grain size Al_2O_3 particles from a distance of 10 mm for 15 s in groups 2 and 4. In groups 1 and 2, a universal ceramic primer (Monobond Plus, Ivoclar Vivadent, Schaan, Liechtenstein) was applied with a microbrush and allowed to react for 60 s. Subsequently, the excess was dispersed with a strong air stream to ensure solvent evaporation. In groups 3 and 4, a self-etching ceramic primer (Monobond etch & prime-MEP, Ivoclar Vivadent, Schaan, Liechtenstein) was applied using a microbrush, agitated into the surface for 20 seconds, allowed to react for another 40 seconds, rinsed thoroughly with water for 20 s, and air-dried for 10 s.

Attachment Preparation and Bonding Procedures

One aligner attachment ($3 \times 3 \times 1$ mm^3) was specially designed (Solidworks, Dassault Systemes SolidWorks Corp.,Waltham, MA, USA), and another software (Mimics, Materialise, Leuven, Provincie Vlaams-Brabant, Belgium) was used to prepare 3D models of the ceramic specimens. All attachments were bonded to each specimen using an attachment template produced by thermoforming an aligner material (Duran, Scheu Dental, Iserlohn, Germany).

Universal adhesive (G-Premio Bond, GC, Tokyo, Japan) was applied to the pretreated surface and light-cured for 10 s. Then, a specially developed aligner composite (GC Aligner Connect, GC Corp, Tokyo, Japan) was applied to the attachment wells of each template, pressed onto the ceramic surface, and then light-cured for 10 s. All bonding procedures were performed by the same researcher (S.Ç).

After the bonding procedure, the specimens were kept in distilled water until the thermocycling process. Thermocycling was performed between 5-55 °C with a dwell time of 30 s at 1000 cycles. A micro-shear bond strength (SBS) testing unit (Mod Dental, Ankara, Turkey) was used at a crosshead speed of 0.1 mm/min until detachment to assess the bond strength of the resin attachments (Figure 1). After the SBS test, the remaining attachment was scored under a stereomicroscope

Table 1. The materials used and their respective compositions		
Ceramic type	**Manufacturer**	**Composition**
Lithium disilicate (IPS e.max CAD)	Ivoclar Vivadent, Schaan, Liechtenstein	SiO_2 57.0-80.0%, Li_2O 11.0-19.0%, K_2O 0.0-13.0%, P_2O_5 0.0-11.0%, ZrO_2 0.0-8.0%, ZnO 0.0-8.0%, Colorants 0.0-18.0%
Monolithic zirconia (Cercon HT)	Dentsply Sirona, Hanau, Germany	Zirconium oxide Yttrium oxide 5% Hafnium oxide <3% Aluminium oxide, Silicon oxide, other oxides <2%
Pretreatment		
Condac Porcelana 5%	FGM Produtos Odont, Joinville, SC, Brazil	5% Hydrofluoric acid
Monobond Plus	IvoclarVivadent, Schaan, Liechteinstein	Ethanol, silane, 10-MDP, and disulfide acrylate
Monobond Etch & Prime	Ivoclar Vivadent, Schaan, Liechteinstein	Silane, ammonium polyfluoride (etchant), alcohol, and water
Attachment bonding		
G-Premio Bond	GC, Tokyo, Japan	MDP, 4-MET, MEPS, methacrylate monomer, acetone, water, initiator, silica filler
GC Aligner Connect	GC Orthodontics, Alsip, IL, USA	Esterification products of 4,4′-isopropylidenediphenol, ethoxylated and 2-methylprop-2-enoic acid, 2,2-dimethyl-1,3-propanediyl bismethacrylate, 1,3,5-Triazine-2,4,6-triamine, polymer with formaldehyde, titanium dioxide, UDMA

(Olympus, SZ61, Munster, Germany) at 20x magnification according to the resin attachment remnant index (RARI). This index was developed on the basis of the original description of Artun and Bergland,[11] although there was no bracket mesh base. The amount of remnant attachment was expressed as a percentage, and the surface damage was also note, resulting in a final score. Consequently, the RARI included five scores as follows:

0: No resin attachment to the surface.

1: Less than 25% of the resin attachment remains on the surface.

2: More than 25% and less than 50% of the resin attachment remains on the surface.

3: More than 50% of the resin attachment is left on the surface.

4: Surface damage.

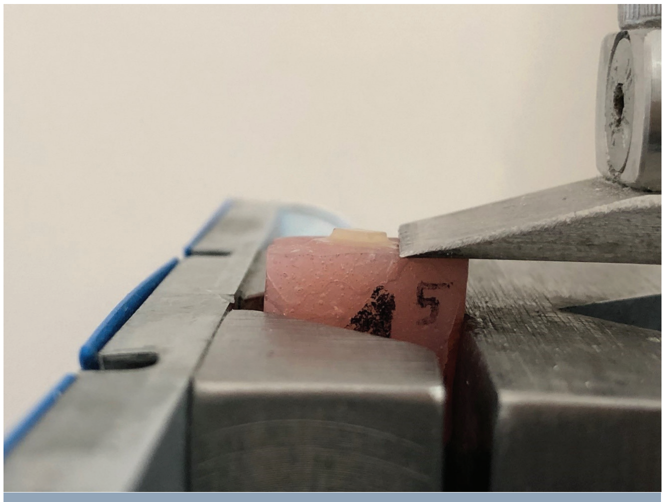

Figure 1. The SBS test
SBS, shear bond strength

Statistical Analysis

The data were analyzed using SPSS software (vers. 21.0, SPSS Inc, Chicago, IL, USA). The normality of distribution was tested using the Shapiro-Wilk test. One-way ANOVA and Tukey tests were used to compare the SBS results. The RARI scores were analyzed using the chi-square test. For all tests, $p<0.05$ was considered statistically significant.

RESULTS

The mean SBS values and intergroup comparisons are shown in Table 2. The pretreatment of LD ceramics with HFA and MP showed the lowest mean SBS value (6.02±2.19) in group 1, whereas the pretreatment of MZ ceramics with MP after sandblasting showed the highest mean SBS value (14.20±6.26) in group 2. There were significant differences between the groups in terms of SBS results ($p=0.002$). The mean SBS value of group 1 was significantly lower than that of the other groups ($p<0.05$). The SBS values are shown as a box plot in Figure 2.

Analysis of the RARI scores provided valuable information concerning remnant attachment on ceramic surfaces. One specimen for each score is shown in Figure 3. There were no significant differences among the groups in terms of RARI scores ($p>0.05$, Table 3). In addition, no ceramic damage was observed during this study.

DISCUSSION

The demand for CA treatment has increased among adults with ceramic restorations recently. Therefore, the appropriate method for conducting ceramic surface treatment in clinical practice has been a topic of discussion. Although many alternatives have been recommended for bracket bonding to LD and MZ ceramics,[12-16] there are limited data on aligner attachment bonding to different ceramics. In a recent study,

Table 2. The comparison of SBS values (MPa) of study groups

Groups	n	Mean±SD	95% confidence interval		Min.-Max.	p value	Post-hoc tests	p value
			Lower Bound	Upper Bound				
Group 1 (LD+HFA+ MP)	10	6.02±2.19[a]	4.46	7.59	1.61-8.62	0.002	LD+HFA+MP versus MZ+S+MP LD+HFA+MP versus LD+MEP LD+HFA+MP versus MZ+S+MEP MZ+S+MP versus LD+MEP MZ+S+MP versus MZ+S+MEP MZ+S+MEP versus MZ+S+MEP	0.003 0.020 0.022 0.871 0.849 0.986
Group 2 (MZ+S+MP)	10	14.20±6.26[b]	9.72	18.69	7.02-25.11			
Group 3 (LD+MEP)	10	12.58±5.57[b]	8.59	16.57	4.82-21.49			
Group 4 (MZ+S+MEP)	10	12.48±3.94[b]	9.66	15.29	8.74-20.18			

Different letters ([a] and [b]) indicate statistically significant difference between groups (Tukey's test; $p<0.05$).
LD, lithium disilicate; HFA, hydrofluoric acid etching; MP, monobond plus (universal primer); MEP, monobond etch & prime (self-etching primer); MZ, monolithic zirconia; S, sandblasting; SD, standard deviation

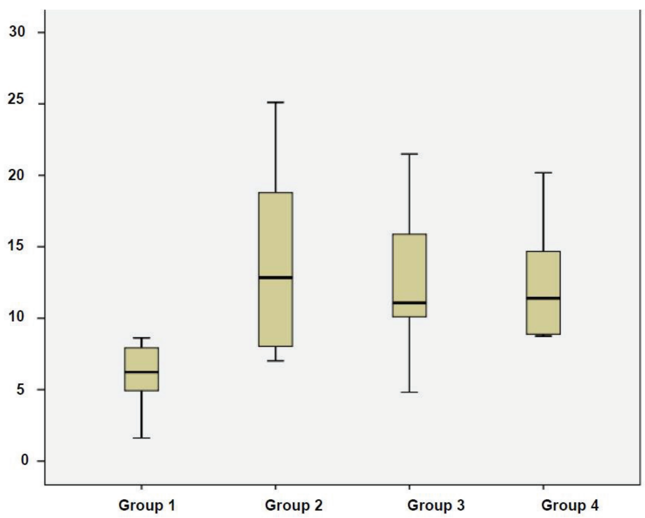

Figure 2. Box plot showing SBS values (MPa) of the study groups
SBS, shear bond strength

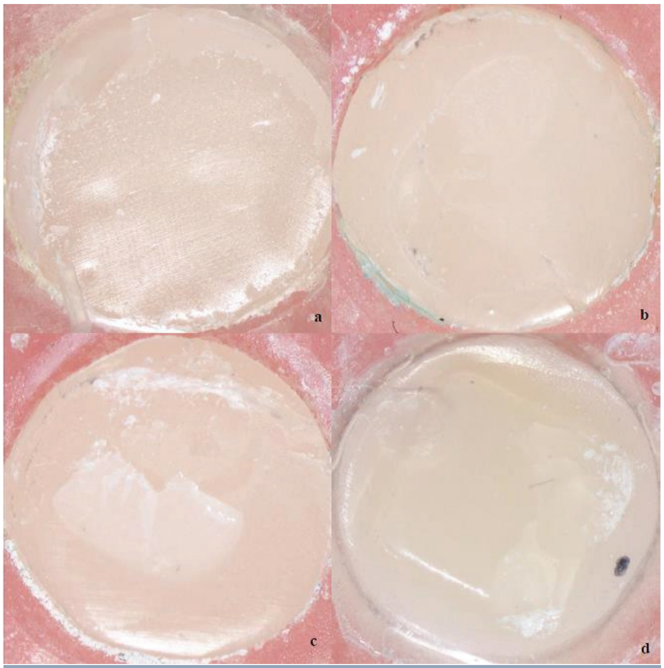

Figure 3. Stereomicroscope images of ceramic specimens
RARI score 0 (a); RARI score 1 (b); RARI score 2 (c); RARI score 3 (d)
RARI, resin attachment remnant index

the use of an all-in-one universal bonding agent and a high-viscosity universal composite after air abrasion resulted in the highest SBS values for attachment bonding to LD ceramics.[17] Conversely, surface etching with Al_2O_3 abrasive particles is not recommended for LD ceramics because it produces extremely irregular surfaces that differ considerably from those produced by acid etching.[18]

A self-etching ceramic primer (MEP), which allowed for etching and silanization in one step, was used in this study, considering the advantages of eliminating the toxic potential of acid etching and minimizing the technique sensitivity of conventional methods. Only silanization can be used to achieve adhesion in glass ceramics, but it is insufficient for zirconia ceramics.[19] Because zirconia has glass-free components, the formation of surface roughness cannot be provided by HFA etching, as occurs in LD ceramics. Therefore, the MZ ceramics were sandblasted to enhance micromechanical retention, although a self-etching ceramic primer (MEP) was used. Conventional pretreatment of the LD and MZ ceramics was performed using HFA etching and sandblasting, respectively, followed by silane application. As the manufacturer advised the use of the aligner composite with G-Premio Bond for bonding of aligner attachments, this universal adhesive was applied to improve the bond strength between pretreated ceramic surfaces and aligner composite.[20]

According to the SBS results, the adhesion between the silane agents and the universal adhesive provided relatively high bond strength with one exception. The LD ceramics pretreated with HFA etching and the universal primer had the lowest bond strength. This result is quite close to the lower bound of the adequate bond strength value reported by Reynolds.[21] Compared with the conventional pretreatment, the MEP increased the bond strength of the LD ceramics. These findings can be explained by the technical sensitivity of the acid etching procedure. HFA etching with a 5% acid concentration and a short application time (20 seconds) was preferred in this study. Ramakrishnaiah et al.[22] reported that etching for a short time produced small pores, whereas etching for a long time

Table 3. The RARI scores of study groups

Groups	RARI scores					p[a]
	0 (%)	1 (%)	2 (%)	3 (%)	4 (%)	
Group 1 (LD+HFA+MP)	5 (50)	5 (50)	0 (0)	0 (0)	0 (0)	0.491
Group 2 (MZ+S+MP)	3 (30)	4 (40)	2 (20)	1 (10)	0 (0)	
Group 3 (LD+MEP)	3 (30)	7 (70)	0 (0)	0 (0)	0 (0)	
Group 4 (MZ+S+MEP)	3 (30)	6 (60)	1 (10)	0 (0)	0 (0)	

[a]Chi-square test
$p<0.05$: statistically significant.
LD, lithium disilicate; HFA, hydrofluoric acid etching; MP, monobond plus (universal primer); MEP, monobond etch & prime (self-etching primer); MZ: monolithic zirconia; S: sandblasting

produced wide irregular grooves. Previous studies have also discovered a positive correlation between surface roughness and etching time.[22-24] Prolonged etching time and high acid concentration may increase the SBS of aligner attachments prepared on LD specimens. The application of 9.6% HFA etching for 60 s was recommended for orthodontic attachment adhesion to ceramic surfaces in a recent review.[25] Asiry et al.[26] reported that conventional pretreatment produced higher SBS values for LD ceramics than self-etching primer. This difference could be due to the acid remnants in the deep porosities of the non-neutralized ceramic surfaces.[27] Similarly, Canay et al.[28] recommended the removal of precipitates that interfere with the bonding mechanism. However, in this study, the acid-etched LD surfaces were rinsed thoroughly to eliminate residuals without additional application. This resulted in the self-etching primer increasing the bond strength of the aligner attachments bonded to the LD ceramics.

The SBS results also revealed that the sandblasted zirconia ceramics had similar bond strengths after silanization with either the universal or self-etching primer. In this context, it should be emphasized that both ceramic primers had the same silanization component. In line with these findings, Gutierrez et al.[29] reported that the use of MDP-containing silane and an MDP-containing universal adhesive for bonding to air-abraded zirconia resulted in more stable results after thermocycling. It is worth noting that the detachment forces decrease after thermocycling.[6,26,30] In this study, the number of cycles was set to 1,000 because the aging procedure was performed, with follow-up visits that were required every four to six weeks being considered. However, this period could be accepted as short-term aging because 10,000 cycles correspond to approximately one year of aging.[31] In contrast, the sandblasted MZ ceramics that were pretreated with the universal primer had a mean SBS value that exceeded the surface damage threshold value reported in the literature (>13 MPa).[30] Therefore, it was necessary to assess the ceramic surfaces after detachment because of the risk of surface damage with or without remnant adhesives caused by high bond strength.[25] In this case, the RARI was developed and used for evaluation and scoring.

According to the RARI scores, the amount of resin attachment remaining on the ceramic surfaces was almost similar, with no statistically significant differences. However, it is worth noting that the higher the bond strength, the greater the remnant resin.[14,26] Consistent with these findings, the conventional pretreatment of LD ceramics with HFA etching demonstrated relatively lower RARI scores in parallel with lower SBS values. In addition, greater bond strength and more attachment remnants were found in MZ ceramics when the pretreatment was performed using universal primer after sandblasting. Under these circumstances, a tungsten carbide bur must be used along with subsequent reglazing or repolishing to eliminate the remaining resin attachments on the ceramic surfaces.[32] Moreover, the detachment that occurs at the ceramic and resin interface could increase the risk of ceramic damage. In this study, no surface damage was observed regardless of the ceramic type and the large detachment forces. In other words, silane application provided surface protection for all groups.

Study Limitations

Based on the SBS and RARI results of this study, the null hypothesis was partially rejected. The self-etching primer produced a significantly higher SBS for the LD ceramics than the universal primer. The major limitation of this study was the difficulty in interpreting the findings in terms of clinical conditions. Another limitation was the interpretation of the findings based on previous bracket bonding studies. Furthermore, this study is the first one on aligner attachment bonding to different ceramics using a self-etching primer, and there is no study on a precise method for determining remnant aligner attachment. Therefore, the developed RARI scoring system is expected to be used in future studies when different bonding protocols are tested under both *in vitro* and *in vivo* conditions.

CONCLUSION

Compared with conventional pretreatment with the universal primer, pretreatment with a self-etching ceramic primer increased the bond strength of the LD ceramics. A self-etching ceramic primer can be used for aligner attachment bonding to LD and MZ ceramics.

Ethics

Ethics Committee Approval: Ethical approval is not applicable because this study does not include any studies with human or animal subjects.

Informed Consent: Informed consent is not applicable because this study does not include any studies with human subjects.

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REFERENCES

1. AlSeraidi M, Hansa I, Dhaval F, Ferguson DJ, Vaid NR. The effect of vestibular, lingual, and aligner appliances on the quality of life of adult patients during the initial stages of orthodontic treatment. *Prog Orthod.* 2021;22(1):3. [CrossRef]
2. Zheng M, Liu R, Ni Z, Yu Z. Efficiency, effectiveness and treatment stability of clear aligners: A systematic review and meta-analysis. *Orthod Craniofac Res.* 2017;20(3):127-133. [CrossRef]
3. Putrino A, Barbato E, Galluccio G. Clear aligners: Between evolution and efficiency-a scoping review. *Int J Environ Res Public Health.* 2021;18(6):2870. [CrossRef]
4. Eliades T, Papageorgiou SN, Ireland AJ. The use of attachments in aligner treatment: Analyzing the "innovation" of expanding the use of acid etching-mediated bonding of composites to enamel and its consequences. *Am J Orthod Dentofacial Orthop.* 2020;158(2):166-174. [CrossRef]
5. Grewal Bach GK, Torrealba Y, Lagravère MO. Orthodontic bonding to porcelain: a systematic review. *Angle Orthod.* 2014;84(3):555-560. [CrossRef]
6. Ahmed T, Fareen N, Alam MK. The effect of surface treatment and thermocycling on the shear bond strength of orthodontic brackets to the Y-TZP zirconia ceramics: A systematic review. *Dental Press J Orthod.* 2021;26(5):e212118. [CrossRef]
7. Ozcan M, Allahbeickaraghi A, Dündar M. Possible hazardous effects of hydrofluoric acid and recommendations for treatment approach: a review. *Clin Oral Investig.* 2012;16(1):15-23. [CrossRef]
8. Franz A, Raabe M, Lilaj B, Dauti R, Moritz A, Müßig D, Cvikl B. Effect of two different primers on the shear bond strength of metallic brackets to zirconia ceramic. *BMC Oral Health.* 2019;19(1):51. [CrossRef]
9. González-Serrano C, Phark JH, Fuentes MV, et al. Effect of a single-component ceramic conditioner on shear bond strength of precoated brackets to different CAD/CAM materials. *Clin Oral Investig.* 2021;25(4):1953-1965. [CrossRef]
10. Yildirim B, Recen D, Paken G. Effect of self-etching ceramic primer on the bond strength of feldspathic porcelain repair. *J Adhes Sci Technol.* 2019;33(14):1598-1610. [CrossRef]
11. Artun J, Bergland S. Clinical trials with crystal growth conditioning as an alternative to acid-etch enamel pretreatment. *Am J Orthod.* 1984;85(4):333-340. [CrossRef]
12. Mehmeti B, Kelmendi J, Iiljazi-Shahiqi D, et al. Comparison of shear bond strength orthodontic brackets bonded to zirconia and lithium disilicate crowns. *Acta Stomatol Croat.* 2019;53(1):17-27. [CrossRef]
13. Francisco I, Travassos R, Nunes C, et al. What is the most effective technique for bonding brackets on ceramic-a systematic review and meta-analysis. *Bioengineering (Basel).* 2022;9(1):14. [CrossRef]
14. Goracci C, Di Bello G, Franchi L, et al. Bracket bonding to all-ceramic materials with universal adhesives. *Materials (Basel).* 2022;15(3):1245. [CrossRef]
15. Jungbauer R, Kirschneck C, Hammer CM, Proff P, Edelhoff D, Stawarczyk B. Orthodontic bonding to silicate ceramics: impact of different pretreatment methods on shear bond strength between ceramic restorations and ceramic brackets. *Clin Oral Investig.* 2022;26(3):2827-2837. [CrossRef]
16. Jungbauer R, Proff P, Edelhoff D, Stawarczyk B. Impact of different pretreatments and attachment materials on shear bond strength between monolithic zirconia restorations and metal brackets. *Sci Rep.* 2022;12(1):8514. [CrossRef]
17. Alsaud BA, Hajjaj MS, Masoud AI, Abou Neel EA, Abuelenain DA, Linjawi AI. Bonding of clear aligner composite attachments to ceramic materials: An in vitro study. *Materials (Basel).* 2022;15(12):4145. [CrossRef]
18. Rigolin FJ, Negreiros WM, Giannini M, Rizzatti Barbosa CM. Effects of sandblasting and hydrofluoric acid etching on surface topography, flexural strength, modulus and bond strength of composite cement to ceramics. *J Adhes Dent.* 2021;23(2):113-119. [CrossRef]
19. Lung CY, Matinlinna JP. Aspects of silane coupling agents and surface conditioning in dentistry: an overview. *Dent Mater.* 2012;28(5):467-477. [CrossRef]
20. Kalavacharla VK, Lawson NC, Ramp LC, Burgess JO. Influence of etching protocol and silane treatment with a universal adhesive on lithium disilicate bond strength. *Oper Dent.* 2015;40(4):372-378. [CrossRef]
21. Reynolds IR. A review of direct orthodontic bonding. *Br J Orthod.* 1975;2(3):171-178. [CrossRef]
22. Ramakrishnaiah R, Alkheraif AA, Divakar DD, Matinlinna JP, Vallittu PK. The effect of hydrofluoric acid etching duration on the surface micromorphology, roughness, and wettability of dental ceramics. *Int J Mol Sci.* 2016;17(6):822. [CrossRef]
23. Zogheib LV, Bona AD, Kimpara ET, McCabe JF. Effect of hydrofluoric acid etching duration on the roughness and flexural strength of a lithium disilicate-based glass ceramic. *Braz Dent J.* 2011;22(1):45-50. [CrossRef]
24. Veríssimo AH, Moura DMD, Tribst JPM, Araújo AMM, Leite FPP, Souza ROAE. Effect of hydrofluoric acid concentration and etching time on resin-bond strength to different glass ceramics. *Braz Oral Res.* 2019;33:e041. [CrossRef]
25. Labunet A, Kui A, Voina-Tonea A, Vigu A, Sava S. Orthodontic attachment adhesion to ceramic surfaces. *Clin Cosmet Investig Dent.* 2021;13:83-95. [CrossRef]
26. Asiry MA, AlShahrani I, Alaqeel SM, Durgesh BH, Ramakrishnaiah R. Effect of two-step and one-step surface conditioning of glass ceramic on adhesion strength of orthodontic bracket and effect of thermo-cycling on adhesion strength. *J Mech Behav Biomed Mater.* 2018;84:22-27. [CrossRef]
27. Özcan M, Volpato CA. Surface conditioning protocol for the adhesion of resin-based materials to glassy matrix ceramics: How to condition and why? *J Adhes Dent.* 2015;17(3):292-293. [CrossRef]
28. Canay S, Hersek N, Ertan A. Effect of different acid treatments on a porcelain surface. *J Oral Rehabil.* 2001;28(1):95-101. [CrossRef]
29. Gutierrez MF, Perdigão J, Malaquias P, et al. Effect of methacryloyloxydecyl dihydrogen phosphate-containing silane and adhesive used alone or in combination on the bond strength and chemical interaction with zirconia ceramics under thermal aging. *Oper Dent.* 2020;45(5):516-527. [CrossRef]
30. Thurmond JW, Barkmeier WW, Wilwerding TM. Effect of porcelain surface treatments on bond strengths of composite resin bonded to porcelain. *J Prosthet Dent.* 1994;72(4):355-359. [CrossRef]
31. Gale MS, Darvell BW. Thermal cycling procedures for laboratory testing of dental restorations. J Dent. 1999;27(2):89-99. [CrossRef]
32. Bourke BM, Rock WP. Factors affecting the shear bond strength of orthodontic brackets to porcelain. *Br J Orthod.* 1999;26(4):285-290. [CrossRef]

