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Comparison of the effect of different rapid maxillary expansion treatments on tooth hardness values: Splint mouth study

Seda Sağoğlu[1], Mücahid Yıldırım[1], Mehmet Akın[2], Emire Aybüke Erdur[3]

[1] Necmettin Erbakan University, Faculty of Dentistry, Department of Orthodontics, Konya, Türkiye
[2] Alanya Alaaddin Keykubat University, Faculty of Dentistry, Department of Orthodontics, Antalya, Türkiye
[3] Private Practice, Ankara, Türkiye

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Correspondence:

Dr. Seda SAĞOĞLU
Necmettin Erbakan University, Faculty of Dentistry, Department of Orthodontics, Konya, Türkiye.
E-mail: ssagoglu@gmail.com

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Abstract

Aim: The purpose of this study, planned as a splint mouth design, is to compare the effects of different rapid maxillary expansion (RME) appliances on the hardness values of teeth.

Methodology: This study utilized extracted upper first premolar teeth from a previous study conducted on 20 patients. Five patients were excluded from this study due to fractures of the tooth crown during extraction, which also necessitated the exclusion of the opposing arch teeth. The extracted teeth were stored in distilled water at +4 degrees Celsius. The crowns and roots of these teeth were separated at the cementoenamel junction using an aerator and a diamond bur under water cooling. The crowns were then embedded into rings of standard thickness using the cold acrylic dripping method. Hardness measurements were performed using a Vickers Hardness tester. Enamel samples obtained from the patients were placed under a test microscope and examined at X40 magnification; force was applied to each enamel sample for 10 s. The device automatically calculated and recorded the microhardness value relationship. The Shapiro-Wilk test was used to confirm the normal distribution of the data. Comparisons between groups were conducted using Student's t-test.

Results: The group using the hybrid maxillary expansion appliance showed lower hardness values than the conventional group, although the difference was statistically significant.

Conclusion: Fixed orthodontic treatments increase the demineralization of teeth. Therefore, individual or preventive measures by dentists or orthodontists should be taken against mineral losses.

Keywords: Hardness test, rapid maxillary expansion, splint mouth design, tooth extraction, hardness

Introduction

Skeletal transverse deficiency stems from transverse incompatibility between the lower and upper jaws, constituting a skeletal disorder (1). Rapid maxillary expansion (RME) has long been a leading method for treating cases of transverse deficiency in the upper jaw (2). The appliance used during rapid maxillary expansion should be designed according to the patient's age, skeletal and muscular structure, severity of the constriction, oral hygiene, cooperation, axial inclination of the upper molars and premolars, and the biomechanical needs of the case