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Original Article

Correlation Between Cephalometric Values and Soft Tissue Profile in Class I and Class II Adult Patients based on Vertical Patterns

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Main Points

- The increase in the vertical dimension of the face leads to a more convex general and subnasal soft tissue profiles, and the effect is more significantly noticed in the hyperdivergent skeletal patterns.
- An increase in Class II sagittal skeletal discrepancy results in a retrusive lower lip and chin, and thus a more convex general soft tissue profile.
- Changes in the vertical dimension had a greater impact on the soft tissue profile in class II cases than other sagittal classifications.
- Intergender differences were limited to the subnasal profile, where females had a more convex subnasal soft tissue profile.

ABSTRACT

Objective: To compare soft tissue profile variations between Class I and Class II adult patients due to three vertical skeletal facial patterns (normodivergent, hypodivergent and hyperdivergent) and determine which skeletal variation has the most significant impact on soft tissue profile.

Methods: Retrospective soft tissue profile analysis was performed on lateral cephalograms of 131 adult patients. The analysis was divided into two categories correlated with subnasal and general soft tissue profiles. The sample was divided based on two sagittal skeletal patterns (Class I and II) and three vertical groups. In addition, comparisons were made between males and females. Viewbox 4 was used for the analysis. Descriptive, comparative, and correlation statistics were performed using SPSS software.

Results: Statistically significant inter-gender differences were found at the subnasal profile level, but not at the general profile level. No significant differences were observed when comparing subnasal profiles for the sagittal groups. However, significant differences were observed at the level of the general profile, especially at the level of Z-angle, lower lip, and chin prominence. In the vertical groups, hyperdivergent facial patterns had significant differences at the level of subnasal and general profiles compared with other vertical facial patterns.

Conclusion: Females had more convex subnasal profiles than males. Hyperdivergent facial patterns had an impact on both general and subnasal soft tissue profiles. The sagittal dimension affected only the general soft tissue profile. Therefore, changes in the vertical dimension had the greatest impact on facial esthetics.

Keywords: Soft tissue profile, facial esthetics, skeletal patterns, vertical dimension, cephalometric analysis

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INTRODUCTION

Soft tissue profile assessment has been historically implemented and has served as a blueprint for guiding orthodontists in harmonizing facial profile features with either jaw or tooth movement.[1] It plays a vital role in orthodontic treatment planning, and some orthodontists who initially overlooked the profile may eventually find it more pleasant before treatment.[2] Interest in facial profile assessment has increased over time. Other specialties, such as plastic surgery, continue to seek to define the ideal soft tissue profile, considering it as one of the main determinants of facial esthetics. In orthodontics, various methods have been used to evaluate facial soft tissue characteristics. Moreover, several studies have aimed at defining an ideal profile as a reference for planning orthodontic treatment.[3-7] One recent study relied on morphometric methods to assess shape variability and gender dimorphism in soft tissue profile.[8] Other studies have integrated the use of three-dimensional (3D) imaging, such as cone beam computed tomography (CBCT) scans, as a method for analyzing facial profiles. Most recent techniques involve non-invasive imaging such as stereophotogrammetry and laser facial scanning, to acquire 3D facial soft tissue.[9] However, lateral cephalograms have been the primary and most commonly used radiographs in evaluating both hard and soft tissue profiles for orthodontic patients.[10,11]

Several angles and reference planes have been described to analyze different aspects of the profile using lateral cephalograms.[12,13] Soft tissue cephalometric analysis has been divided into two parts: subnasal and general. The subnasal profile involves the area under the nose and evaluates lip position relative to the nose and chin. The general soft tissue profile includes the entire face and evaluates lip and chin positions accordingly. Ricketts and Holdaway described two different approaches for analyzing the subnasal profile. The general profile assessment is often performed using the nasolabial angle, Z-angle, 0-degree meridian, facial angle, and lip/chin prominence.[14]

The influence of changes in the sagittal plane on the soft tissue profile has been previously investigated. For Class II malocclusion, one study showed that Class II subjects often have a convex facial appearance related to small mandibles rather than large maxillae. The ANB angles' value are relatively increased because of decreased SNB angles' value in those subjects.[15] Likewise, soft tissue profile changes following maxillary protraction in Class III patients were investigated. The concave soft tissue profile of the maxilla was primarily corrected by anterior movement of the maxilla and a concomitant increase in the fullness of the upper lip.[16]

However, the variation in soft tissue profile does not only come from the sagittal skeletal discrepancy. Furthermore, the vertical skeletal pattern impacts the surrounding tissues. Vertical growth at the level of the condyle may directly affect the rotation of the mandible; i.e., if condylar growth is slower than that at the level of the facial sutures or alveolar bone, the mandible will rotate clockwise. This will eventually impact the sagittal position of the chin and therefore alter the soft tissue facial profile.[17,18] Accordingly, the correlation between the hard and soft tissue profiles is of interest to the orthodontist. Any dentoskeletal alteration associated with growth or treatment may affect the overall soft tissue profile. Therefore, treatment decisions should be based on changes in facial esthetics due to alterations in skeletal and dental hard tissues.[19] Changes in both the sagittal and vertical facial dimensions should be considered when diagnosing orthodontic patients.

The majority of previous studies have focused on the effect of orthodontic treatment on the overall facial profile.[20-25] Therefore, the present study was conducted to comprehensively evaluate the combined effects of variations in both sagittal and vertical skeletal patterns on the soft tissue profile. The study further compared variations in soft tissue profiles between Class I and Class II adult patients for different vertical facial patterns. Moreover, analysis of the relationship between soft and underlying hard tissues was performed to specifically localize the skeletal parameters that might have an impact on the soft tissue profile.

METHODS

Data Collection

This retrospective cross-sectional study was approved by the Scientific Committee of Lebanese University Faculty of Dental Medicine (approval no: 34/2022, date: October 2019). Lateral cephalograms for 131 healthy adult patients (47 males and 84 females) at the Department of Orthodontics of Lebanese University were selected according to the following criteria: Lebanese origin, 18-30 years of age, complete maxillary and mandibular dentition with the exception of the third molars. The exclusion criteria comprised patients with rhinoplasty, facial surgical/non-surgical interventions, craniofacial syndromes, previous orthodontic treatment, prosthetic restorations, and severe skeletal discrepancies. Written consent was obtained from patients during the initial consultation to allow the use of records for educational and scientific purposes.

Cephalometric Analysis

Patients were asked to occlude with relaxed lips and remain immobile during the acquisition of the radiographs. X-rays with strained lips or mentalis muscle were excluded from the sample. Pre-treatment digital lateral cephalograms were transformed to digital imaging and communications in medicine format, and further analyzed via the Viewbox Cephalometric tracing software (Viewbox Version 4.0.1.7, 2013, dHAL Software, Kifissia, Greece).

The sagittal skeletal patterns of the subjects were identified and Classified using the ANB angle:

- Class I $0° \leq$ ANB $\leq 4°$
- Class II ANB $>4°$

The vertical skeletal patterns were identified and Classified according to the FMA angle:

- Hypodivergent pattern FMA <22°
- Normodivergent pattern 22°≤ FMA ≤28°
- Hyperdivergent pattern FMA >28°

Soft Tissue Profile Analysis

Pre-treatment digital lateral cephalograms were analyzed using Viewbox tracing software. Each lateral cephalogram was divided into two subgroups: general and subnasal profiles. General profile assessment (Figure 1A-C) was performed using the nasolabial angle, Merrifield's Z-angle, 0-degree meridian, facial angle, and lip/chin prominence.[14] The subnasal profile assessment (Figure 1D) adopted both Holdaway's H-line and Ricketts' E-line.[14]

Statistical Analysis

All measurements were exported to Windows Microsoft Excel, where they were grouped and then transferred to SPSS software (SPSS Statistics, version 18.0 IBM, Chicago, Illinois, USA) where all statistical tests were performed. Several comparative analyses were performed to compare soft tissue values among different sagittal and vertical skeletal groups in males and females. Parametric tests were used to analyze normally distributed data, whereas non-parametric tests were used to analyze data showing an abnormal distribution. For the comparison of two independent groups, such as Class I and Class II, t-test was performed when normality was proven; otherwise, Mann-Whitney U test was conducted. As for vertical skeletal groups, the Kruskal-Wallis H test was adopted because the sample sizes between the groups were unevenly distributed. The Spearman correlation coefficient was calculated to check the association between two skeletal variables (FMA and ANB) and the soft tissue cephalometric values. The Shapiro-Wilk method was used to test for normality. The significance level was set at α=5%.

RESULTS

Comparison of Soft Tissue Variables Between Males and Females

Ricketts analysis showed significant differences between genders, with females displaying greater values for both upper and lower lips to the E-plane (p=0.043 and p=0.029 respectively). Additionally, the Holdaway analysis showed significant differences between genders. Nose projection (p=0.024) and soft tissue A to the Holdaway line (p=0.027) were greater in males, whereas soft tissue B to the Holdaway line was greater in females (p=0.000). No statistically significant differences were observed at the general profile level. Because significant intergender differences were found, the overall sample was divided based on gender, and comparative statistics between soft tissue variables and skeletal patterns were performed on each gender group individually (Table 1).

Comparison of Soft Tissue Variables Between Class I and Class II Males and Females

When comparing Class I and Class II males, significant differences were found at the level of the naso-labial angle (p=0.007), z-angle (p=0.018), lower lip (p=0.009), and chin (p=0.0039). Class I males showed greater values for the previously mentioned variables, except for the naso-labial angle (Table 2).

When females were assessed, significant differences were observed in z-angle (p=0.001), 0-degree meridian (p=0.014), facial angle (p=0.043), lower lip prominence (p=0.004), and chin prominence (p=0.001). They were found to be greater in Class I females (Table 2).

Comparison of Soft Tissue Variables Between Different Vertical Patterns in Males and Females

Hyperdivergent males had significantly greater values for lower lip to E-plane distance (p=0.008) and soft tissue B to Holdaway line (p=0.007) compared with the normodivergent group. There were no major differences in soft tissue variables between the hypodivergent and normodivergent groups. When comparing hyperdivergent to hypodivergent males, the latter exhibited significantly greater values for facial angle (p=0.031) and chin prominence (p=0.022). On the other hand, the hyperdivergent group displayed significantly greater values for the lower lip to

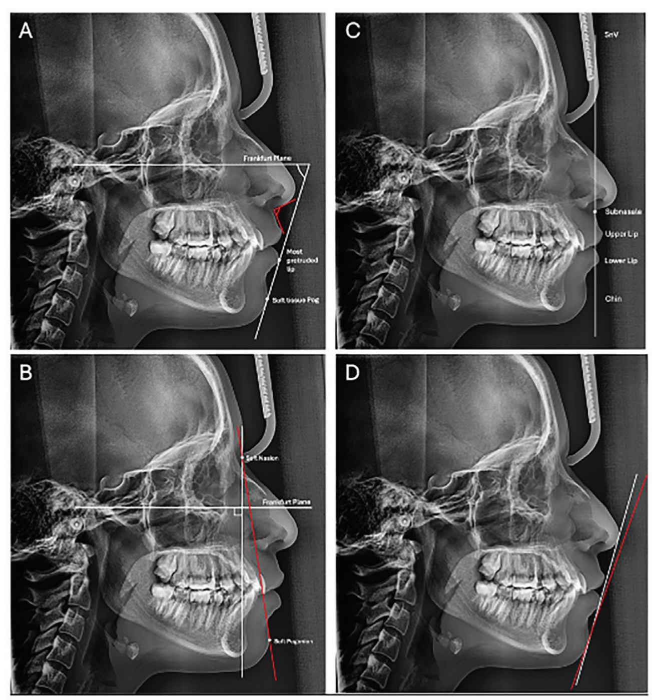

Figure 1. General Profile Analysis; **A**, Nasolabial angle (red), formed by columella and upper lip tangents; Z-angle (white), formed by line passing through soft pogonion and the most protruded lip and Frankfurt horizontal; **B**, 0-degree meridian (white), distance from soft pogonion to a line drawn perpendicular to Frankfurt horizontal through soft nasion; Facial angle (red), intersection of Frankfurt horizontal with a line extended from soft nasion to soft pogonion; **C**, Lip and chin prominence, distance from upper lip, lower lip and soft pogonion to SnV; **D**, Subnasal profile analysis; E-line (white); Holdaway line (red)

Table 1. Mann-Whitney test comparing soft tissue between males and females

Soft tissue variables	Males (n=47) Mean±SD	Females (n=84) Mean±SD	p value (0.05)
Upper lip to E-plane	-5.43±2.8	-4.43±2.04	0.043*
Lower lip to E-plane	-2.85±3.2	-1.70±2.5	0.029*
Nose	9.41±4.5	7.64±3.5	0.024*
Soft A to Holdaway	-3.64±1.6	-4.19±1.5	0.027*
Soft B to Holdaway	-6.53±2.4	-4.64±1.5	0.000*

*Significant difference (p value <0.05)
SD, standard deviation

the E-plane (p=0.003), lower lip to the Holdaway line (p=0.002), and soft tissue B to the Holdaway line (p=0.000) (Tables 3 and 4).

Compared with hypodivergent females, normodivergent females had significantly greater upper lip to E-plane (p=0.025) and lower lip to E-plane (p=0.006). Conversely, hypodivergent females displayed significantly greater nose projection (p=0.011), z-angle (p=0.009), and chin prominence (p=0.012). Significant differences were also observed between hypodivergent and hyperdivergent females; the latter presented greater values for the lower lip to the E-plane (p=0.000), lower lip to the Holdaway line (p=0.000), and soft tissue B to the Holdaway line (p=0.029). On the other hand, hypodivergent females displayed significantly greater values for nose projection (p=0.03), z-angle (p=0.000), 0-degree meridian (p=0.000), and chin prominence (p=0.000). Only one variable, the 0-degree meridian, displayed a significant difference (p=0.03) between hyperdivergent and normodivergent females (Tables 3 and 5).

Correlation Between Soft Tissue Variables and Vertical and Sagittal Skeletal Patterns in Males and Females

Weak to moderate negative correlations were observed between the soft tissue variables and the sagittal skeletal groups at the level of the general profile, specifically z-angle (-0.313 males and -0.571 females) and chin prominence (-0.337 males and -0.526 females). A weak positive correlation was observed at the level of the upper lip to the E-plane of the subnasal profile (0.307 males and 0.385 females) (Table 6).

The vertical groups displayed a moderate positive correlation at the level of the subnasal profile, specifically soft tissue B to the Holdaway line (0.555 males). Weak to moderate negative correlations were observed in both males and females at the level of the general profile, specifically Z-angle, 0-degree meridian, facial angle, and chin prominence (Table 6).

DISCUSSION

To maximize the accuracy of our results, measurements were performed on lateral cephalometric X-rays for the patients in the relaxed lip position. Arnett and Gunson[26] proposed that while evaluating a patient's soft tissue profile, his/her lips must be in the rest position. This relaxed lip posture best displays the patient's soft tissues without any strain or muscular contractions that might compensate for the dentoskeletal abnormalities.[26] Other studies have also adopted the same criteria in their evaluation for the soft tissue profile.[9,17,27] However, patients who had missing teeth and underwent previous orthodontic or extensive prosthodontic treatment were excluded from the study because of the presence of factors that may alter the natural soft tissue profile. Moreover, growing patients were excluded from the study, and the age range of the included subjects was between 18 and 30 years to guarantee the maturity of soft tissue profile.[28]

Jacob and Buschang[15] showed that Class II subjects are characterized by a smaller SNB angle compared with Class I subjects, whereas the SNA angle between two groups were similar. This indicates that Class II subjects are characterized by a retrognathic mandible, which impacts soft tissue profile.[15] The findings of Jacob and Buschang[15] are similar to our findings. The Class II group in our study displayed a significantly decreased SNB angle. Mandibular retrognathism in the absence of soft tissue compensation often results in posterior positioning of both the lower lip and chin, resulting in an expected convex general profile. Consequently, underlying sagittal skeletal variations in the Class II direction had an immediate impact on the general soft tissue profile in both males and females.

Soft tissue profiles were analyzed dividing them into general and subnasal profiles. Subnasal analysis via Ricketts and H-line methods showed no significant differences between

Table 2. Comparison of soft tissue variables between Class I and Class II males and females

Soft tissue variables	Class I (n=26) Mean±SD Males	Class II (n=21) Mean±SD Males	p value (0.05)	Class I (n=35) Mean±SD Females	Class II (n=49) Mean±SD Females	p value (0.05)
Nasolabial angle	95.12±10.8	105.19±13.6	0.007*	97.71±12.5	102.61±9.7	0.087
Z-angle	78.62±5.2	74.95±4.8	0.018*	78.86±4.4	75.06±5.5	0.001*
0-degree meridian	2.19±8.2	2.62±6.1	0.845	5.29±4.3	2.47±6.7	0.014*
Facial angle	92.00±4.1	91.33±3.3	0.546	93.03±2.5	87.92±2.6	0.043*
Lower lip prominence	-0.92±3.6	-3.95±3.8	0.009*	-0.09±3.1	-2.10±2.9	0.004*
Chin prominence	-7.00±5.2	-9.95±3.9	0.039*	-5.03±4.3	-8.67±5.1	0.001*

*Significant difference (p value <0.05)
SD, standard deviation

Class I and Class II groups, indicating virtually identical profiles.[2] However, general profile analyses showed significant differences between the two groups. Thus, the H-line and the E-plane offered no additional information on chin projection or overall profile. The sagittal dimension had a minimal impact on the subnasal profile convexity. However, an increase in the sagittal dimension in the Class II direction led to a more convex general profile due to the backward projection of the lower lip and chin.

The increased nasolabial angle observed in Class II patients suggests a posterior subnasal region position, crucial for orthognathic surgical planning. It may have a negative implication on Class II distalization treatment protocols by worsening the nasolabial angle.[29] Our Class II sample comprised both divisions (1 and 2), which might have contributed to the results of our study. Often in a Class II division 1 sample, a decreased nasolabial angle is more likely to be observed due to proclined maxillary incisors. Hence, if the sample was further divided into Class II divisions 1 and 2, this could have resulted in more precise outcomes.

The literature has given minimal attention to the impact of the vertical dimension on the soft tissue profile. Jacob and Buschang[15] concluded that hyperdivergent patterns exhibit more retrusive profiles. Our study indicated that the vertical dimension affected all levels of the soft tissue profile, i.e., subnasal and general profiles. As the vertical dimension increased from hypodivergent to hyperdivergent, lip protrusion increased, resulting in hyperdivergent patients displaying a more convex subnasal profile. This could be related to the chin's a more backward position in high-angle cases due to clockwise

Table 3. Descriptive statistics showing soft tissue variables of vertical groups in males and females. 1, Normodivergent; 2, Hypodivergent; 3, Hyperdivergent

Soft tissue variables	(1) Males (n=15) Mean±SD	(2) Males (n=25) Mean±SD	(3) Males (n=7) Mean±SD	(1) Females (n=32) Mean±SD	(2) Females (n=33) Mean±SD	(3) Females (n=19) Mean±SD
Upper lip to E-plane	-6.53±3	-5.24±2.5	-3.71±2.5	-3.91±2.1	-5.21±1.9	-3.95±1.6
Lower lip to E-plane	-3.40±2.6	-3.52±3.1	0.71±2.2	-1.19±2.4	-3.00±2.2	-0.32±1.9
Nose	10.89±4.7	9.41±4.3	6.26±4	6.70±3.6	9.11±3.2	6.65±3.1
Soft A to Holdaway	-3.40±1.3	-3.48±1.6	-4.71±1.8	-4.44±1.2	-3.70±1.4	-4.63±1.7
Lower lip to H-plane	0.40±2.1	-0.72±2.1	2.71±2.8	0.84±1.6	-0.09±1.6	1.89±1.5
Soft B to Holdaway	-6.40±2.2	-7.48±2	-3.43±1.2	-4.56±1.3	-5.09±1.4	-4.00±1.7
Nasolabial angle	99.47±10.5	101.68±14.1	92.5±13	100.41±10.8	100.12±11.9	101.63±10.8
Z-angle	76.60±4.8	78.20±4.9	73.43±6.9	75.78±4.4	79.45±4.1	73.21±6.6
0-degree meridian	0.67±6.7	4.36±6.7	-1.00±9.2	3.63±5.6	6.06±3.1	-0.53±8.1
Facial angle	91.20±3.1	92.80±3.1	88.86±5.2	92.13±2.8	93.58±2.1	80.42±4.1
Upper lip prominence	0.80±2.8	0.88±3.1	1.57±2.3	1.81±2.3	1.42±1.9	1.16±2.6
Lower lip prominence	-2.60±3.6	-2.44±4.1	-1.00±4.4	-1.19±3.2	-0.82±3.1	-2.16±3.2
Chin prominence	-8.93±5.1	-6.84±3.6	-12.29±6.6	-7.88±3.9	-4.52±3.9	-10.53±6.3

SD, standard deviation

Table 4. Comparison of the soft tissue variables between vertical groups in males. 1, Normodivergent; 2, Hypodivergent; 3, Hyperdivergent

Soft tissue variables	Vertical groups		p value (0.05)	Soft tissue variables	Vertical groups		p value (0.05)	Soft tissue variables	Vertical groups		p value (0.05)
Lower lip to E-plane	1	2	0.991	**Soft B to Holdaway**	1	2	0.248	**Facial angle**	1	2	0.353
		3	0.008*			3	0.007*			3	0.321
	2	1	0.991		2	1	0.248		2	1	0.353
		3	0.003*			3	0.000*			3	0.031*
	3	1	0.008*		3	1	0.007*		3	1	0.321
		2	0.003*			2	0.000*			2	0.031*
Lower lip to H-plane	1	2	0.266	**Chin prominence**	1	2	0.355				
		3	0.063			3	0.261				
	2	1	0.266		2	1	0.355				
		3	0.002*			3	0.022*				
	3	1	0.063		3	1	0.261				
		2	0.002*			2	0.022*				

*Significant difference (p value <0.05)

Table 5. Comparison of the soft tissue variables between vertical groups in females. 1, Normodivergent; 2, Hypodivergent; 3, Hyperdivergent

Soft tissue variables	Vertical groups		p value (0.05)	Soft tissue variables	Vertical groups		p value (0.05)	Soft tissue variables	Vertical groups		p value (0.05)
Upper lip to E-plane	1	2	0.025*	**Soft B to Holdaway**	1	2	0.312	**Chin prominence**	1	2	0.012*
		3	0.997			3	0.378			3	0.122
	2	1	0.025*		2	1	0.312		2	1	0.012*
		3	0.073			3	0.029*			3	0.000*
	3	1	0.997		3	1	0.378		3	1	0.122
		2	0.073			2	0.029*			2	0.000*
Lower lip to E-plane	1	2	0.006*	**Lower lip to H-plane**	1	2	0.057	**Z-angle**	1	2	0.009*
		3	0.390			3	0.069			3	0.170
	2	1	0.006*		2	1	0.057		2	1	0.009*
		3	0.000*			3	0.000*			3	0.000*
	3	1	0.390		3	1	0.069		3	1	0.170
		2	0.000*			2	0.000*			2	0.000*
Nose	1	2	0.011*	**0-degree meridian**	1	2	0.183				
		3	0.999			3	0.030*				
	2	1	0.011*		2	1	0.183				
		3	0.030*			3	0.000*				
	3	1	0.999		3	1	0.030*				
		2	0.030*			2	0.000*				

*Significant difference (p value <0.05)

Table 6. Correlation between soft tissue variables, sagittal and vertical skeletal patterns

	Soft tissue variables	ANB males	ANB females	FMA males	FMA females
Subnasal profile	**Upper lip to E-plane**	0.307	0.385	-0.053	0.282
	Lower lip to E-plane	0.176	0.090	0.041	0.229
	Soft A to Holdaway	-0.029	-0.204	-0.212	-0.256
	Lower lip to H-plane	-0.025	0.130	0.155	0.169
	Soft B to Holdaway	0.018	-0.054	0.555	0.262
General profile	**Nasolabial angle**	0.266	0.228	-0.214	0.052
	Z-angle	-0.313	-0.571	-0.312	-0.490
	0-degree meridian	0.112	-0.154	-0.379	-0.463
	Facial angle	-0.087	-0.293	-0.420	-0.221
	Upper lip prominence	-0.032	-0.021	0.044	0.025
	Lower lip prominence	-0.150	-0.202	-0.018	-0.123
	Chin prominence	-0.337	-0.526	-0.432	-0.509

mandibular rotation, giving the impression of protruding lips. This observation was not observed when comparing the sagittal groups because Class I and Class II patients had similar subnasal lip projection. Similar to the sagittal dimension, the vertical dimension also impacted the general profile. As the FMA angle increased, the profile was seen to be more convex. The chin was more retruded or least prominent in the hyperdivergent group and most prominent in the hypodivergent group. Therefore, we can infer that an increase in FMA and ANB angles have similar effects on the general profile, making it more convex as they increase.

Thus, a change in mandibular divergence will likely have a more widespread influence on the soft tissue profile compared with the anteroposterior relationship of the jaws. With regard to gender differences, females had more convex subnasal profiles, mainly due to lip protrusion. No difference in the general profile was found between the two genders. Clinically, careful attention must be paid to the vertical dimension when diagnosing and planning orthodontic treatment mechanics. In high-angle cases, clinicians should minimize mechanics that would potentially harm facial esthetics and lead to a further increase in mandibular divergence. According to our findings, any increase in the mandibular plane angle would worsen the overall profile convexity. Early intervention in high-angle cases to help minimize vertical growth and strict retention protocols to avoid relapse should be considered.

Study Limitations and Future Considerations

This study is retrospective and 2D cephalometric radiographs were used for the analysis. With the evolution of 3D radiographs, the use of CBCT scans for such analysis could have been more accurate. On the other hand, body mass index should be considered for future studies because it has a significant impact on soft tissues. Further division of the Class II group into divisions 1 and 2 could provide more information on the effect of the incisor position on the nasolabial angle. Finally, equal gender distribution and an age group older than 21 years should be considered for future evaluations to avoid confounding effects due to late growth, especially in males.

CONCLUSION

- The vertical dimension significantly impacts the soft tissue profile more than the sagittal dimension.

- Changes in the vertical dimension influence both subnasal and general profiles, resulting in in a more convex profile with increased vertical dimension.

- Chin projection was the most affected region for the soft tissue profile.

- The vertical dimension had the greatest influence on the soft tissue profile.

- When analyzing the general profile, Z-angle, facial angle, and subnasal prominence are highly accurate tools. However; H-line and E-line measurements should be limited to subnasal profile assessment because they provide no information regarding the general profile.

Ethics

Ethics Committee Approval: This retrospective cross-sectional study was approved by the Scientific Committee of Lebanese University Faculty of Dental Medicine (approval no: 34/2022, date: October 2019).

Informed Consent: Retrospective cross-sectional study.

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

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REFERENCES

1. Turley PK. Evolution of esthetic considerations in orthodontics. *Am J Orthod Dentofacial Orthop.* 2015;148(3):374-379. [CrossRef]
2. Holdaway RA. A soft-tissue cephalometric analysis and its use in orthodontic treatment planning. Part I. *Am J Orthod.* 1983;84(1):1-28. [CrossRef]
3. Ghorbanyjavadpour F, Rakhshan V. Factors associated with the beauty of soft-tissue profile. *Am J Orthod Dentofacial Orthop.* 2019;155(6):832-843. [CrossRef]
4. Rakhshan V, Ghorbanyjavadpour F. Anteroposterior and vertical soft tissue cephalometric norms of Iranians, interethnic comparisons, sex dimorphism, and the effect of age on cephalometric variables. *Oral Maxillofac Surg.* 2019;23(2):167-178. [CrossRef]
5. Amini F, Razavian ZS, Rakhshan V. Soft tissue cephalometric norms of Iranian Class I adults with good occlusions and balanced faces. *Int Orthod.* 2016;14(1):108-122. [CrossRef]
6. Erbay EF, Caniklioğlu CM. Soft tissue profile in Anatolian Turkish adults: Part II. Comparison of different soft tissue analyses in the evaluation of beauty. *Am J Orthod Dentofacial Orthop.* 2002;121(1):65-72. [CrossRef]
7. Qutub Khan Sh, Ashraf B, Ghulam Abbas Ir, Mahmood S. Soft tissue analysis of aesthetically pleasing faces. *Pak Oral Dent J.* 2015;35(3)424-428. [CrossRef]
8. Halazonetis DJ. Morphometric evaluation of soft-tissue profile shape. *Am J Orthod Dentofacial Orthop.* 2007;131(4):481-489. [CrossRef]
9. Zecca PA, Fastuca R, Beretta M, Caprioglio A, Macchi A. Correlation assessment between three-dimensional facial soft tissue scan and lateral cephalometric radiography in orthodontic diagnosis. *Int J Dent.* 2016 Oct;2016. [CrossRef]
10. Incrapera AK, Kau CH, English JD, McGrory K, Sarver DM. Soft tissue images from cephalograms compared with those from a 3D surface acquisition system. *Angle Orthod.* 2010;80(1):58-64. [CrossRef]
11. Arash V, RahmatiKamel M, OstadRahimi A, Ghorbanipour R. Evaluation of soft tissue norms on lateral cephalograms in babol. *Casp J Dent Res.* 2017;6(2):30-34. [CrossRef]
12. Bravo LA. Soft tissue facial profile changes after orthodontic treatment with four premolars extracted. *Angle Orthod.* 1994;64(1):31-42. [CrossRef]
13. Lange DW, Kalra V, Broadbent Jr BH, Powers M, Nelson S. Changes in soft tissue profile following treatment with the bionator. *Angle Orthod.* 1995;65(6):423-430. [CrossRef]
14. Jacobson A. Radiographic Cephalometry: From Basics to Videoimaging. Quintessence Publishing Company, 1995. *J Oral Maxillofac Surg.* 1996 Nov 1;54(11):1378. [CrossRef]
15. Jacob HB, Buschang PH. Mandibular growth comparisons of Class I and Class II division 1 skeletofacial patterns. *Angle Orthod.* 2014;84(5):755-761. [CrossRef]
16. Kilic N, Catal G, Kiki A, Oktay H. Soft tissue profile changes following maxillary protraction in Class III subjects. *Eur J Orthod.* 2010;32(4):419-424. [CrossRef]
17. Celikoglu M, Buyuk SK, Ekizer A, Sekerci AE, Sisman Y. Assessment of the soft tissue thickness at the lower anterior face in adult patients with different skeletal vertical patterns using cone-beam computed tomography. *Angle Orthod.* 2015;85(2):211-217. [CrossRef]

18. Isaacson JR, Isaacson RJ, Speidel TM, Worms FW. Extreme variation in vertical facial growth and associated variation in skeletal and dental relations. *Angle Orthod.* 1971;41(3):219-229. [CrossRef]
19. Sarver DM, Ackerman JL. Orthodontics about face: the re-emergence of the esthetic paradigm. *Am J Orthod Dentofacial Orthop.* 2000;117(5):575-576. [CrossRef]
20. Almurtadha RH, Alhammadi MS, Fayed MMS, Abou-El-Ezz A, Halboub E. Changes in soft tissue profile after orthodontic treatment with and without extraction: a systematic review and meta-analysis. *J Evid-Based Dent Pract.* 2018;18(3):193-202. [CrossRef]
21. Maetevorakul S, Viteporn S. Factors influencing soft tissue profile changes following orthodontic treatment in patients with Class II Division 1 malocclusion. *Prog Orthod.* 2016;17:13. [CrossRef]
22. Janson G, Mendes LM, Junqueira CHZ, Garib DG. Soft-tissue changes in Class II malocclusion patients treated with extractions: a systematic review. *Eur J Orthod.* 2016;38(6):631-637. [CrossRef]
23. Konstantonis D, Vasileiou D, Papageorgiou SN, Eliades T. Soft tissue changes following extraction vs. nonextraction orthodontic fixed appliance treatment: a systematic review and meta-analysis. *Eur J Oral Sci.* 2018;126(3):167-179. [CrossRef]
24. Atik E, Akarsu-Guven B, Kocadereli I. Soft tissue effects of three different Class II/1- camouflage treatment strategies. *J Orofac Orthop.* 2017;78(2):153-165. [CrossRef]
25. Elnagar MH, Elshourbagy E, Ghobashy S, Khedr M, Kusnoto B, Evans CA. Threedimensional assessment of soft tissue changes associated with bone-anchored maxillary protraction protocols. *Am J Orthod Dentofacial Orthop.* 2017;152(3):336-347. [CrossRef]
26. Arnett GW, Gunson MJ. Facial planning for orthodontists and oral surgeons. *Am J Orthod Dentofacial Orthop.* 2004;126(3):290-295. [CrossRef]
27. Uysal T, Yagci A, Basciftci FA, Sisman Y. Standards of soft tissue Arnett analysis for surgical planning in Turkish adults. *Eur J Orthod.* 2009;31(4):449-456. [CrossRef]
29. Ashraf K, Kulshrestha R, Azam A, Shabir S, Kaur H. Soft tissue analysis of chin, upper lip length and thickness in patients with different mandibular divergent patterns-A cephalometric study. *Indian J Orthod Dentofac Res.* 2018;4(2):88-93. [CrossRef]
30. Jo SY, Bayome M, Park J, Lim HJ, Kook Y-A, Han SH. Comparison of treatment effects between four premolar extraction and total arch distalization using the modified C-palatal plate. *Korean J Orthod.* 2018 Jul;48(4):224-235. [CrossRef]

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Original Article

Evaluation of the Quality and Reliability of YouTube™ Videos Created by Orthodontists as an Information Source for Clear Aligners

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Main Points

- Videos about orthodontic aligner treatment have average reliability and quality but insufficient content.
- The reliability, quality, and content usefulness of the videos are interrelated.
- Video interaction and viewing rates were associated with video quality and reliability, suggesting that viewers should consider these factors
- Orthodontists should pay attention to issues such as information flow, consistency, image use, and enrichment of the content while creating video content.

ABSTRACT

Objective: This study aimed to evaluate the quality, reliability, and content usefulness of videos created by orthodontists on clear orthodontic aligners.

Methods: Videos were screened using YouTube™ by conducting a search for "Invisalign". After a preliminary evaluation of the first 250 results, 61 videos that met the selection criteria were scored and their length, days since upload, and numbers of views, likes, dislikes, and comments were recorded. These data were used to calculate the interaction index and viewing rate. Video reliability was assessed using a five-item modified DISCERN index, and video quality was assessed using the Video Information and Quality Index. A 10-item content usefulness index was created to determine the usefulness of the video content. Descriptive statistics of the parameters were calculated, and correlation coefficients were calculated to evaluate the relationships between the parameters.

Results: The mean reliability score was 2.75±1.02 (out of 5), and the total quality score was 11.80±3.38 (out of 20). The total content usefulness index was quite low, with a mean score of 2.52±2.14 (out of 10). Interaction index and viewing rate were positively correlated with reliability score ($r=0.463$, $p<0.01$; $r=0.295$, $p<0.05$) and total quality score ($r=0.365$, $p<0.01$; $r=0.295$, $p<0.01$, respectively). The reliability score was positively correlated with the total quality score ($r=0.842$, $p<0.01$) and total content usefulness index ($r=0.346$, $p<0.01$).

Conclusion: Videos about orthodontic aligner treatment have average reliability and quality but largely insufficient content.

Keywords: Clear aligners, invisalign, invisible orthodontics, video quality, YouTube

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INTRODUCTION

Humanity's striving through the ages to reach a higher esthetic has led to advances in technology that have also impacted the field of orthodontics and brought along with it the search for more esthetic methods to achieve the ideal result. One of the most recent examples of these methods is the use of clear orthodontic aligners. The evolution and adoption of clear aligners, which started with the introduction of thermoplastic tooth positioning appliances by Kesling,[1] accelerated after the US Food and Drug Administration approved clear aligners produced by Align Technology© in 1998. The widespread clinical application and research about clear aligner treatments led to their current popularity.[2,3] Patients welcomed these practices with a wave of curiosity and a desire to learn more about them.

YouTube™ and similar video sharing sites allow users to share their experiences and knowledge and provide access to audiovisual information about various areas. Studies have shown that most active internet users access health information online.[4,5] Today, parameters such as the smile and physical appearance have an important place in many people's lives and lead younger people to continually produce more content, especially on YouTube™, on subjects such as oral hygiene and dental treatments.[6] The growing number of dentistry-related videos produced both by "YouTubers" and healthcare professionals has recently attracted researchers' interest in terms of examining their content, quality, and reliability.[7-13]

With their increasing popularity, more videos about orthodontic aligners are appearing daily. However, previous studies have raised questions about whether this increasing amount of content is a source of information pollution and misdirection and about the quality and reliability of the videos.[10,14] While content created by patients is primarily based on sharing personal opinions and experience, orthodontists' main goals in producing content are to provide accurate information to patients or the people to whom a treatment is targeted and to produce high-quality, reliable content based on scientific data. To the best of our knowledge, no studies have investigated YouTube™ content related to clear aligners created only by orthodontists.

Considering the ethical responsibility of this information, this study aimed to evaluate the quality, reliability, and usefulness of content in videos created by orthodontists about orthodontic aligners. The null hypothesis of this study was "quality, reliability, and content usefulness of videos created by orthodontists about orthodontic aligners are high".

METHODS

The Google Trends application (https://trends.google.com) provides users with statistical information about the geographical regions, languages, and frequencies for which words or sentences are searched. This site was utilized to determine the most commonly used search term for "orthodontic aligner" worldwide based on searches using various keywords. Search parameters were limited to the last 5 years and worldwide. The search was conducted using the keywords "aligners," "clear aligners," "teeth aligners," "Invisalign," "SmileDirectClub," "ClearCorrect," "Byte," and "Candid." According to comparative search results, the most commonly used search term related to "orthodontic aligners" was "Invisalign" (Google Trends, April 23, 2021).

The YouTube™ website (https://www.youtube.com) was used to screen videos on "orthodontic aligners." A search for the word "Invisalign" was conducted, and the results were sorted using the "relevance" filter (April 25, 2021). All cookies and past searches were cleared before searching to prevent bias. The first 250 videos in the search results were evaluated. As the order of the videos shown can change in searches performed on different days, a new playlist was created from the evaluated videos in the same order, and uniform resource locators were saved. Multi-part videos were evaluated as a single video.

In the initial evaluation of the videos, videos created by companies/manufacturers, blogs and promotional videos made by aligner users, videos in languages other than English, videos with no audio and/or subtitles, videos irrelevant to the topic of clear aligners, clinic promotional videos not including orthodontists, and videos longer than 15 min were excluded (Table 1). A total of 61 videos that met these criteria were included in the analysis.

Video Assessment

All videos were watched in their entirety, and data on the number of views, likes, dislikes, comments, time since upload (in days), and video length (in seconds) were recorded. Using these data, interaction index and viewing rate formulas that have been used in previous studies to determine viewer interaction and viewing rates were employed.[7,10,12] In this study, similar rates for each video were determined using the following formulas:

$$\text{Interaction index (\%)} = \frac{\text{number of likes - number of dislikes}}{\text{number of views}} \times 100$$

$$\text{Viewing rate (\%)} = \frac{\text{number of views}}{\text{number of days}} \times 100$$

Table 1. Reasons for excluding videos

Reasons for exclusion	Number of videos
Not in English	19
No audio/subtitles	19
Based on patient experience/vlogs	95
Not related to subject	7
Manufacturer/company advertisements/videos	15
Clinical promotional videos (not including dentist)	9
Longer than 15 minutes	25
Total	189

DISCERN (Quality Criteria for Consumer Health Information), a 16-item tool published in 1999 for assessing written information, is valuable for determining the reliability and quality of written text. However, its questions may not be suitable for web and video formats.[15] Therefore, in previous studies, investigators preferred to use a modified version this tool consisting of 5 questions to evaluate the information reliability of videos.[10,11,16] The five-item modified index was also used to assess video reliability in this study (Table 2). While assessing the videos, each question was scored as 0 (no) or 1 (yes), resulting in a reliability score between 0 and 5.

Video quality was assessed using the Video Information and Quality Index (VIQI), which corresponds all components of the Global Quality Scale used to assess the quality of websites.[17,18] Although the Global Quality Scale was used t in some similar studies to determine video quality, VIQI was preferred because it is more appropriate for video assessment. In VIQI, video quality is rated on a 5-point Likert-type scale (0=poor quality, 5=high quality) in four different areas: flow, accuracy of the information, quality (1 point each for using images, using animations, including interviews with community members, including subtitles, and using a summary report), and precision (level of agreement between video title and content). These scores are totaled to obtain a total quality score ranging from 0 to 20.[7]

To assess the usefulness of the video content, a 10-part content usefulness index was created: 1. Definition and purpose of aligner treatment, 2. Indications and contraindications of treatment, 3. Advantages and disadvantages, 4. Instructions for using the aligner (daily use time, how it is inserted and removed, cleaning and maintenance instructions), 5. Aligner treatment application procedures, 6. Treatment biomechanics, 7. Comparison with other treatment methods, 8. Effect on quality of life (pain, soft tissue damage, effect on speech, psychosocial effect), 9. Cost of treatment and 10. Duration of treatment. The video was given 1 point for each section it provided information about, yielding a total content usefulness score ranging from 0 to 10.

Statistical Analysis

All evaluations were performed simultaneously and independently by two orthodontists (E.C., 10 years of experience and K.T., 4 years of experience), and interclass correlation coefficients were calculated to evaluate interclass reliability. Two weeks after the first evaluation, 15 of the 61 scored videos were randomly selected using an online randomization website (https://www.randomizer.org) and reevaluated by both researchers. The intraclass correlation coefficient was calculated to determine intrarater reliability. The study data were analyzed using SPSS version 21.0 (IBM Corp, Armonk, NY, USA). The Shapiro- Wilk test was performed to determine whether the data were distributed normally. Descriptive statistics of the parameters were calculated. The Spearman correlation test was used for correlations, and correlation coefficients were calculated to evaluate the relationships between the parameters. A p-value of 0.05 was considered statistically significant.

Table 2. Assessment of reliability scores of videos on Invisalign[10,16]

Reliability score
1. Are the aims clear and achieved?
2. Are reliable sources of information used? (i.e., publication cited, speaker is an orthodontist)
3. Is the presented information balanced and unbiased?
4. Are additional sources of information listed for patient reference?
5. Does the video mention areas of controversy/uncertainty?

RESULTS

The interobserver correlation coefficients were in the range of 0.754-0.981, indicating high agreement between the two raters. Both raters were consistent in repeated assessments, with intraobserver correlation coefficients of 0.941-0.985 for the first rater and 0.885-0.982 for the second rater. Therefore, the statistical analyses were based on the evaluations of the senior orthodontist (E.C.).

The descriptive statistics of the 61 videos evaluated are presented in Table 3. The mean DISCERN reliability score was 2.75±1.02, while the mean VIQI total quality score was 11.80±3.38, approximately half of the maximum possible score of 20. Of the VIQI quality criteria, the mean scores were above average for video flow (3.11±1.29), information accuracy (3.67±0.97), and precision (3.44±1.50), while quality (use of images, use of animations, including interviews with community members, video subtitles, and using a summary report) had the lowest score (1.57±0.88). The total content usefulness index was quite low at 2.52±2.14 (Table 3).

When the relationships between video characteristics, reliability score, quality scores, and content usefulness index were evaluated, significant positive correlations were detected between video duration and reliability score ($r=0.542$, $p<0.01$), flow ($r=0.564$, $p<0.01$), information accuracy ($r=0.541$, $p<0.01$), and total quality score ($r=0.497$, $p<0.01$). Days since upload negatively correlated with reliability score ($r=-0.332$, $p<0.01$) and total quality score ($r=-0.263$, $p<0.05$). The number of views was positively correlated with flow ($r=0.275$, $p<0.05$), while the number of likes was positively correlated with flow ($r=0.375$, $p<0.01$) and information accuracy ($r=0.357$, $p<0.01$). In addition, the number of comments was positively correlated with flow ($r=0.359$, $p<0.01$), information accuracy ($r=0.302$, $p<0.05$), and total quality score ($r=0.257$, $p<0.05$). Similarly, both interaction rate and viewing rate were positively correlated with reliability score ($r=0.463$, $p<0.01$; $r=0.295$, $p<0.05$), flow ($r=0.460$, $p<0.01$; $r=0.420$, $p<0.01$), information accuracy ($r=0.448$, $p<0.01$; $r=0.325$, $p<0.05$), and total quality score ($r=0.365$, $p<0.01$; $r=0.295$, $p<0.01$, respectively) (Table 4).

Analysis of the relationships between reliability score, quality scores, and total content usefulness index revealed that reliability score was positively correlated with flow (r=0.842, p<0.01), information accuracy (r=0.786, p<0.01), precision (r=0.533, p<0.01), total quality score (r=0.842, p<0.01), and total content usefulness index (r=0.346, p<0.01). Flow was positively correlated with information accuracy (r=0.773, p<0.01), precision (r=0.371, p<0.01), total quality score (r=0.803, p<0.01), and total content usefulness index (r=.389, p<0.05). There were similar relationships between information accuracy and precision (r=0.543, p<0.01) and total quality score (r=0.847, p<0.01). The quality parameter was positively correlated with the total quality score (r=0.381, p<0.01) and total content usefulness index (r=0.365, p<0.01). There were also significant positive correlations between precision and total quality score (r=0.766, p<0.01) and between total quality score and total content usefulness index (r=0.347, p<0.01) (Table 5).

Table 3. Descriptive statistics for YouTube™ videos (n=61)

	Min.	Max.	Mean	SD
Duration (seconds)	47.00	831.00	329.42	211.92
Days since upload	7.0	3050.0	609.09	636.61
Number of views	11.0	738,515.0	44,021.55	110,044.69
Number of likes	0.0	7,600.0	398.47	1,059.55
Number of dislikes	0.0	481.0	17.88	62.58
Number of comments	0.0	1158.0	69.23	164.92
Interaction index	0.00	12.21	1.48	1.81
Viewing rate	0.910	134,765.00	6,771.41	18,003.75
Reliability score	1.0	5.0	2.75	1.02
Flow	0.0	5.0	3.11	1.29
Information accuracy	1.0	5.0	3.67	0.97
Quality	0.0	5.0	1.57	0.88
Precision	0.0	5.0	3.44	1.50
Total quality score	4.0	18.0	11.80	3.38
Total content usefulness index	0.0	8.0	2.52	2.14

Min., minimum; Max., maximum; SD, standard deviation

DISCUSSION

Increased sharing of knowledge and experience related to aligners through social media has led to research evaluating this content.[10,14,19,20] To the best of our knowledge, three previous studies in the literature have evaluated videos about clear aligners.[10,14,21] In a study evaluating YouTube™ content related to orthodontic aligners, Ustdal and Guney[10] reported that the content produced was insufficient and unreliable, with only 12 of the 100 videos selected created by dentists or orthodontists. Sadry and Buyukbasaran[21] also found YouTube videos lacking as a source of information on orthodontic treatment with clear aligners. Livas et al.[14] conducted another study evaluating patient testimonials. In planning this study, the starting point was to evaluate whether content produced by orthodontists is appropriate for patients, and if video reliability, quality, and content contribute to video interaction and viewing. Therefore, unlike other studies, we comprehensively evaluated video content created only by orthodontists to inform patients, rather than videos made by aligner users. The Google Trends app identified "Invisalign" as the most searched term related to "orthodontic aligners". "Invisalign" term was used in this study However, the use of other terms such as "clear aligners" during the study would have allowed the video alternatives to be diversified. Therefore, using a single term in searches may be a limitation for this study.

Studies of search engine user behavior have reported that users tend to focus on the first few results encountered without scrolling further down the page.[22,23] In previous studies, it was emphasized that 90% of YouTube™ users clicked on results within the first 3 pages, and only a small proportion of users continued beyond the first page.[7-12] Considering this, we

Table 4. Correlations between video characteristics (duration, days since upload, number of views, number of likes, number of dislikes, number of comments, interaction index, viewing rate) and reliability, quality, and content usefulness scores

	Duration		Days since upload		Number of views		Number of Likes		Number of dislikes		Number of comments		Interaction index		Viewing rate	
	r	p	r	p	r	p	r	p	r	p	r	p	r	p	r	p
Reliability score	0.542**	0.000	-0.332**	0.009	0.174	0.179	0.248	0.054	0.085	0.516	0.231	0.073	0.463**	0.000	0.295*	0.021
Flow	0.564**	0.000	-0.224	0.082	0.275*	0.032	0.375**	0.003	0.191	0.140	0.359**	0.005	0.460**	0.000	0.420**	0.001
Information accuracy	0.541**	0.000	-0.244	0.058	0.187	0.149	0.357**	0.005	0.173	0.181	0.302*	0.018	0.448**	0.000	0.325*	0.011
Quality	0.202	0.119	-0.016	0.905	0.066	0.613	0.042	0.747	0.072	0.579	0.138	0.287	-0.043	0.741	0.157	0.226
Precision	0.180	0.166	-0.173	0.182	0.023	0.859	0.051	0.697	-0.049	0.707	0.094	0.471	0.163	0.208	0.101	0.440
Total quality score	0.497**	0.000	-0.263*	0.041	0.144	0.269	0.244	0.058	0.084	0.521	0.257*	0.046	0.365**	0.004	0.295*	0.021
Total content usefulness score	0.201	0.121	-0.197	0.128	-0.081	0.534	-0.006	0.964	-0.060	0.649	-0.058	0.655	0.224	0.082	-0.048	0.716

Spearman correlation coefficients; *p<0.05, **p<0.01

expanded our search to include the first 250 results. Although evaluating many videos is a strength, it may also be a limitation considering the evidence that lower-ranking studies are less likely to attract attention. Additionally, videos longer than 15 minutes were excluded based on user behavior data, as most sessions are less than 15 minutes.[22] This exclusion aimed to ensure user interest and facilitate simultaneous evaluation.

According to the results of this study, the reliability and total quality scores of the videos were near the middle of the possible score range. Similarly, Ustdal and Guney[10] found these parameters to be close to average, whereas Lena and Dindaroğlu[7] evaluated videos related to lingual orthodontic treatment and reported a slightly higher total quality score. Within the VIQI total quality score, video quality scored the lowest in this study. This was because most of the videos lacked images or animations and did not include the opinions/experiences of treated individuals. Therefore, incorporating more visuals and patient experiences is recommended to enhance video quality. Additionally, the total content usefulness index score of the videos in this study was well below average, compared to similar studies in dentistry.[7,10,24-26] A major limitation was that most videos focused on specific topics. It may be reasonable to focus on specific points related to aligner treatment, and it would be unreasonable to expect all videos to cover all the details relevant to the subject. However, omitting background and key informations may lead to the misconceptions. Therefore, to increase the usefulness of the content, it would be beneficial to provide brief, evidence-based information highlighting the definition and main points of treatment in these videos.

When evaluating the relationships between video characteristics and their reliability, quality, and content usefulness, it was observed that longer video length correlated with higher reliability and total quality scores. This finding aligns with studies by Yavan and Gökçe[26], where videos on adult orthodontics with richer content and scored higher in quality.[26] Lena and Dindaroğlu[7] reported that viewers lost interest in longer videos, with the average length of rich-content videos was 7.47 minutes. Although previous studies have shown that long videos are not preferred by viewers, longer durations were associated with better video quality and reliability. While this may seem like a dilemma for content creators, the positive correlation between interaction and viewing rates with video reliability, information flow, accuracy, and total quality score indicates that viewers value and are influenced by these factors. Therefore, orthodontists who create content should consider these aspects and develop videos based on scientific data while keeping them at an acceptable length.

Another interesting finding was that video reliability and total quality score decreased with longer time since upload. This suggests that more recently posted videos are perceived as more reliable and higher in quality. This could be attributed to the continuous improvement in knowledge, experience, and technology related to aligner treatment, as well as advancements in video technology/quality over time. Therefore, regular updates of content can be beneficial for maintaining video quality and reliability.

When the correlations between reliability score, quality score, and total content usefulness index were evaluated, significant positive relationships were observed among them. Previous studies have shown that video quality, reliability, and content are interrelated parameters.[7,10] Therefore, using reliable sources, results in more useful content that provides balanced and consistent information. Similarly, as information flow, accuracy, and precision improve, videos become more reliable and useful. Consequently, it's essential to consider these parameters collectively rather than separately.

CONCLUSION

The null hypothesis was rejected. The results reveal that videos on aligner treatment have average reliability and quality but

Table 5. Correlations between the reliability score, quality scores, and total content usefulness index

		Flow	Information accuracy	Quality	Precision	Total quality score	Total content usefulness index
Reliability score	r	0.842**	0.786**	0.231	0.533**	0.842**	0.346**
	p	0.000	0.000	0.073	0.000	0.000	0.006
Flow	r		0.773**	0.220	0.371**	0.803**	0.289*
	p		0.000	0.089	0.003	0.000	0.024
Information accuracy	r			0.181	0.543**	0.847**	0.163
	p			0.162	0.000	0.000	0.209
Quality	r				0.067	0.381**	0.365**
	p				0.606	0.002	0.004
Precision	r					0.766**	0.148
	p					0.000	0.254
Total quality score	r						0.342**
	p						0.007

Spearman correlation coefficients; *p<0.05, **p<0.01

largely insufficient content. Video interaction and viewing rates were associated with video quality and reliability, suggesting that viewers should consider these factors. In addition, the reliability, quality, and content usefulness of videos are interrelated. Therefore, when orthodontists create content, providing balanced and current scientific information, paying attention to issues such as information flow, consistency, and image use, and enriching the content accordingly will be beneficial both to ensure that patients are appropriately informed and to generate more interaction.

Ethics

Ethics Committee Approval: Ethical approval for the study was obtained from the İstanbul Medipol University Ethics Committee (IRB no: E-10840098-772.02-2354).

Informed Consent: Since this research was not conducted on patients and patient datas were not used, informed consent was not obtained.

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

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REFERENCES

1. Kesling HD. The philosophy of the tooth positioning appliance. *Am J Orthod Oral Surg.* 1945;31(6):297-304. [CrossRef]
2. Weir T. Clear aligners in orthodontic treatment. *Aust Dent J.* 2017;62 Suppl 1:58-62. [CrossRef]
3. Rossini G, Parrini S, Castroflorio T, Deregibus A, Debernardi CL. Efficacy of clear aligners in controlling orthodontic tooth movement: a systematic review. *Angle Orthod.* 2015;85(5):881-889. [CrossRef]
4. Rutten LJ, Squiers L, Hesse B. Cancer-related information seeking: hints from the 2003 Health Information National Trends Survey (HINTS). *J Health Commun.* 2006;11(Suppl 1):147-156. [CrossRef]
5. Madathil KC, Rivera-Rodriguez AJ, Greenstein JS, Gramopadhye AK. Healthcare information on YouTube: A systematic review. *Health Informatics J.* 2015;21(3):173-194. [CrossRef]
6. Meisels I, Musset AM, Fernandez De Grado G, Offner D. Evaluation of the Quality of Dentistry Related Youtube Videos Made by Youtubers. Public Health Tool, or Large Scale Danger? *J Epidemiol Public Health Rev.* 2018;3(3). [CrossRef]
7. Lena Y, Dindaroğlu F. Lingual orthodontic treatment: a YouTubeTM video analysis. *Angle Orthod.* 2017;88(2):208-214. [CrossRef]
8. Kılınç DD, Sayar G. Assessment of Reliability of YouTube Videos on Orthodontics. *Turk J Orthod.* 2019;32(3):145-150. [CrossRef]
9. Pasaoglu Bozkurt A, Gaş S, Özdal Zincir Ö. YouTube video analysis as a source of information for patients on impacted canine. *Int Orthod.* 2019;17(4):769-775. [CrossRef]
10. Ustdal G, Ustdal Guney A. YouTube as a source of information about orthodontic clear aligners. *Angle Orthod.* 2020;90(3):419-424. [CrossRef]
11. Buyuk SK, Alpaydın MT. Quality of Information on YouTube™ about Rapid Maxillary Expansion. *Turk J Orthod.* 2021;34(2):116-121. [CrossRef]
12. Yilmaz H, Aydin MN. YouTube™ video content analysis on space maintainers. *J Indian Soc Pedod Prev Dent.* 2020;38(1):34-40. [CrossRef]
13. Özbay Y, Çırakoğlu NY. YouTube as an information source for instrument separation in root canal treatment. *Restor Dent Endod.* 2021;46(1):e8. [CrossRef]
14. Livas C, Delli K, Pandis N. "My Invisalign experience": content, metrics and comment sentiment analysis of the most popular patient testimonials on YouTube. *Prog Orthod.* 2018;19(1):3. [CrossRef]
15. Charnock D, Shepperd S, Needham G, Gann R. DISCERN: an instrument for judging the quality of written consumer health information on treatment choices. *J Epidemiol Community Health.* 1999;53(2):105-111. [CrossRef]
16. Singh AG, Singh S, Singh PP. YouTube for information on rheumatoid arthritis--a wakeup call? *J Rheumatol.* 2012;39(5):899-903. [CrossRef]
17. Nagpal SJ, Karimianpour A, Mukhija D, Mohan D, Brateanu A. YouTube videos as a source of medical information during the Ebola hemorrhagic fever epidemic. *Springerplus.* 2015;4:457. [CrossRef]
18. Kumar N, Pandey A, Venkatraman A, Garg N. Are video sharing web sites a useful source of information on hypertension? *J Am Soc Hypertens.* 2014;8(7):481-490. [CrossRef]
19. Adobes-Martin M, Montoya-Morcillo ML, Zhou-Wu A, Garcovich D. Invisalign treatment from the patient perspective: A Twitter content analyses. *J Clin Exp Dent.* 2021;13(4):e376-e382. [CrossRef]
20. Noll D, Mahon B, Shroff B, Carrico C, Lindauer SJ. Twitter analysis of the orthodontic patient experience with braces vs Invisalign. *Angle Orthod.* 2017;87(3):377-383. [CrossRef]
21. Sadry S, Buyukbasaran E. Content analysis and reliability of YouTube™ videos on clear aligner. *APOS Trends Orthod.* 2021;11(3):209-217. [CrossRef]
22. Lewandowski D. Search engine user behaviour: How can users be guided to quality content? *Information Services & Use.* 2008;28(3):261-268. [CrossRef]
23. Jansen BJ, Spink A. How are we searching the World Wide Web? A comparison of nine search engine transaction logs. *Information Processing & Management.* 2006;42(1):248-263. [CrossRef]
24. Grewal J, Marria G, Goel S. Information content of YouTube videos on orthognathic surgery - Helpful? *Indian J Dent Sci.* 2019;11(2):90-94. [CrossRef]
25. Hatipoğlu Ş, Gaş S. Is Information for Surgically Assisted Rapid Palatal Expansion Available on YouTube Reliable? *J Oral Maxillofac Surg.* 2020;78(6):1017.e1-1017.e10. [CrossRef]
26. Yavan MA, Gökçe G. YouTube as a source of information on adult orthodontics: a video analysis study. *J World Fed Orthod.* 2022;11(1):41-46. [CrossRef]

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Original Article

Evaluation of Pain Perception During Orthodontic Debonding of Metallic Brackets with Simultaneous Application of TENS Therapy

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Main Points

- The application of transcutaneous electrical nerve stimulation (TENS) therapy results in pain reduction during the debonding procedure.
- Female subjects experienced more pain than the male subjects during debonding.
- Higher pain scores were recorded for the mandibular anterior teeth than for the maxillary teeth.
- Patients displayed good acceptance and satisfaction with TENS therapy for pain control during the debonding of fixed appliances.

ABSTRACT

Objective: The objective of the present study was to evaluate the effectiveness of transcutaneous electrical nerve stimulation (TENS) therapy on pain during the debonding procedure.

Methods: A placebo-controlled, randomized split - mouth study was conducted on 30 orthodontic patients. The right and left anterior teeth in the maxilla and mandible were randomly allocated to the control and experimental groups (EG) and were stimulated. TENS application was made through a modified electrode probe that was used from an ammeter. The control group (CG) received the mechanical application of the device with no current, whereas the EG received progressively increasing current from 0.1 mA to the point where the patient experienced a mild tingling sensation for 60 s for each tooth. This was followed by a debonding procedure using an orthodontic debonding plier. Pain perception was recorded on a numerical rating scale after debonding each tooth.

Results: The mean pain score was higher in the CG than in the EG, and the difference between the two groups was significant (p=0.001). The pain score was higher in the mandibular teeth than in the maxillary teeth, and the difference between the two groups was also significant (p=0.021). Pain score was higher in female subjects than in male subjects, and the difference between the two groups was significant (p=0.015).

Conclusion: The application of TENS therapy results in pain reduction during the debonding procedure. The female subjects experienced more pain. Higher pain scores were recorded for the mandibular anterior teeth than for the maxillary teeth.

Keywords: Debonding, randomized controlled clinical trials, transcutaneous electrical nerve stimulation

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INTRODUCTION

A frequent adverse effect of many orthodontic procedures is pain. Pain is subjective and is expressed both verbally and non-verbally.[1] It has been noticed that pain is typically felt during or immediately after the adjustment of an orthodontic appliance and may even last for 2 to 4 days, despite there being no quantitative documentation. From a slight soreness when clenching to a constant, throbbing pain, the level of pain varies.[2] Orthodontic pain is a result of pressure, ischemia, inflammation, and edema at the periodontium level. 95% of orthodontic patients feel some level of pain or discomfort during or after various orthodontic operations. The insertion of separators, activation or placement of archwires, use of miniscrews, and debonding of fixed appliances are among the orthodontic operations that are most likely to cause pain or discomfort.[1]

Techniques used to control pain are broadly classified into pharmacological and non-pharmacological methods. Pharmacological methods include local anesthesia, general anesthesia, pharmacologic sedation, nitrous oxide relative analgesia, and hypnosis. Bite wafers, chewing gum, low-level laser therapy (LLLT), vibratory stimulation, transcutaneous electrical nerve stimulation (TENS), application of ice/cryotherapy, acupuncture/acupressure, and psychological interventions such as a structured phone call to patients during treatment are examples of non-pharmacological methods for pain control. TENS has found its greatest use with physical therapists in rehabilitation and chronic pain control.[2-4]

Greeks were the first to document the use of electricity to ease pain in writing. Walsh and Cavendish provided the first written account of the numbing effects of electrical generators in the 1770s. The first person to mention the use of electricity to treat tooth discomfort was Francis in the 19th century.[3,4] TENS is used to treat the symptoms of mild to moderate pain from any source, including neuropathic, musculoskeletal, and nociceptive pain.[5] TENS has been used previously for the treatment of myofascial pain dysfunction, trigeminal neuralgias, and temporomandibular joint pain.

Bond strength is crucial for maintaining the effectiveness of orthodontic treatment, but quick debonding of the brackets is preferable at the end of the procedure.[6,7]

A thorough review of the literature found no studies evaluating the effect of TENS during the debonding procedure. Therefore, the objective of this study was to evaluate the analgesic effect of a single application of TENS on pain during the debonding procedure. Therefore, the aim of the present study was to evaluate and compare the effectiveness of TENS therapy on pain during the debonding procedure.

METHODS

This study was approved by the I.T.S. Institutional Ethics Committee with protocol number: ITSCDSR/IIEC/RP/2019/014 and date: 22.11.2019. Sample size was estimated using the data obtained from a previous study conducted by Roth and Thrash[2] where the mean and standard deviation of visual analog scale scores were 4.77±6.96 for the treatment group and 15.22±15.86 for the control group (CG). This data revealed that, for an effect size of 0.85, a total sample size of 60 sites would provide an adequate statistical power of 95% to detect a significant difference.

This placebo-controlled, randomized split - mouth study was conducted on 30 orthodontic patients aged between 12 and 27 years in whom fixed orthodontic treatment had been performed using conventional metallic MBT brackets and in whom debonding was scheduled. Patients who had no missing teeth except the first premolar and who had not undergone any tooth transplantation were selected. Patients using antibiotics or analgesics, pregnant or breastfeeding, and those with a history of systemic diseases such as seizures, cardiac arrhythmia, or pacemakers were excluded. Patients with treated or untreated apical bone lesions, parafunctional habits, temporomandibular dysfunction, or smokers and alcoholics were also not included in study.

All patients meeting the inclusion criteria were given oral and written information by the operator and consented to participate in the study. Before starting the procedure, 30 opaque envelopes were made, out of which 15 envelopes were from the experimental group (EG) and 15 were from the CG. Allocation concealment was performed via unmarked envelopes. When the operator was about to start the procedure, patients were instructed to choose one envelope, and subsequently, the right maxillary and left mandibular teeth were given the same intervention as mentioned in the envelope. The left maxillary and right mandibular teeth were subjected to the opposite intervention. Both groups were informed that they would be evaluating a pain reduction device that would administer a mild electric current and that the strength of the stimulation could range from sub-sensory to negligible tingling.

The brackets on the anterior teeth in the maxilla and mandible were deboned in the study for pain evaluation. Immediately before the debonding procedure, a conductive gel was applied to the labial surface of the anterior teeth. The teeth allocated to the EG received stimulation from the TENS device on the incisal edges of the anterior teeth (Figure 1a). The device used was a modified electrode probe that was derived from an ammeter. It was selected because it had a detachable metallic head that could be autoclaved (Figure 1b). It generated a biphasic, symmetrical pulse with a net neutral charge and a maximum current of 10 mA. The current was progressively increased from 0.1 mA to the point where the patient experienced a mild tingling sensation (Figure 2). From this stage, the current was delivered for 60 s to each tooth. The teeth in the CG group received the same mechanical application of the device with no current. After delivery of the current for 60 s, the dental operator started the debonding procedure. The elastomeric modules, ligature ties, e-chains, and any other accessories were removed to separately record the pain score of each tooth. Debonding was performed with debonding pliers by placing the blades of the plier at the bracket-adhesive interface, and gentle squeezing action was applied until bond failure occurred.

Pain intensity was scored on a numerical rating scale after debonding in both the EG and CG groups immediately after the debonding procedure. A score of 0 indicated no pain, whereas a score of 10 indicated maximum pain. The patients were asked to rate the pain levels separately for each tooth. Acceptance of TENS therapy was assessed after the debonding procedure using a questionnaire provided to the patients.

Statistical Analysis

Data were analyzed using SPSS v20.0 software (SPSS Inc, Chicago, Il, USA). The level of significance was maintained at 5%. The data were subjected to normality testing using the Shapiro-Wilk test, which showed that the data deviated from the normal distribution. The demographic details of the study participants were presented using descriptive statistics. Pain scores between the control and EG groups were compared using the Mann-Whitney U test. Pain scores were also compared between gender and arch using the Mann-Whitney U test.

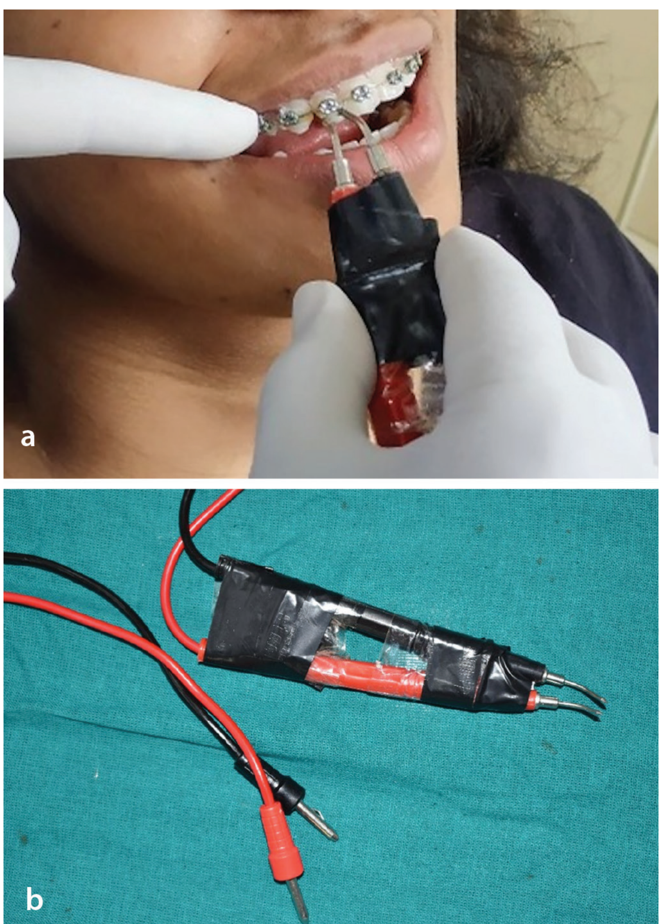

Figure 1. a) Patient receiving tens application. b) Modified electrodes for intraoral application

RESULTS

The mean age of the sample was 19.63±3.11 years. The sample size was 30 out of which 13 participants were male and 17 participants were female (Table 1). The Mann-Whitney U test revealed that the mean pain score was higher in the CG than in the EG, and the difference between the two groups was significant (p=0.001). A significant difference was also observed when comparing pain score in individual arches in the CG as compared to EG (p=0.001) (Table 2). Also, the pain score was higher in mandibular teeth as compared to maxillary teeth in control (p=0.021) and EG, and the difference between the two groups was significant (p=0.012).

Female subjects had a higher score than male subjects in both groups, and the difference between the two groups was significant (Table 3).

The pain score was higher in the CG than in the EG in female and male subjects, and the difference between the two groups was significant (p=0.001) for females and non-significant for males (p=0.064) (Table 4).

For individual teeth pain scores, the maximum mean pain score was recorded for the lower right central and lateral incisors and the minimum for the upper right central incisor in the CG. For the EG, the maximum mean pain score was recorded for the lower right central incisors and the minimum mean pain was recorded for the upper left central incisors (Table 5).

The questionnaire regarding their experience with TENS therapy revealed that 50% of patients expected the debonding procedure was painful, whereas 76.7% reported mild pain. Thirty percent of patients had excellent responses, and 60%

Figure 2. TENS machine
TENS, transcutaneous electrical nerve stimulation.

reported excellent responses with TENS therapy. 93.3% patients agreed to use the same therapy as needed. Almost all the patients 100% agreed to recommend this therapy to friends and family, and only 13% of patients were aware of the TENS machine/therapy (Table 6).

DISCUSSION

Modern dentistry has increasingly prioritized minimizing patient pain and discomfort during dental procedures. However, in orthodontics, research in this area is relatively limited compared to other fields within orthodontics.[8] Pain remains a significant concern as it can impact patient decisions and treatment acceptability.[9] Management of orthodontic pain includes both pharmacological and non-pharmacological interventions. Pharmacological therapeutic therapies, however, may have some side effects and limitations. For these reasons, non-pharmacological treatments for orthodontic discomfort have also been explored, including chewing gum, bite-sized wafers, LLLT, vibratory stimulation, and TENS.[10]

TENS, approved by FDA in 1972, delivers a pulsed electrical current via electrodes on the skin to stimulate superficial nerves for pain relief.[4] It offers advantages such as non-invasiveness and safety, but its use in dentistry, particularly in orthodontics, has received only limited attention.

The analgesic action of TENS is mediated by two mechanisms: it stimulates the A-delta and A-beta fibers, which blocks the transmission of painful stimuli by the small unmyelinated C-fibers in the spinal cord; this is in accordance with Melzack and Wall's "gate control" theory. The endogenous opioid theory is an alternative explanation for this and was given by Reynolds. According to this theory, TENS stimulates the activation of local circuits within the spinal cord or from the activation of descending pain-inhibitory pathways, which results in the release of endogenous opioids in the spinal cord.[4] The present study evaluated the efficacy of TENS application to control pain during the debonding procedure in fixed orthodontic patients. The results showed that the pain score was higher in the CG than in the EG, and the difference between the two groups

Table 1. Demographic details of study participants

Variable	Category	Mean±SD/n (%)
Age	--	19.63±3.11 years
Gender	Male	13 (43.3%)
	Female	17 (56.7%)

SD, standard deviation

Table 2. Comparison of pain score between control and experimental groups of maxilla and mandible

Groups (n=30 each)	Mean±SD	Difference (95% CI of difference)	Maxilla	Mandible	P value Maxilla vs mandible	p value
Control	3.11±2.08	2.01 (1.16-2.85)	2.35±1.88	3.60±1.97	0.021	0.001*
Experimental	1.10±0.96		0.76±0.96	1.49±1.38	0.012*	

*p<0.05 indicating a statistically significant difference. SD, standard deviation; CI, confidence interval

Table 3. Comparison of pain score between maxillary teeth and mandibular teeth in the two study groups

Groups	Gender	n	Mean	SD	Difference (95% CI of difference)	p value
Control	Female	17	3.91	2.00	1.84 (0.40-3.27)	0.015*
	Male	13	2.07	1.76		
Experimental	Female	17	1.38	1.07	0.63 (-0.02-1.28)	0.094 (NS)
	Male	13	0.75	0.66		

*p<0.05 indicating a statistically significant difference. SD, standard deviation; CI, confidence interval

Table 4. Comparison of pain score between males and females

Groups	Gender	n	Mean	SD	Difference (95% CI of difference)	p value
Female	Control	17	3.91	2.00	2.53 (1.41-3.65)	0.001*
	Experimental	17	1.38	1.07		
Male	Control	13	2.07	1.76	0.63 (0.25-2.40)	0.064 (NS)
	Experimental	13	0.75	0.66		

*p<0.05 indicating a statistically significant difference. SD, standard deviation; CI, confidence interval

Table 5. Descriptive statistics of pain scores in different teeth in the control and experimental group

		Control group			Experimental group		
Tooth no	N	Minimum	Maximum	Mean±SD	Minimum	Maximum	Mean±SD
11	15	0	4	1.13±1.45	0	6	0.93±1.62
12	15	0	7	2.53±2.56	0	4	0.93±1.28
13	15	0	7	2.07±2.55	0	2	0.73±0.88
21	15	0	7	2.87±2.53	0	2	0.2±0.56
22	15	0	9	3.13±2.61	0	3	0.87±1.18
23	15	0	5	2.4±1.88	0	4	0.93±1.48
31	15	0	8	2.93±2.76	0	5	1.8±1.56
32	15	0	6	2.47±2.35	0	9	1.87±2.41
33	15	0	8	2.07±2.25	0	3	0.8±0.94
41	15	1	9	5.2±2.1	0	6	2.07±2.08
42	15	3	9	5.47±1.60	0	5	1.6±1.45
43	15	1	6	3.47±1.50	0	4	0.8±1.26

SD, standard deviation

Table 6. Descriptive table of responses of questionnaire to assess acceptance of TENS therapy by patients

	No pain	Mild	Moderate	Severe
1. What type of pain did you expect in the postoperative period?	1 (3.3%)	5 (16.7%)	15 (50%)	9 (30%)
2. What type of pain did you experience in postoperative period?	7 (23.3%)	23 (76.7%)	0	0
	Excellent	**Very good**	**Fair**	**Poor**
3. What was the quality of pain relief after TENS therapy?	9 (30%)	18 (60%)	3 (10%)	0
4. How was your overall experience with pain management/TENS therapy?	13 (48.3%)	14 (46.7%)	3 (10%)	0
	Yes		No	
5. Would you use the same analgesia modality again if required?	28 (93.3%)		2 (6.7%)	
6. Would you recommend the same modality to your family/friends?	30 (100%)		0	
7. Were you aware of this treatment modality prior to its application?	4 (13.3%)		26 (86.7%)	

TENS, transcutaneous electrical nerve stimulation

was significant (p=0.001) which indicated that the patients experienced less pain when subjected to TENS therapy.

This result is in accordance with two studies that have previously reported the use of TENS therapy for pain control in orthodontic patients. Roth and Thrash[2] demonstrated reduced pain in orthodontic patients receiving TENS therapy, while Haralambidis[7] found pain relief for up to 48 hours post-TENS application. Additionally, TENS therapy has also been reported to be effective for pain control in different dental procedures. Suzuki suppressed pain during cavity preparation using 4 to 10 AA through the bur.

Christensen and Radue[11] provided updates on TENS use for dental anesthesia, reporting a 50% success rate in 1987. Clark et al.[12] treated fifty patients, with an 80% effectiveness rate in the active group. Six hundred patients were examined by Hochman[13], with 76% experiencing pain relief. Jensen examined 35 people using three different waveforms and three different frequencies. Patients' expectations of pain were positively correlated with success. Malamed et al.[14] achieved an 86% success rate in 109 patients treated with H-Wave equipment.

Electrodes are crucial for TENS equipment. Intraoral electrodes come in sponges, conductive fabrics, and adhesive materials.[14] Different types of electrodes have been used in previous studies, such as through burs, and on the lip and mucosa, and extraoral pads. In this study, a modified electrode probe was used directly on the tooth's incisal edge. Roth and Thrash[2] noted rapid onset of analgesia with TENS, lasting for several hours. Therefore, in the present study, the current intensity was gradually increased until a mild tingling sensation was felt, then delivered for 60 seconds per tooth.

Debonding process should be swift, painless, and safe. Previous research analyzed the pain and discomfort during appliance implantation, but debonding pain remains process poorly understood.[6] According to Williams and Bishara[15] the mobility of the tooth and the direction of force application have a considerable impact on the threshold of patient discomfort at debonding. Patients have been found to be far more able to endure intrusive forces than mesial, distal, facial, lingual, or extrusive forces at the moment of debonding.[15] Applying a biting force stabilizes teeth and balances debonding pressures applied to the periodontal ligament. In addition, increased pressure on the periodontal ligament can induce proprioceptive stimulation that lessens discomfort.[1] Therefore, in this study, debonding was performed mesio-distally with a plier, while applying intrusive force on the incisal edge of the tooth. The study found significant differences in pain scores between mandibular and maxillary teeth, with mandibular teeth exhibiting higher pain scores in both study groups. Additionally, females experienced higher pain levels compared to males, consistent with previous findings.

Study Limitations

The present study had some limitations, such as a small sample size and unequal number of males and females. It is recommended that more procedures should be evaluated at different time periods to evaluate the duration of pain control and follow-up. To test various electrodes, electrode placements, wave patterns, frequencies, and combinations with other pain control methods, a pain model that mimics the discomfort of surgical operations is required.

CONCLUSION

Within the limitations of this study, the following conclusions may be drawn:

• The application of TENS therapy results in pain reduction during the debonding procedure.

• The female subjects experienced more pain than the male subjects during debonding.

• Higher pain scores were recorded for the mandibular anterior teeth than for the maxillary teeth.

Patients displayed good acceptance and satisfaction with TENS therapy for pain control during the debonding of fixed appliances.

Ethics

Ethics Committee Approval: This study was approved by the I.T.S. Institutional Ethics Committee with protocol number: ITSCDSR/IIEC/RP/2019/014 and date: 22.11.2019.

Informed Consent: All patients meeting the inclusion criteria were given oral and written information by the operator and consented to participate in the study.

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

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REFERENCES

1. Almuzian M, Rizk MZ, Ulhaq A, Alharbi F, Alomari S, Mohammed H. Effectiveness of different debonding techniques and adjunctive methods on pain and discomfort perception during debonding fixed orthodontic appliances: a systematic review. *Eur J Orthod.* 2019;41(5):486-494. [CrossRef]
2. Roth PM, Thrash WJ. Effect of transcutaneous electrical nerve stimulation for controlling pain associated with orthodontic tooth movement. *Am J Orthod Dentofacial Orthop.* 1986;90(2):132-138. [CrossRef]
3. Black RR. Use of transcutaneous electrical nerve stimulation in dentistry. *J Am Dent Assoc.* 1986;113(4):649-652. [CrossRef]
4. Kasat V, Gupta A, Ladda R, Kathariya M, Saluja H, Farooqui AA. Transcutaneous electric nerve stimulation (TENS) in dentistry- A review. *J Clin Exp Dent*. 2014;6(4):e562-e568. [CrossRef]
5. Banerjee G, Johnson M. Transcutaneous electrical nerve stimulation (TENS): A potential intervention for pain management in India? *Indian J Pain.* 2013;27(3):132-141. [CrossRef]
6. Kilinç DD, Sayar G. Evaluation of pain perception during orthodontic debonding of metallic brackets with four different techniques. *J Appl Oral Sci.* 2019;27:e20180003. [CrossRef]
7. Haralambidis C. Pain-Free Orthodontic Treatment with the Dental Pain Eraser. *J Clin Orthod.* 2019;53(4):234-242. [CrossRef]
8. Pithon MM, Santos Fonseca Figueiredo D, Oliveira DD, Coqueiro Rda S. What is the best method for debonding metallic brackets from the patient's perspective? *Prog Orthod.* 2015;16:17. [CrossRef]
9. Nóbrega C, da Silva EM, de Macedo CR. Low-level laser therapy for treatment of pain associated with orthodontic elastomeric separator placement: a placebo-controlled randomized double-blind clinical trial. *Photomed Laser Surg.* 2013;31(1):10-16. [CrossRef]
10. Fleming PS, Strydom H, Katsaros C, et al. Non-pharmacological interventions for alleviating pain during orthodontic treatment. *Cochrane Database Syst Rev*. 2016;12:CD010263. [CrossRef]
11. Christensen LV, Radue JT. Lateral preference in mastication: relation to pain. *J Oral Rehabil.* 1985;12:461-467. [CrossRef]
12. Clark MS, Silverstone LM, Lindenmuth J, Hicks MJ, Averbach RE, Kleier DJ, Stoller NH. An evaluation of the clinical analgesia/anesthesia efficacy on acute pain using the high frequency neural modulator in various dental settings. *Oral Surg Oral Med Oral Pathol.* 1987;63:501-505. [CrossRef]
13. Hochman R. Neurotransmitter modulator (TENS) for control of dental operative pain. *J Am Dent Assoc.* 1988;116:208-212. [CrossRef]
14. Malamed SF, Quinn CL, Torgersen RT, Thompson W. Electronic dental anesthesia for restorative dentistry. *Anesth Prog.* 1989;36:195-198. [CrossRef]
15. Williams OL, Bishara SE. Patient discomfort levels at the time of debonding: a pilot study. *Am J Orthod Dentofacial Orthop.* 1992;101(4):313-317. [CrossRef]

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Original Article

Accuracy of Dental Calcification Stages in Predicting the Peak Pubertal Stage of Females

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Main Points

- All four study teeth had high accuracy in predicting peak pubertal stage.
- The coinciding chance of peak pubertal stage with stage H in all studied teeth and with stage G in the second premolars and second molars was higher than in other stages.
- Stage G of the second molar is the best predictor of peak pubertal stage.

ABSTRACT

Objective: This study aimed to evaluate the accuracy of dental calcification stages in predicting the peak pubertal stage.

Methods: This retrospective study was conducted on panoramic and lateral cephalometric images of 406 female patients aged 9-14 years. The skeletal maturity and calcification stages of the mandibular canines, first premolars, second premolars, and second molars were determined using the Hassel-Farman and Demirjian (DI) methods, respectively. The prediction accuracy of the peak pubertal stage with the studied teeth was assessed using a receiver operating characteristic curve and the area under the curve (AUC). The DI stage of H was designated as the reference level, and Bayesian logistic regression analysis was used to assess the coinciding chance of each DI stage and peak pubertal stage.

Results: The AUC range of studied teeth was 0.84-0.92 in predicting peak pubertal stage (all $p<0.001$). In the canines and first premolars, the coinciding chance of peak pubertal stage and stage H was significantly higher than that in other stages [$p<0.05$, odds ratio (OR) ≤ 0.14]. In the second premolars and second molars, the chance of peak pubertal stage coinciding with stages H and G did not significantly differ ($p>0.05$); however, the chance of stage G coinciding with peak pubertal stage in the second molars was higher than in stage H (OR=4.59).

Conclusion: Stage H in all studied teeth and stage G in the second premolars and second molars predict peak pubertal stage with high accuracy. Considering that stage H is the end of tooth calcification stages and the accuracy of predicting stage G of second molar teeth is higher than the above stage, estimating the peak pubertal stage is recommended by the second case.

Keywords: Calcification, cervical vertebrae, puberty, tooth

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INTRODUCTION

Developmental scheduling plays a vital role in orthopedic treatment outcomes for musculoskeletal disorders in developing patients.[1,2] The highest response to jaw functional appliances depends on their performance during the peak pubertal stage (PPS).[3,4] Chronological age is not a valid measure of growth, and biological age is more reliable. Bone maturity indices of the wrist and cervical vertebrae on radiographs are common methods for biological age definition.[5-7] The stages of dental development are considered a potential method to estimate skeletal age and can be examined from two aspects. The first is the eruption phases of the tooth, for which studies have shown a weak correlation between the eruption phases and skeletal maturation. The second is the dental calcification stage, which is a more reliable parameter. With a simple and reliable method based on the dental developmental stages, the routine use of panoramic and periapical radiography in most dental clinics can justify the evaluation of skeletal maturity without the need for additional radiographs, thus decreasing patient exposure according to the principle of as low as reasonably achievable principle.[2,5,8]

Most studies have shown a high correlation between the stages of tooth calcification and indicators of skeletal maturity.[1-3,5,6,8,9] However, some studies have shown a poor correlation.[10,11] To determine a reliable method instead of skeletal maturity, further studies with statistically more accurate methods than Pearson and Spearman's correlation coefficients are necessary. On the other hand, some studies have examined the relationship between the stages of dental calcification and PPS separately.[12] Therefore, despite evidence of a strong relationship between dental calcification and skeletal maturation, a practical recommendation based on dental calcification stages for PPS prediction is not possible.[12] This study aimed to assess the accuracy of dental calcification stages for predicting the peak pubertal growth stage compared with cervical vertebral maturation in females.

METHODS

This retrospective study involved panoramic and lateral cephalometric images of 406 female patients aged 9-14. According to the statistical power analysis, 5% of type one error, and Spearman's rank correlation tests, the sample size of the study (n=406) obtained 80% of the statistical power. The study protocol was approved by the Ethics Committee of Urmia University of Medical Sciences under the code IR.UMSU.REC.1397.420 and date 30.01.2019.

All panoramic and lateral cephalometric images were collected from the archives of orthodontic treatment centers. The inclusion criteria consisted of a) simultaneous preparation of both images (i.e., panoramic and lateral cephalograms), b) proper image quality, and c) the presence of all studied teeth. The exclusion criteria included a) radiographs of patients with a history of hormonal, developmental, and nutritional diseases, b) radiographs of patients with a history of trauma to the jaw and face, c) root canal treatment of the studied teeth, d) shape and size anomalies of the studied teeth, and d) history of orthodontic treatment. The images were saved in the Digital Imaging and Communications in Medicine format. All observations were performed using Romexis software (version 3.8.2) on a 14-inch LCD monitor (ASUS, China) with a resolution of 768 × 1366.

The calcification stages of the mandibular canines, first premolars, second premolars, and second molars were obtained by the Demirjian (DI) method on panoramic images (Figure 1).[13] In this method, there are eight stages of dental development:

- A: In single-rooted or multi-rooted teeth, the onset of calcification at the top of the crypt is observed as one or more inverted cones with no connections between them.
- B: By connecting the calcified areas, one or more cusps are formed, determining the morphology of the crown.
- C: Enamel formation is completed at the occlusal surface and extends to the cementoenamel junction (CEJ), the pulp chamber is formed, and dentin deposition begins.
- D: Crown formation is complete until CEJ, the pulp chamber becomes trapezoidal, and the roots begin to form.
- E: The formation of root divisions begins; nevertheless, the root is still shorter than the crown.
- F: The end of the root is funnel-shaped, and the length of the root is equal to or greater than that of the crown.
- G: The root canal walls are parallel, and the apex is open.
- H: The apex is completely closed, and the periodontal ligament has the same width around the apex and root.

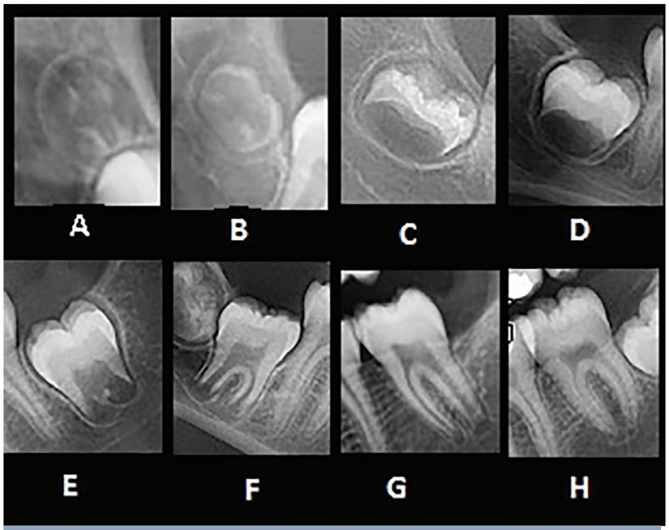

Figure 1. Demirjian (DI) tooth calcification stages: A, to H

The cervical vertebral maturation index (CVMI) for each patient was obtained by examining the morphology of the bodies of C2, C3, and C4 vertebrae on lateral cephalograms using the Hassel-Farman method[7] with no knowledge of the results of the dental calcification stage and without observing their panoramic images. (Figure 2). In this method, according to the presence or absence of concavity in the lower borders of the C2, C3, and C4 vertebrae and the difference in the shape of the body of the vertebrae, there are six stages:

- CVMI 1 (Initiation): The lower borders of C2, C3, and C4 are flat. The body shapes of C3 and C4 are trapezoidal, and their upper border converges from posterior to anterior.

- CVMI 2 (Acceleration): Concavity forms in the lower borders of C2 and C3, and the lower border of C4 remains flat. The shapes of the bodies of C3 and C4 are almost rectangular.

- CVMI 3 (Transition): A clear concavity is observed in the lower borders of C2 and C3, and a concavity is formed in the lower border of C4. The shapes of the C3 and C4 bodies are rectangular.

- CVMI 4 (Deceleration): A clear concavity is observed in the lower borders of C2, C3, and C4. C3 and C4 are close to square in shape.

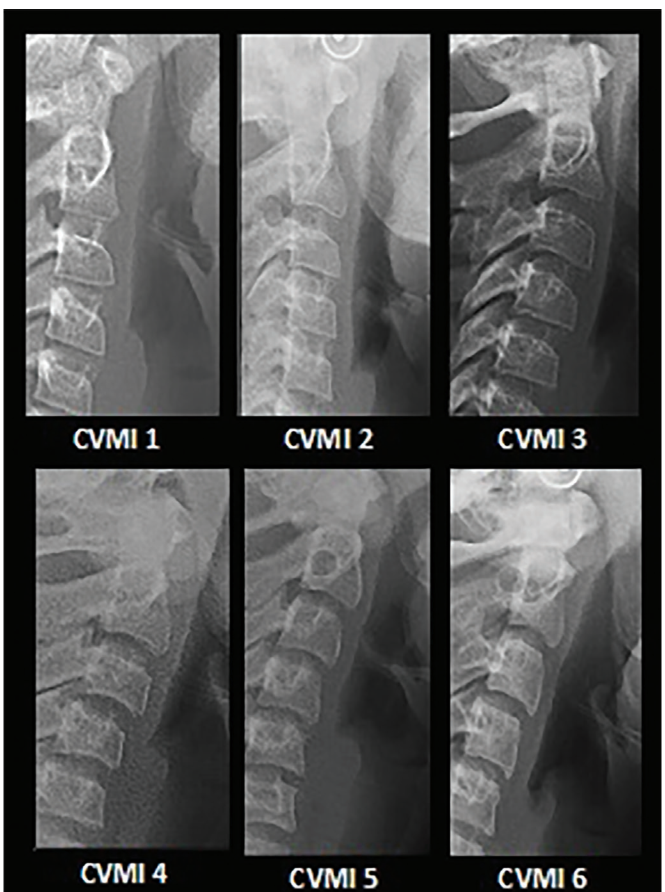

Figure 2. Cervical vertebral developmental stages, CVMI 1 to CVMI 6, proposed by Hassel-Farman
CVMI, cervical vertebral maturation index.

- CVMI 5 (Maturation): A clearer concavity is observed in the lower borders of C2, C3, and C4. The bodies of C3 and C4 are square.

- CVMI 6 (Completion): Deep concavity is observed in the lower borders of the C2, C3, and C4 vertebrae. The C3 and C4 bodies are vertical rectangles.

All observations were performed by an oral and maxillofacial radiologist with 14 years of experience. To ensure the reliability of the results and methods, 10% of the samples were examined 2 weeks later by the main observer (intra-observer) and an experienced orthodontist (inter-observer). ICC (CI 95%) in determining all stages of DI and CVMI was found as ≥0.942.

Statistical Analysis

Statistical analysis of data was performed using R software (version 3.6.3, Lucent Technologies, New Jersey, USA) and the "arm" package. Spearman's correlation coefficient was used to evaluate the correlation between DI stages and CVMI. The pre-pubertal stage was defined as the reference level. The coinciding chance of the PPS and DI stages was assessed using Bayesian logistic regression. For a more complete explanation, the science of statistics is generally divided into two concepts: classical and Bayesian. Most statistical methods in the classical concept require a large sample size and inference asymptotically. In contrast, methods based on the Bayesian concept are more efficient in small sample sizes. The Bayesian logistic regression method with a weak informative prior was used in this study to increase the robustness of the results. Multiple collinearity is a problematic case in statistical modeling, which is caused by the correlation of predictor variables. Performing multiple Bayesian logistic regression with the presence of correlated covariates leads to invalid results. In this study, univariate Bayesian models were used to avoid multiple collinearity problems. The DI stage of H was designated as the reference level because of the higher prevalence of the data. The first type error of 0.05 was considered to be a significance level. The prediction accuracy of the PPS for each tooth was evaluated in two steps. In the first step, PPS attainment probabilities were predicted. In the second step, the probability values were analyzed using the area under the curve (AUC).

RESULTS

The calcification stages of the canines were distributed in four stages from E to H, the first and second premolars in five stages from D to H, and the second molars in six stages from C to H (Table 1). Highest frequency of the DI stages in the CVMI 3 and 4 (i.e, PPS) was related to stage H of the canines, with the frequency of (75.3%) and (95.5%), respectively (Table 2). There was only one case of CVMI 6, and all four teeth were in stage H; therefore, these data were not included in Table 2.

The results of the Spearman test showed a good correlation between the DI stages of the studied teeth and CVMI.

Table 1. Distribution of stages of dental calcification with the Demirjian method

Stage	Number (%)			
	Canine	First premolar	Second premolar	Second molar
C	0 (0)	0 (0)	0 (0)	1 (0.2)
D	0 (0)	1 (0.2)	14 (3.4)	13 (3.2)
E	4 (1)	30 (7.4)	42 (10.3)	66 (16.3)
F	54 (13.3)	93 (22.9)	144 (35.5)	112 (27.6)
G	98 (24.1)	101 (24.9)	127 (31.3)	188 (46.3)
H	250 (61.6)	181 (44.6)	79 (19.5)	26 (6.4)
Total	406 (100)	406 (100)	406 (100)	406 (100)

Table 2. Distribution of DI stages of studied teeth with regard to CVMI stages, No. (%)

							CVMI, Number (%)
	CVMI 1 (Pre-pubertal)						CVMI 1
DI stage	C	D	E	F	G	H	
Canine	0 (0.0)	0 (0.0)	4 (5.9)	35 (51.5)	22 (32.4)	7 (10.3)	68 (16.7)
First premolar	0 (0.0)	1 (1.5)	27 (39.7)	34 (50.0)	6 (8.8)	0 (0.0)	
Second premolar	0 (0.0)	13 (19.1)	26 (38.2)	28 (41.2)	1 (1.5)	0 (0.0)	
Second molar	1 (1.5)	12 (17.6)	39 (57.4)*	16 (23.5)	0 (0.0)	0 (0.0)	
	CVMI 2 (Pre-pubertal)						CVMI 2
Canine	0 (0.0)	0 (0.0)	0 (0.0)	16 (18.2)	53 (60.2)	19 (21.6)	88 (21.7)
First premolar	0 (0.0)	0 (0.0)	3 (3.4)	47 (53.4)	29 (33.0)	9 (10.2)	
Second premolar	0 (0.0)	1 (1.1)	11 (12.5)	58 (65.9)*	16 (18.2)	2 (2.3)	
Second molar	0 (0.0)	1 (1.1)	25 (28.4)	54 (61.4)	8 (9.1)	0 (0.0)	
	CVMI 3 (Peak pubertal)						CVMI 3
Canine	0 (0.0)	0 (0.0)	0 (0.0)	2 (2.5)	18 (22.2)	61 (75.3)*	81 (19.9)
First premolar	0 (0.0)	0 (0.0)	0 (0.0)	8 (9.9)	43 (53.1)	30 (37.0)	
Second premolar	0 (0.0)	0 (0.0)	2 (2.5)	33 (40.7)	37 (45.7)	9 (11.1)	
Second molar	0 (0.0)	0 (0.0)	2 (2.5)	34 (42.0)	45 (55.6)	(0)	
	CVMI 4 (Peak pubertal)						CVMI 4
Canine	0 (0.0)	0 (0.0)	0 (0)	1 (0.8)	5 (3.8)	127 (95.5)*	133 (32.6)
First premolar	0 (0.0)	0 (0.0)	0 (0)	4 (3.0)	23 (17.3)	106 (79.7)	
Second premolar	0 (0.0)	0 (0.0)	3 (2.3)	23 (17.3)	68 (51.1)	39 (29.3)	
Second molar	0 (0.0)	0 (0.0)	0 (0.0)	8 (6.0)	120 (90.2)	5 (3.8)	
	CVMI 5 (Post-pubertal)						CVMI 5
Canine	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)	35 (100)*	35 (8.5)
First premolar	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)	35 (100)*	
Second premolar	0 (0.0)	0 (0.0)	0 (0.0)	2 (5.7)	5 (14.3)	28 (80)	
Second molar	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)	15 (42.9)	20 (57.1)	

*Represents the highest frequency of DI stages in each CVMI stage.
DI, Demirjian index; CVMI, cervical vertebral maturation index; No. (%), number (percent)

Table 3. Spearman correlation between CVMI stages and calcification stages of studied teeth

	Number (%)			
	Canine	First premolar	Second premolar	Second molar
Spearman correlation	0.732	0.793	0.716	0.847
p value	<0.001	<0.001	<0.001	<0.001

P value of 0.05 was considered to be a significance level
CVMI, cervical vertebral maturation index.

The highest correlation was related to the second molar (Table 3). Due to the high correlation between the DI stages of the studied teeth, leading to multicollinearity, multiple Bayesian logistic regression analysis results were not valid, and univariate analysis presented more acceptable and applicable results. The results of the univariate analysis (when each tooth was analyzed independently of the other teeth) are presented in Table 4.

In the canines and the first premolars, the coinciding chance of PPS and stage H was significantly higher than that in other stages [p<0.001, odds ratio (OR)≤0.14]. In the second premolars (p=0.14) and the second molars (p=0.09), there was no significant difference between stage G and stage H; however, the coinciding chance of the PPS and stage G of the second molars was insignificantly higher than stage H (OR=4.59) (Table 4).

According to the results of the receiver operating characteristic (ROC) analysis in Table 4 and the AUC in Figure 3, all four teeth had high accuracy in predicting PPS (AUC≥0.84, p<0.001). The highest prediction accuracy was related to the second molars (AUC=0.92, p<0.001).

DISCUSSION

In orthodontic patients, determining the skeletal maturity stage is of utmost importance before initiating developmental treatment. The common method used in this case is to examine the changes in the cervical vertebrae on lateral cephalograms. As panoramic radiography is a standard record before orthodontic treatment, it might reduce the need for additional radiographs if it is possible to determine the stage of skeletal maturation using panoramic views. This approach not only minimizes the patient's exposure to radiation but also reduces costs. The calcification stages of teeth, which can be examined through panoramic radiography, have shown a significant relationship with skeletal maturity indices in various studies.[1-3,5,6,8,9] Due to superimpositions in the maxillary area of panoramic radiographs, this study focused on examining mandibular canines, first premolars, second premolars, and second molars. DI was used to evaluate tooth calcification stages. According to Björk and Helm's[11] study, DI has the lowest inter-examiner and intra-examiner errors and exhibits the highest correlation with biological age. In orthodontic growth modification therapies, knowledge of the timing of the growth spurt is essential. The PPS occurs in CVMI 3 and 4, according to Baccetti et al.'s[4] study.[4]

One of the influential factors in the occurrence of growth mutations is gender.[13] According to studies, The PPS tends to start earlier in females, and the duration of puberty is generally shorter compared to males. Consequently, the timing of PPS holds greater clinical significance. In the present study, 74.3% of patients were in CVMI stages 2, 3, and 4, which are considered the most clinically important stages. This distribution indicates that the age range of 9-14

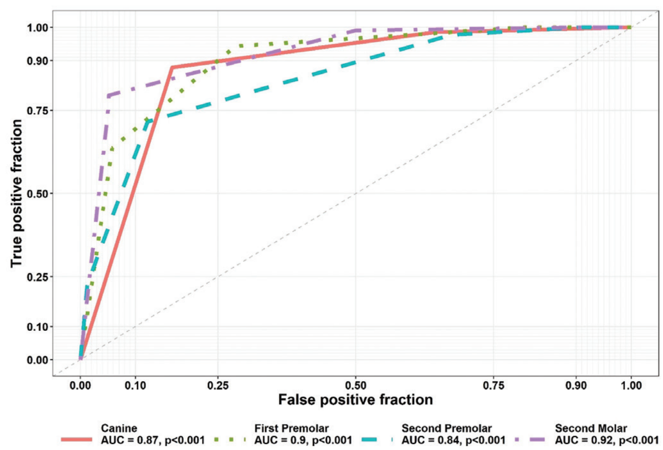

Figure 3. The surface area under the ROC curve for prediction of pubertal stage separately for each tooth
AUC, area under the curve; ROC, receiver operating characteristic.

Table 4. Bayesian logistic regression between DI stages and PPS

Tooth*		Univariate analysis			
		OR (95% CI)	p value	AUC	p value
Canine	F	0.009 (0.003,0.031)	<0.001	0.87	<0.001
	G	0.045 (0.025,0.084)	<0.001		
First premolar	F	0.012 (0.005,0.028)	<0.001	0.9	<0.001
	G	0.147 (0.07,0.311)	<0.001		
Second premolar	E	0.01 (0.003,0.039)	<0.001	0.84	<0.001
	F	0.045 (0.015,0.138)	<0.001		
	G	0.432 (0.137,1.358)	0.148		
Second molar	E	0.008 (0.001,0.068)	<0.001	0.92	<0.001
	F	0.141 (0.025,0.782)	0.026		
	G	4.599 (0.787,27.136)	0.093		

*The "H" stage was set as a reference category, stages without data were not entered in the table
P value of 0.05 was considered to be a significance level.
AUC, area under the curve; OR, odds ratio; CI, confidence interval; DI, Demirjian index; PPS, peak pubertal stage.

years was appropriately selected for the study. The accuracy of the studied teeth in predicting PPS was high (AUCs≥0.84, all p<0.001), and the second molars exhibited the highest accuracy. While there was no statistically significant difference between stages H and G in the second premolar and second molar (p>0.05); the chance of stage G coinciding with PPS in the second molar was higher than that of stage H (OR>1). As a result, stage H of the studied teeth and stage G of the second premolars and second molars were found to coincide with PPS with high accuracy.

Spearman's correlation coefficient was more than 0.7 for the studied teeth; with the highest coefficient being 0.847, observed in the second molar. Various studies have employed Spearman's correlation coefficient to establish the relationship between DI stages, skeletal maturity,[2,3] and PPS.[14-18] The results of these studies indicate a robust association between DI stages and skeletal maturation, aligning with the findings of this study. However, it's important to note that high Pearson and Spearman's correlation coefficients only indicate a strong relationship between the two variables and do not imply that the values obtained by both methods are identical. Therefore, studies such as Valizadeh et al.'s[8], Lopes et al.'s[1], and Rebouças et al.[19] utilized ordinal logistic regression models as a more accurate statistical method to designate the DI stages as indicators of pubertal stage. Nevertheless, due to the frequent occurrence of zero values in the early DI stages, the use of their data is prone to sparsity bias[20] leading to higher OR values than reality. On the other hand, the PPS stage cannot be evaluated separately, or it is impossible to analyze the relationship between individual DI stages and PPS with this analysis. Consequently, all three studies resorted to using the data frequency distribution to investigate this relationship.

Perinetti et al.[21] and Toodehzaeim et al.[22] investigated the diagnostic ability of the DI stages of the mandibular second molar to identify the pre-pubertal, pubertal, and post-pubertal stages using positive likelihood ratio (PLR) analysis with a threshold of ≥10 for satisfactory performance. Despite the high correlation coefficient between DI stage and skeletal maturity, they found DI stages reliable only for identifying the post-pubertal stage. In general, regression analysis is a stronger statistical method than PLR because of the PLR results' dependency on sample size. The PLR (sensitivity/1-specificity) requires a 2 × 2 table; the CVMI is considered the gold standard; each DI stage is considered the exposed cases, and the other stages are considered the unexposed cases.

Due to the sequence of calcification stages, the obtained PLR will not show the actual value. Nevertheless, the present study analyzed the data with the PLR analysis to compare with the above-mentioned study; the PLR of the DI stages in determining the pubertal stage was calculated with a confidence interval of 95%. Because stage H was the most frequent, stage H was considered the reference level (PLR=1), and PLR≥10 was considered clinically significant. 1<PLR<10 means that stage H predicts the stage of puberty better than the desired DI stage, however, the difference between stage H and the DI stage was not clinically significant. The results showed that, stage H in second premolars and second molars predicts PPS significantly better than stages E [$PLR_{\text{second premolar}}$ (CI 95%) =20.53 (5.14, 82.05); $PLR_{\text{second molar}}$ (CI 95%) = 46.20 (6.33, 336.94)] and F [$PLR_{\text{second premolar}}$ (CI 95%) = 20.53 (5.14, 82.05); $PLR_{\text{second molar}}$ (CI 95%) =10.08 (1.28, 79.40)]. Stage G in the second molars [PLR (CI 95%)=0.40 (0.05, 2.98)] predicts PPS non-significantly better than stage H. The difference between these results and results of Perinetti et al.'s[21] and Toodehzaeim et al.'s[22] studies could be attributed to the sample size.According to Spearman's correlation coefficients, univariate Bayesian logistic regression analysis, and ROC and PLR analyses, the second molar G stage has the highest chance of coincidence with PPS.

CONCLUSION

The H stage of the studied teeth estimates the peak pubertal stage with high accuracy; however, considering the end stage of the H stage and the higher prediction accuracy of the G stage of the second molar teeth, PPS estimation is more practical in the latter case.

Ethics

Ethics Committee Approval: The study protocol was approved by the Ethics Committee of Urmia University of Medical Sciences under the code IR.UMSU.REC.1397.420 and date 30.01.2019.

Informed Consent: Retrospective study.

Author Contributions: Concept - M.M.; Design - E.M.; Supervision - M.M.; Data Collection and/or Processing - S.S.; Analysis and/or Interpretation - A.A.; Literature Review - M.H.R.; Writing - R.B.; Critical Review - R.B.

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

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REFERENCES

1. Lopes LJ, de Oliveira Gamba T, Visconti MA, Ambrosano GM, Haiter-Neto F, Freitas DQ. Utility of panoramic radiography for identification of the pubertal growth period. *Am J Orthod Dentofacial Orthop. 2016*;149(4):509-515. [CrossRef]
2. Džemidžić V, Tiro A, Zukanović A, Redžić I, Nakaš E. Skeletal maturity assessment using mandibular canine calcification stages. *Acta Med Acad.* 2016;45(2):128-134. [CrossRef]
3. Srkoc T, Mestrović S, Anić-Milosević S, Slaj M. Association between dental and skeletal maturation stages in croatian subjects. *Acta Clin Croat.* 2015;54(4):445-452. [CrossRef]
4. Baccetti T, Franchi L, McNamara Jr JA. The cervical vertebral maturation (CVM) method for the assessment of optimal treatment timing in dentofacial orthopedics. *Semin Orthod.* 2005;11(3):119-129. [CrossRef]
5. Yadav V, Loomba A, Autar R. A comparative evaluation of dental

calcification stages and skeletal maturity indicators in North-Indian children. *Natl J Maxillofac Surg.* 2017;8(1):26-33. [CrossRef]

6. Giri J, Shrestha BK, Yadav R, Ghimire TR. Assessment of skeletal maturation with permanent mandibular second molar calcification stages among a group of Nepalese orthodontic patients. *Clin Cosmet Investig Dent.* 2016;8:57-62. [CrossRef]
7. Hassel B, Farman AG. Skeletal maturation evaluation using cervical vertebrae. *Am J Orthod Dentofacial Orthop.* 1995;107(1):58-66. Erratum in: *Am J Orthod Dentofacial Orthop.* 1995;107(6):19. [CrossRef]
8. Valizadeh S, Eil N, Ehsani S, Bakhshandeh H. Correlation between dental and cervical vertebral maturation in Iranian females. *Iran J Radiol.* 2012;10(1):1-7. [CrossRef]
9. Bagherpour A, Pousti M, Adelianfar E. Hand skeletal maturity and its correlation with mandibular dental development. *J Clin Exp Dent.* 2014;6(3):e275-e279. [CrossRef]
10. Goyal S, Goyal S, Gugnani N. Assessment of skeletal maturity using the permanent mandibular canine calcification stages. *J Orthod Res.* 2014;2:(1):11-16. [CrossRef]
11. Björk A, Helm S. Prediction of the age of maximum puberal growth in body height. *Angle Orthod.* 1967;37(2):134-143. [CrossRef]
12. Bittencourt MV, Cericato G, Franco A, Girão R, Lima APB, Paranhos L. Accuracy of dental development for estimating the pubertal growth spurt in comparison to skeletal development: a systematic review and meta-analysis. *Dentomaxillofac Radiol.* 2018;47(4):20170362. [CrossRef]
13. Demirjian A, Goldstein H, Tanner JM. A new system of dental age assessment. *Hum Biol.* 1973;45(2):211-227. [CrossRef]
14. Fishman LS. Chronological versus skeletal age, an evaluation of craniofacial growth. *Angle Orthod.* 1979;49(3):181-189. [CrossRef]
15. Mauricio-Vilchez C, Mauricio F, Vilchez L, Cadenillas A, Medina J, Mayta-Tovalino F. Radiographic Correlation of Skeletal Maturation Using the Stages of Dental Calcification in a Peruvian Population. *Scientifica (Cairo).* 2020;2020:4052619. [CrossRef]
16. Kumar S, Roy AS, Garg A, Hamid SB, Tyagi S, Kumar A. Correlation between Maxillary Canine Calcification and Skeletal Maturation. *J Clin Diagn Res.* 2017;11(5):ZC13-ZC16. [CrossRef]
17. Kumar S, Singla A, Sharma R, Virdi MS, Anupam A, Mittal B. Skeletal maturation evaluation using mandibular second molar calcification stages. *Angle Orthod. 2012*;82(3):501-506. [CrossRef]
18. Ojha A, Prasanth MA, Singh V, Sihag T, Bhati V, Tomar H. Assessment of correlation between dental calcification stages and skeletal maturity indicators. *J Forensic Dent Sci.* 2018;10(3):132-136. [CrossRef]
19. Rebouças PRM, Alencar CRB, Arruda MJALLA, Lacerda RHW, Melo DP, Bernardino ÍM, et al. Identification of dental calcification stages as a predictor of skeletal development phase. *Dental Press J Orthod.* 2021;26(4):e2119292. [CrossRef]
20. Greenland S, Mansournia MA, Altman DG. Sparse data bias: a problem hiding in plain sight. *BMJ.* 2016;352:i1981. [CrossRef]
21. Perinetti G, Contardo L, Gabrieli P, Baccetti T, Di Lenarda R. Diagnostic performance of dental maturity for identification of skeletal maturation phase. *Eur J Orthod.* 2012;34(4):487-492. [CrossRef]
22. Toodehzaeim MH, Rafiei E, Hosseini SH, Haerian A, Hazeri-Baqdad-Abad M. Association between mandibular second molars calcification stages in the panoramic images and cervical vertebral maturity in the lateral cephalometric images. *J Clin Exp Dent.* 2020;12(2):e148-e153. [CrossRef]

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Systematic Review

Effect of Lithium on Orthodontic Tooth Movement: a Systematic Review of Animal Studies

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Main Points

- Lithium can decrease the rate of orthodontic tooth movement.
- Lithium may increase bone density and volume and reduce root resorption.
- Lithium enhances alveolar bone formation during orthodontic retention phase.

ABSTRACT

Objective: This study aimed to systematically review the effect of lithium on orthodontic tooth movement (OTM).

Methods: The focus question was "does lithium have an effect on OTM?" A systematic search was conducted using indexed databases and the Preferred Reporting Items for Systematic Reviews and Meta-Analyses guidelines were followed. The quality assessment of the selected studies was performed according to the systematic review center for laboratory animal experimentation.

Results: Five of the initially identified 656 articles fulfilled the eligibility criteria and were selected for this review. The studies reported that lithium administration lowered the rate of OTM by inducing a reduction in the number of osteoclasts and possibly inhibiting osteoclastogenesis. These studies further showed an increase in bone density and bone volume by promoting the Wnt/ß-catenin signaling pathway and osteoblastogenesis. It was also noted that lithium reduced orthodontically induced root resorption during experimental OTM. Further, standardized studies are warranted to understand the impact of lithium in OTM. Overall, the risk of bias for 3 studies was very high, high in 1 study, and moderate in 1 study.

Conclusion: On an experimental level in animals, lithium decreased the rate of OTM during the active treatment phase by increasing bone density and bone volume and reducing root resorption. In addition, lithium may enhance alveolar bone formation during orthodontic retention. Clinically, this may impact the orthodontic treatment duration in patients receiving lithium, and further studies are needed to understand the true impact of lithium on OTM.

Keywords: Lithium, orthodontic tooth movement, systematic review

INTRODUCTION

Orthodontic tooth movement (OTM) is a complex process involving the application of mechanical force followed by a biological response as well as genetic and environmental interactions. OTM encompasses the dynamic process of alveolar bone remodeling in response to controlled orthodontic forces through bone deposition and bone resorption on the tension and pressure sides, respectively. The tooth displacement following OTM varies according to the magnitude, frequency, and duration of the applied force and the biological response of the

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periodontal ligament and bone.[1,2] The carefully orchestrated biological responses, such as osteoblastogenesis and osteoclastogenesis, in response to controlled orthodontic forces may also be affected by a plethora of genetic, environmental, local, and systemic factors, including medications.[3,4]

The majority of mental illnesses are diagnosed in adolescences, young adults or adults <50 years.[5] The symptoms of several disorders may fluctuate over time, and management may be lifelong.[5] Bipolar disorders (BDs) are one of the most common mental illnesses affecting adolescents and adults. According to the World Health Organization, approximately 40 million people globally suffer from BD. The prevalence in Turkey was 0.84% during 2006-2019. However, the population has also increased from 69 million to approximately 83 million in the same period as that reported by the World Bank. Lithium is one of the oldest and first-line medications used for the management of BD and is often considered a gold standard in the management of BD. Lithium salts have been used since the early 19th century for the management of manic episodes of BD.[6,7] Lithium salts have also been used in the management of a variety of psychiatric conditions, including obsessive compulsive disorders, hyperactivity disorders in adolescents, attention deficit disorders in children, and unipolar depression in adults. Lithium salts are occasionally used in the management of refractory cases of schizophrenia, certain impulse control disorders, and prophylaxis of certain trigeminal autonomic cephalalgias.[6,8-12] Vestergaard et al.[13] reported that the risk of fracture in Colles and spines among children were lower following lithium consumption. Studies have shown that lithium can increase bone density and bone volume by promoting the Wnt/ß-catenin signaling pathway in mice. The Wnt/ß-catenin signaling pathway not only promotes the production of osteoblasts and osteoblastogenesis but also inhibits the production of osteoclasts and osteoclastogenesis processes, effectively reducing bone resorption.[14] Studies dwelling into the role of lithium in OTM have varied results. Some studies have suggested that lithium may reduce orthodontically induced root resorption[3,15] while others reported it may promote alveolar bone formation.[16] Chronic use of lithium has also been suggested to lower rate of tooth movement.[17,18] Hashimoto et al.[14] reported a negative correlation between bone morphometric measurements and OTM, particularly trabecular bone structure in rats that had undergone ovariectomy procedures.

Because lithium is administered on a long-term basis and significant portion of the population opts for orthodontic treatment in various age groups, the aim of the present systematic review was to assess the influence of lithium on OTM. Due to a lack of clinical studies, pre-clinical animal studies were evaluated with the anticipation of future translation studies.

METHODS

This systematic review was conducted in accordance with the guidelines of the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA).[19]

A meta-analysis was not performed because of the high heterogeneity of the included studies.

Questions

The addressed focused question was "does lithium affect orthodontic tooth movement?"

Patients, Interventions, Control, Outcome (PICO)

Population (P): subjects who underwent orthodontic treatment; Interventions (I): effect of lithium therapy on OTM; Control (C): orthodontic treatment without adjunct lithium administration; and Outcome (O): tooth movement.

Study Eligibility

The eligibility criteria were based on PICO, and controlled studies involving animals and human subjects undergoing active OTM were reviewed. Non-comparative studies (letters to the editor, commentaries, historic reviews, case reports and case series), systematic reviews, and meta-analyses were excluded from this review.

Search Protocol and Study Selection

An electronic search was performed based on the "Preferred Reporting Items for Systematic Review and Meta-Analysis" (PRISMA) guidelines by two authors (AW and KK). A search without time or language restrictions was conducted up to June 2021 in PubMed (National Library of Medicine), Cochrane Library, EMBASE, MEDLINE (OVID), Scopus, Google Scholar, and Web of Science databases. The search was performed using a combination of the following MeSH terms with Boolean operators (AND, OR): 1) orthodontic therapy; 2) orthodontic treatment; 3) OTM; 4) tooth movement techniques; 5) orthodontics; 6) orthodontic brackets; 7) orthodontic appliances; 8) lithium; 9) lithium salts. Two authors (AW and KK) electronically assessed the retrieved records for eligibility independently. The authors were not blinded to the identity of the authors, their institution, or the results of the research. Subsequently, the full report of records considered by each reviewer to meet the eligibility criteria was obtained and assessed a second time independently, with any disagreements resolved by consultation with the sixth author (JK) (Table 1).

Risk of Bias (ROB) Assessment

The systematic review center for laboratory animal experimentation[20] was used to assess ROB in the included studies by author ST. A total of nine questions were used to assess ROB, and based on the results, the overall ROB was evaluated as low, moderate, high, and very high. The following questions were addressed: 1) sequence generation, 2) baseline characteristics, 3) allocation concealment, 4) random housing,

Table 1. Search criteria

	Keywords	MeSH
Lithium	Lithium, Lithium Salts, Lithium compounds, Lithium Chloride, Lithium Carbonate, Lithium acetate, Lithium Sulfate, Lithium Citrate, Lithium Orotate, Lithium Gluconate, Lithium bromide, Lithium Chloride, Lithium iodide, Lithium Fluoride	Lithium (MeSH Term)
Orthodontic tooth movement	Orthodontic, orthodontics, Orthodontic tooth movement, tooth movement, tooth movement technique, orthodontic appliances	Tooth movement technique (MeSH Term)
(("lithium"[MeSH Terms] OR "lithium"[All Fields]) OR (("lithium"[MeSH Terms] OR "lithium"[All Fields]) AND ("sodium chloride"[MeSH Terms] OR ("sodium"[All Fields] AND "chloride"[All Fields]) OR "sodium chloride"[All Fields] OR "salt"[All Fields])) OR ("lithium compounds"[MeSH Terms] OR ("lithium"[All Fields] AND "compounds"[All Fields]) OR "lithium compounds"[All Fields] OR ("lithium"[All Fields] AND "compound"[All Fields]) OR "lithium compound"[All Fields])) AND (("tooth movement techniques"[MeSH Terms] OR ("tooth"[All Fields] AND "movement"[All Fields] AND "techniques"[All Fields]) OR "tooth movement techniques"[All Fields] OR ("orthodontic"[All Fields] AND "tooth"[All Fields] AND "movement"[All Fields]) OR "orthodontic tooth movement"[All Fields]) OR ("tooth movement techniques"[MeSH Terms] OR ("tooth"[All Fields] AND "movement"[All Fields] AND "techniques"[All Fields]) OR "tooth movement techniques"[All Fields] OR ("tooth"[All Fields] AND "movement"[All Fields] AND "technique"[All Fields]) OR "tooth movement technique"[All Fields]) OR Orthodontic[All Fields])		

5) blinding, 6) random outcome assessment, 7) incomplete data outcome, 8) selective outcome reporting, and 9) other sources of bias.

RESULTS

Study Selection

The initial search identified 656 potential manuscripts. Thirty manuscripts were duplicates, and 621 articles did not address the focused question and/or eligibility criteria. Five animal studies that fulfilled the eligibility criteria were included in this systematic review and processed for data extraction.[3,15-18] (Figure 1).

General Characteristics of the Included Studies

All the included studies[3,15-18] in this review were conducted in rodents. No clinical studies were available at the time of the search. The included studies had an experimental study design. The mean age of the rodents ranged from 7 to10 weeks, and the weight of the rodents ranged from 194 to 350 g. The study duration for the included studies ranged from 14 to 51 days. Three studies included male rats and two studies included female rats (Table 2).

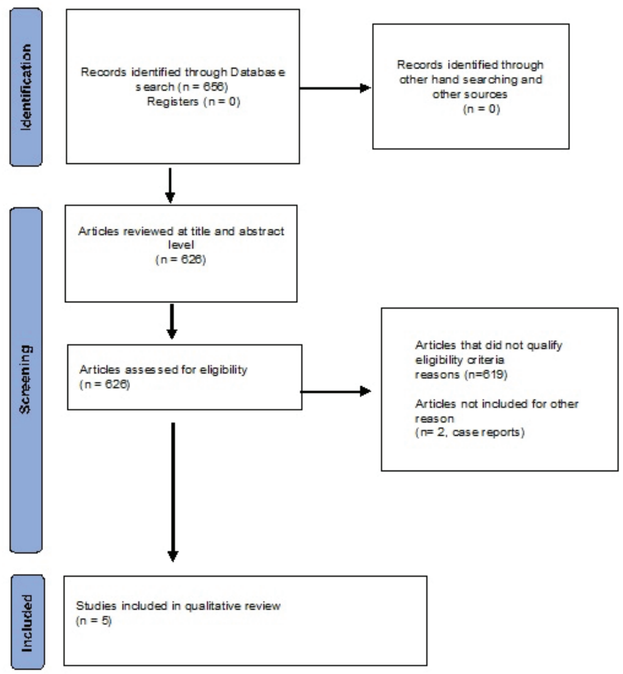

Figure 1. PRISMA flow chart

PRISMA, Preferred Reporting Items for Systematic Reviews and Meta-Analyses

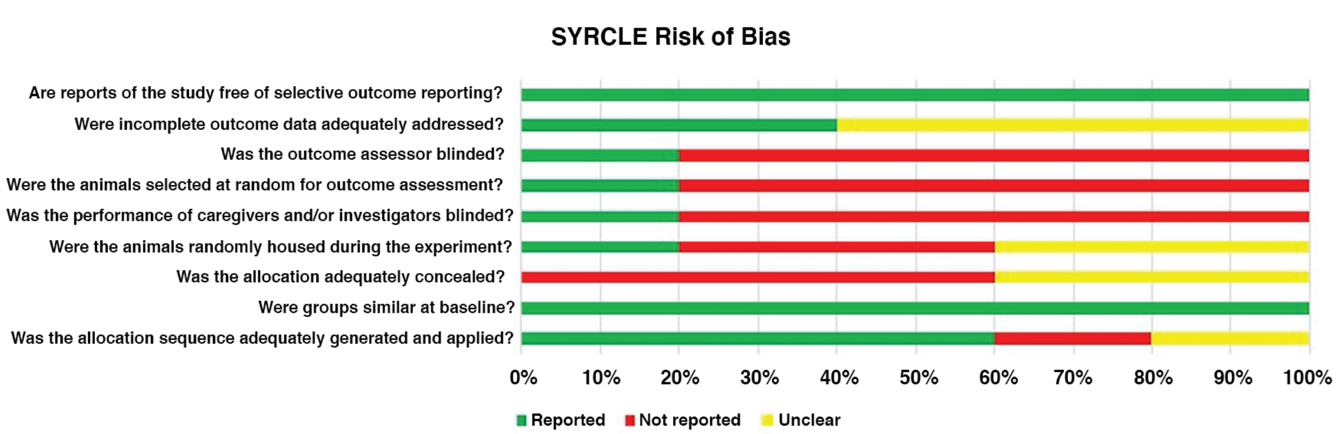

Figure 2. Risk of bias in included studies

Table 2. General characteristics of the included studies

Author	Country of study	Publication year	Number of animals	Sex	Rodent type	Mean age (weeks)	Weight (g=grams)	Groups	Study duration
Ino-Kondo et al.[15]	Japan	2018	32	Female	Sprague-Dawley rats	10	194-234 g	(4 groups, n=8 rats/group) Group 1=Saline only (Control Group) Group 2=0.32 mM/kg of LiCl (Exp Group) Group 3=0.64 mM/kg of LiCl (Exp Group) Group 4=1.28 mM/kg of LiCl (Exp Group)	14 days
Pan et al.[16]	China	2017	42	Male	Wistar Rats	8	200+10 g	OTM induced 14 days and divided equally into 2 groups, Group 1=LiCl, n=18 Group 2=Saline, n=18 Rats were randomly sacrificed post OTM on days 3, 7, and 14 (n=6/group) Initial control (n=6)	14 days of OTM followed by days 0, 3, 7, and 14 of the retention phase
da Silva Kagy et al.[17]	Brazil	2016	192	Male	Wistar Rats	9	300-350 g	(3 groups, n=64 rats/group) L group received 60 mg/kg LC in saline solution, resulting in serum lithium levels of 1.30 +/- 0.55 mmol/L at 90 min after administration The LM group received prior daily administration of LC for 30 days and then subdivided into groups that subsequently received additional LC for 3, 7, 14, or 21 days. All groups had serum lithium levels of 1.34 +/- 0.53 mmol/L SM=Saline group	16 rats from each group were euthanized on days 33, 37, 44, and 51 to measure OTM
Wang et al.[3]	China	2013	10	Male	Sprague-Dawley rats	8	200+10 g	2 groups, n=5 rats/group Group 1=lithium chloride Group 2=Control group (NR)	14 days
Huang et al.[18]	China	2021	42	Female	C57BL/6 mice	7	NR	2 groups Group 1=Sham, n=15 Group 2=Ovariectomy, n=27. In this group, 12 of 27 mice received LiCl only.	14 days

OTM, orthodontic tooth movement; LiCl, lithium chloride; LC, lithium carbonate; Exp Group, experimental group; NR, not reported; g, grams; n, number of animals.

Characteristics of studies involving lithium

Four studies[3,15,16,18] used lithium chloride (LiCl) versus one study that used lithium carbonate (LC).[17] Two studies[3,17] administered lithium intraperitoneally, whereas three studies[3,16,18] used gavages. Ino-Kondo et al.[15] administered LiCl at 0, 0.32, 0.64, and 1.28 mM/kg of body weight, which was dissolved in saline and administered daily. In the study by Pan et al.,[16] the animals received 200 mg/kg, whereas the study by da Silva Kagy et al.[17] administered LC at the rate of 60 mg/kg in 3 groups: L group (that resulted in lithium serum levels of 1.30 +/- 0.55 mmol/L), LM group (that resulted in lithium serum levels of 1.34 +/- 0.53 mmol/L), and SM (saline group, no changes). In addition, the LM group received the drug subsequently at 3, 7, 14, and 21 days, corresponding to the induced tooth movement. Wang et al.[3] administered 200 mg/kg of LiCl, whereas Huang et al.[18] administered 200 mg/kg daily for 14 days (Table 3).

Characteristics of Orthodontic Force Application and Tooth Displacement

Four studies[3,15-17] mentioned closed-coil springs in their experiments with Ino-Kondo et al.[15], using 10 cN; Pan et al.,[16] Wang et al.,[3] using 50 g; da Silva Kagy et al.,[17] using 30 cN of force; and Huang et al.,[18] using 10g of force to induce OTM with a customized closed coil spring. The duration of OTM ranged from 14 to 51 days. Ino-Kondo et al.[15] reported that the higher the dose of LiCl administered, the lower was the OTM,

Table 3. Characteristics of studies involving lithium

Authors	Lithium salt	Dilution medium	Dosage	Delivery method and duration of administration	Frequency of administration
Ino-Kondo et al.[15]	Lithium chloride	Saline	4 groups with 4 independent doses Group 1=Saline only Group 2=0.32 of LiCl mM/kg of body weight. Group 3=0.64 of LiCl mM/kg of body weight. Group 2=1.28 of LiCl mM/kg of body weight.	Intraperitoneal (immediate)	Daily
Pan et al.[16]	Lithium chloride	NR	Group 1=200 mg/kg of LiCl Group 2=200 mg/kg of saline	Gavage (immediate)	Daily
da Silva Kagy et al.[17]	Lithium carbonate	Saline	Group 1=L group, 60 mg/kg of LC Group 2=LM group, 60 mg/kg of LC Group 3=Saline group, 60 mg/kg of LC	Intraperitoneal (immediate)	Daily
Wang et al.[3]	Lithium chloride	NR	Group 1=200 mg/kg of LiCl (Exp group) Group 2=Control (No treatment)	Gavage (immediate)	Every 48 h
Huang et al.[18]	Lithium chloride	Double-distilled H_2O	Group 1=200 mg/kg of LiCl (Exp group) Group 2=Control (Sham)	Gavage (immediate)	Daily

LiCl, lithium chloride; LC, lithium carbonate.

Table 4. Characteristics of orthodontic force application and tooth displacement

Authors	Orthodontic appliance and material	Site of the OTM	Duration of the OTM	Force	Tooth displacement evaluation	Magnitude of OTM in the control groups	Magnitude of OTM in the experimental (lithium) group
Ino-Kondo et al.[15]	Nickel-Titanium closed-coil spring	Distal surface of the maxillary left first molar and mesial surface of the maxillary left second molar	14 days	10 cN	1. Measure OTM between maxillary 1st and 2nd molars 2. ShD between CPD 3. TIA 4. RAD	ShD 0.3-0.4 mm Distance between CPD was between 0.5 and 0.6 mm	0.32 group: ShD was 0.3-0.4 mm. Distance between CPD was 0.4-0.5 mm 0.64 group: ShD was 0.2-0.3 mm. Distance between CPD was 0.3-0.4 mm 1.28 group: ShD was 0.2-0.3 mm. CPD was 0.3-0.4 mm
Pan et al.[16]	Closed-coil spring	Maxillary left first molar and incisor	OTM for 14 days and retention measured on days 3, 7 and 14	50 g	Distance between maxillary 1st and 2nd molars	The mesial movement achieved between maxillary 1st and 2nd molars remained the same during the retention phase	The mesial movement achieved between maxillary 1st and 2nd molars remained the same during the retention phase
da Silva Kagy et al.[17]	Nickel-Titanium closed-coil spring	Central incisors and 1st molar	Days 33, 37, 44, and 51 per group	30 cN	Distance between the central incisors and 1st molar	Day 33=4.05+/-3.61 mm Day 37=5.23+/-3.23 mm Day 44=6.22+/-3.90 mm Day 51=6.13+/-3.53 mm	Day 33=1.76+/-1.29 mm Day 37=3.02+/-2.0 0 mm Day 44=1.84+/-1.49 mm Day 51=3.14+/-2.10
Wang et al.[3]	Nickel-Titanium closed-coil spring	Nearest points between the first and second molars	14 days	50 g	Distance between maxillary 1st and 2nd molars	0.1120+/-0.061 mm	0.1755+/-0.106 mm
Huang et al.[18]	Customized nickel-titanium spring	Nearest points between the first and second molars	14 days	10 g	Distance between maxillary 1st and 2nd molars	0.11 mm	0.14 mm

cN, centinewton of force; mm, millimeters; CPD, distance between contact points; TIA, angle of tooth inclination; RAD, the distance of movement of the root apex; OVX group, group that received ovariectomies; ShD, shortest distance.

as measured by the distance between tooth contact points.[15] Pan et al.,[16] reported that the mesial movement achieved between maxillary 1st and 2nd molars remained the same during the retention phase; however, these measurements were not reported in the paper. da Silva Kagy et al.[17] reported that the distance between maxillary 1st and 2nd molars on day 33 was 4.05 +/- 3.61 mm vs 1.76 +/- 1.29 mm in the control vs. experimental group, respectively; 5.23 +/- 3.23 mm vs. 3.02 +/- 2.00 mm in the control vs. experimental group on day 37, respectively; 6.22 +/- 3.90 mm vs. 1.84 +/- 1.49 mm in the control vs. experimental groups on day 44, and 6.13 +/- 3.53 mm vs 3.14 +/- 2.10 mm in the control vs. experimental group on day 51. Wang et al.[3] reported that the distance between maxillary 1st and 2nd molars on day 14 was 0.1120 +/- 0.061 mm for the control and 0.1755 +/- 0.106 mm for the experimental group. Huang et al.[18] reported that the distance between maxillary 1st and 2nd molars was 0.11 mm in the sham group vs. 0.14 mm in the experimental (osteoporotic model) group on day 14 (Table 4).

Study Outcomes

The first study[15] measured 4 parameters between maxillary 1st and 2nd molars: shortest distance (ShD), distance between contact points (CPD), angle of tooth inclination, and distance of movement of the root apex. The second study[16] measured the effect of lithium on OTM during the retention phase. In addition, histology and immunohistochemistry were performed to measure bone volume and total volume in the regions of interest, which were the distal buccal root of the maxillary first molar and the adjacent periodontal ligament and alveolar bone. In the third study,[17] in addition to studying OTM, biochemical analysis was performed to record the plasma levels of inorganic serum phosphate (PO4), alkaline phosphatase (ALP), aspartate aminotransferase (AST), and creatinine as well as serum levels of lithium, calcium, and albumin. The fourth study[3] also studied the root resorption area ratio. The fifth study[18] studied OTM in the presence in an osteoporotic model with ovariectomise.

The first study[15] noted that there was no significant difference in the ShD between the control and experimental groups. The distance between contact points mildly decreased with lithium administration, and the root apex moved distally in tipping tooth movement in the control and experimental groups receiving a dose of 0.32 mM/kg of LiCl. The root apex moved mesially during tipping tooth movement in the experimental group receiving 0.64 and 1.28 mM/kg of LiCl. It was concluded that lithium reduced orthodontically induced root resorption, which included mesial movement. The second study[16] reported that lithium promotes alveolar bone formation during orthodontic retention and may have therapeutic potential in shortening the retention period. We also noted that the osteogenic activity of lithium may be related to the activation of the Wnt signaling pathway and enhancement of Runx2 and Osterix expression. Resorption lacunae and multinucleated osteoclasts seen on day 0 disappeared by day 14. Monolayers of osteoblasts lined the lacunae on the surface of the newly developing alveolar bone. The LiCl experimental group exhibited significantly more osteoblasts than the control group on day 14. Immunohistochemistry revealed that the expression of Runx2 and Osterix increased markedly on days 7 and 14 compared with the controls. This study concluded that lithium promotes alveolar bone formation. This may also have therapeutic potential in shortening the retention period. The third study[17] noted that the lithium group showed a lower rate of movement on day 44 than the saline group. Higher serum lithium levels were observed in the L and LM experimental groups; higher PO4 were observed in the SM saline (control) group. The LM group showed a higher mean value than the L experimental group. Higher ALP values were verified in the L experimental group compared with the SM and LM experimental groups. Serum creatinine was found in lower levels in the LM experimental group than in the L experimental and SM groups. The weight variation was higher in the L and LM experimental groups. No statistical differences were observed in the SM and LM experimental groups at any time point, although there was a tendency toward a reduction in the number of osteoclasts in the LM experimental group at 44 days. This study concluded that the induced tooth movement associated with chronic lithium lowered the rate of tooth movement during 14 days, possibly due to a reduction in the number of osteoclasts. The fourth study[3] noted that the average distance measurement in the control group was slightly higher than that in the lithium group. It was also noted that the mean root resorption area ratio of the control group was significantly greater than that of the lithium group. The fifth study concluded that the lithium group protects tooth movement in osteoporosis by upregulating osteogenic differentiation and suppressing apoptosis in bone marrow-derived mesenchymal stem cells, in turn reducing OTM compared with the group that did not receive LiCl. It stated that LiCl promoted autophagy, inhibited apoptosis, and osteoclastogenesis, and effectively restored bone formation in preexisting osteoporotic alveolar bone. We concluded that the average distance of OTM measured in the control and osteoporotic groups was slightly higher than that in the group that received LiCl[18] (Table 5).

ROB of the included Studies

Regarding individual criteria, the maximum frequencies of reporting were recorded for abstract, background, objectives (introduction-based), ethical statement, study design, experimental procedures, experimental animals used in the study, housing of animals, sample size, allocation of test groups and experimental outcomes, baseline data, number of animals analyzed, outcomes and estimations and scientific implications, study generalizability, and statistical methods results for each analysis. Funding was reported in only 80% of the studies only, and no adverse events were reported. The allocation sequence was adequately generated in 3 studies,[15,16,18] but it was unclear in 1 study and was not adequately generated in 1 study.[3] All five studies have groups similar at baseline.[3,15-18] Allocation was not adequately concealed in 3 studies[15-17] and was unclear in 2 studies.[3,18] Animals were not randomly housed in 2 studies,[15,17]

Table 5. Study outcomes regarding the effect of lithium on orthodontic tooth movement

Authors	Primary methods of evaluation	Primary study outcome	Secondary study outcome	Conclusions	Statistical analysis	P value	Power analysis
Ino-Kondo et al.[15]	- Micro CT - Scanning Electron Microscope - Scanning Laser Microscope Images	- LiCl reduced OIRR - No significant difference in ShD between the groups - CPD mildly decreased with lithium administration - Root apex moved distally in tipping tooth movement in the control and 0.32 exp groups versus mesially in 0.64 and 1.28 exp groups	- No significant difference in body weight between the various groups - OIRR correlated with cortical bone morphometry	- Lithium reduced orthodontically induced root resorption, which included mesial movement	- One-Way ANOVA	- Reported as significant	NR
Pan et al.[16]	- Micro CT	- Lithium promotes alveolar bone formation during orthodontic retention - May have therapeutic potential in shortening the retention period - Osteogenic activity of lithium may be related to activation of the Wnt signaling pathway and enhancement of Runx2 and Osterix gene expression	- Resorption lacunae and multinucleated osteoclasts disappeared by day 14 - Monolayer of osteoblasts lined the lacunae on the surface of newly developing alveolar bone - The LiCl group exhibited significantly higher osteoblasts on day 14 - Expression of Runx2 and Osterix genes increased significantly on days 7 and 14	- Lithium promotes alveolar bone formation	- Two-Way ANOVA	- Reported as insignificant on 3, significant on days 7 and 14	NR
da Silva Kagy et al.[17]	- Digital Caliper	- Lithium group showed a lower rate of movement on day 44	- Higher serum lithium levels were observed in the L and LM groups - Higher values of ALP were reported in the L group compared to the SM and LM groups - Serum creatinine levels were lower in the LM group than in the L and SM groups - No. of osteoclasts in the L group remained constant at all times	- Chronic use of lithium lowered rate of tooth movement, possibly due to reduction in the number of osteoclasts	- One-Way ANOVA	- Reported as insignificant. (p>0.05)	NR
Wang et al.[3]	- Micro CT	- Average distance measurement in the control group slightly higher than that in the lithium group	- The root resorption area ratio of the control group was significantly higher compared to the lithium group	- The average distance of OTM measured in the control group was slightly higher than that in the experimental group	- One-Way ANOVA	- Reported as insignificant	NR
Huang et al.[18]	- Micro CT	- Lithium group protects tooth movement in osteoporosis by upregulating osteogenic differentiation and suppressing apoptosis in bone marrow-derived mesenchymal stem cells, in turn reducing OTM	- LiCl promoted autophagy and inhibited apoptosis and osteoclastogenesis - LiCl effectively restored bone formation in preexisting osteoporotic alveolar bone	- The average distance of OTM measured in the control and osteoporotic groups was slightly higher than that in the group that received LiCl	- Two-Way ANOVA	- Reported as significant	NR

CT, computed tomography scan; ANOVA, analysis of variance; OTM, orthodontic tooth movement; ALP, alkaline phosphatase; PO4, serum phosphate; OIRR, orthodontic-induced root resorption.

were unclear in 2 other studies,[3,16] and were randomly housed in 1 study.[18] Caregivers and/or investigators were blinded in 1 study[16] and unblinded in 4 studies.[3,15,17,18] All five studies did not randomly select animals for outcome assessment. The outcome assessor was blinded in 1 study,[16] whereas addressing the outcome data was unclear in 3 studies and adequately addressed adequately in 2 studies.[16,18] All five studies were free of selective outcome reporting. Among all the included studies, 3 studies[3,15,17] had a very high ROB, 1 study[16] had a high ROB, and 1 study[18] had a moderate ROB (Table 6).

DISCUSSION

Studies have shown that lithium can activate the Wnt/beta-catenin pathway,[21-23] which may have an impact on bone mass. Wnt/β-catenin signaling stimulates the generation of osteoblastic cells by promoting the differentiation of pluripotent mesenchymal stem cells (MSCs) toward the osteoblastic lineage, while simultaneously suppressing commitment to the chondrogenic and adipogenic lineages.[24] In particular, Wnt/β-catenin signaling has promoted the progression of Osterix1-expressing cells to osteoblasts that produce bone. In addition, Wnts signaling has been shown to prevent apoptosis of mature osteoblastic cells and thereby increasing their lifespan by both β-catenin independent as well as β-catenin dependent pathways.[25]

All five studies included in this review reported a reduction in the active phase of OTM upon lithium administration and had a direct effect on the retention phase after OTM was achieved. Huang et al.[18] provided evidence to support the use of LiCl in providing safe orthodontic treatment to osteoporotic patients with better and more controllable outcomes. Pan et al.[16] reported that LiCl strongly reduced the area, depth, and volume of orthodontically induced root resorption (OIRR). Subsequently, the ratio of OIRR per CPD was significantly smaller in the 0.64 and 1.28 mM/kg experimental groups than in the control group. These results suggested that LiCl inhibited OIRR more efficiently than OTM. The osteogenic activity of lithium may be related to the activation of the Wnt signaling pathway and the enhancement of Runx2 and Osterix gene expression, which are cytoplasmic markers of osteoblasts.

Strengths of this review include the utilization of an well-established method. A comprehensive search was conducted up to June 2021 without any pre-determined limitations regarding the status of publication and languages. Processes for verifying eligibility, screening, and abstraction of information from studies involving both animal and human subjects were performed in duplicate. However, limitations of this review are based on the number of experiments; thus, additional studies are warranted to confirm the above findings. Furthermore, this review relies on animal model studies. Based on the search criteria, no human studies were identified. In addition, there was inconsistency in the species of rats or mice included in the studies, and tooth displacement was measured at different sites within the oral cavity. In addition to other limitations, the assessment of OTM using micro CT, considered the gold standard, was not as effective as da Silva Kagy et al.[17] who used a digital caliper for the measurement. In studies by Pan et al.[16] and Huang et al.[18], OTM in the LiCl group was not recorded, which is a significant shortcomings.

OTM can be performed via traditional fixed appliances, which have been used for decades, as well as clear aligners, which have become extremely popular in the past decade. The normal orthodontic treatment duration with aligners is approximately 12-18 months depending on the severity of malocclusion. In this day and age, the current trend and high demand for cosmetic dentistry in any age group is rising significantly. More and more people are receptive about their smile, and orthodontists often offer home remedies for managing malocclusion. In addition, as the stigma of mental health is narrowing in society, it is important that both the patient and healthcare provider have an understanding of how either of these conditions can affect each other. The normal orthodontic treatment duration with fixed treatment or aligners is approximately 12-24 months depending on the severity of malocclusion. Based on the aforementioned studies, lithium may affect the treatment periods for OTM. Based on the current literature of studies published only on animal studies, there is limited evidence of the effect of lithium on OTM. Further standardized prospective studies mainly on humans are warranted to evaluate the influence of lithium on OTM.

CONCLUSION

Lithium, a commonly used drug used for decades for the treatment of BD, has primarily been studied in animal models. These studies indicate decreased rates of OTM during the active treatment phase by increasing bone density and bone volume and reducing root resorption. In addition, lithium enhances alveolar bone formation during the orthodontic retention

Table 6. Risk of bias using SYRCLE

Author	Q1	Q2	Q3	Q4	Q5	Q6	Q7	Q8	Q9	Overall risk	ROB
Ino-Kondo et al.[15]	Yes	Yes	No	No	No	No	No	UC	Yes	33.3%	Very high
Pan et al.[16]	Yes	Yes	No	UC	Yes	No	Yes	Yes	Yes	55.5	High
da Silva Kagy et al.[17]	UC	Yes	No	No	No	No	No	UC	Yes	22.2%	Very high
Wang et al.[3]	No	Yes	UC	UC	No	No	No	UC	Yes	22.2%	Very high
Huang et al.[18]	Yes	Yes	UC	Yes	No	Yes	No	Yes	Yes	66.6%	Moderate

UC, unclear; ROB, Risk of Bias.

phase. These findings have significant clinical implications, potentially affecting treatment duration and retention phase in long-term lithium medication patients. Further clinical studies are warranted to assess the impact of lithium on OTM.

Ethics

Peer-review: Externally peer-reviewed.

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

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References

1. Proffit WR, Fields HW, Sarver DM. Biologic basis of orthodontic therapy. In: *Contemporary Orthodontics*. 4th edition ed. 2007:331-358. [CrossRef]
2. Ren Y, Maltha JC, Kuijpers-Jagtman AM. Optimum force magnitude for orthodontic tooth movement: a systematic literature review. *Angle Orthod.* 2003;73(1):86-92. [CrossRef]
3. Wang Y, Gao S, Jiang H, et al. Lithium chloride attenuates root resorption during orthodontic tooth movement in rats. *Exp Ther Med.* 2014;7(2):468-472. [CrossRef]
4. Kommuri K, Javed F, Akram Z, Khan J. Effect of statins on orthodontic tooth movement: A systematic review of animal and clinical studies. *Arch Oral Biol.* 2020;111:104665. [CrossRef]
5. https://www.nimh.nih.gov/ [Internet]. The National Institute of Mental Health; 2022 [December 21, 2021]. Available from: https://www.nimh.nih.gov/health/statistics/mental-illness [CrossRef]
6. Altamura AC, Gomeni R, Sacchetti E, Smeraldi E. Plasma and intracellular kinetics of lithium after oral administration of various lithium salts. *Eur J Clin Pharmacol.* 1977;12(1):59-63. [CrossRef]
7. Kessler RC. National Comorbidity Survey: Adolescent Supplement (NCS-A), 2001-2004. In: Inter-university Consortium for Political and Social Research [distributor]; 2017. [CrossRef]
8. Merikangas KR, Jin R, He JP, et al. Prevalence and correlates of bipolar spectrum disorder in the world mental health survey initiative. *Arch Gen Psychiatry*. 2011;68(3):241-251. [CrossRef]
9. https://medlineplus.gov. The National Library of Medicine; 2022 [December 21, 2021]. Available from: https://medlineplus.gov/druginfo/meds/a681039.html [CrossRef]
10. Lepkifker E, Iancu I, Horesh N, Strous RD, Kotler M. Lithium therapy for unipolar and bipolar depression among the middle-aged and older adult patient subpopulation. *Depress Anxiety.* 2007;24(8):571-576. [CrossRef]
11. Pearson GS, Banga A. Psychopharmacology column: the use of lithium carbonate with pediatric populations. *J Child Adolesc Psychiatr Nurs.* 2012;25(4):232-234. [CrossRef]
12. Patel BD, Barzman DH. Pharmacology and pharmacogenetics of pediatric ADHD with associated aggression: a review. *Psychiatr Q.* 2013;84(4):407-415. [CrossRef]
13. Vestergaard P, Rejnmark L, Mosekilde L. Reduced relative risk of fractures among users of lithium. *Calcif Tissue Int.* 2005;77(1):1-8. [CrossRef]
14. Hashimoto M, Hotokezaka H, Sirisoontorn I, et al. The effect of bone morphometric changes on orthodontic tooth movement in an osteoporotic animal model. *Angle Orthod.* 2013;83(5):766-773. [CrossRef]
15. Ino-Kondo A, Hotokezaka H, Kondo T, et al. Lithium chloride reduces orthodontically induced root resorption and affects tooth root movement in rats. *Angle Orthod.* 2018;88(4):474-482. [CrossRef]
16. Pan J, He S, Yin X, Li Y, Zhou C, Zou S. Lithium enhances alveolar bone formation during orthodontic retention in rats. *Orthod Craniofac* Res. 2017;20(3):146-151. [CrossRef]
17. da Silva Kagy V, Trevisan Bittencourt Muniz L, Michels AC, et al. Effect of the Chronic Use of Lithium Carbonate on Induced Tooth Movement in Wistar Rats. *PLoS One.* 2016;11(8):e0160400. [CrossRef]
18. Huang L, Yin X, Chen J, et al. Lithium chloride promotes osteogenesis and suppresses apoptosis during orthodontic tooth movement in osteoporotic model via regulating autophagy. *Bioact Mater.* 2021;6(10):3074-3084. [CrossRef]
19. Moher D, Liberati A, Tetzlaff J, Altman DG; PRISMA Group. Preferred reporting items for systematic reviews and meta-analyses: the PRISMA statement. *BMJ.* 2009;339:b2535. [CrossRef]
20. Hooijmans CR, Rovers MM, de Vries RB, Leenaars M, Ritskes-Hoitinga M, Langendam MW. SYRCLE's risk of bias tool for animal studies. *BMC Med Res Methodol.* 2014;14:43. [CrossRef]
21. Arioka M, Takahashi-Yanaga F, Sasaki M, et al. Acceleration of bone regeneration by local application of lithium: Wnt signal-mediated osteoblastogenesis and Wnt signal-independent suppression of osteoclastogenesis. *Biochem Pharmacol.* 2014;90(4):397-405. [CrossRef]
22. Clément-Lacroix P, Ai M, Morvan F, et al. Lrp5-independent activation of Wnt signaling by lithium chloride increases bone formation and bone mass in mice. *Proc Natl Acad Sci U S A.* 2005;102(48):17406-17411. [CrossRef]
23. Hedgepeth CM, Conrad LJ, Zhang J, Huang HC, Lee VM, Klein PS. Activation of the Wnt signaling pathway: a molecular mechanism for lithium action. Dev Biol. 1997;185(1):82-91. [CrossRef]
24. Rodda SJ, McMahon AP. Distinct roles for Hedgehog and canonical Wnt signaling in specification, differentiation and maintenance of osteoblast progenitors. *Development.* 2006;133(16):3231-3244. [CrossRef]
25. Almeida M, Han L, Bellido T, Manolagas SC, Kousteni S. Wnt proteins prevent apoptosis of both uncommitted osteoblast progenitors and differentiated osteoblasts by beta-catenin-dependent and -independent signaling cascades involving Src/ERK and phosphatidylinositol 3-kinase/AKT. *J Biol Chem.* 2005;280(50):41342-41351. [CrossRef]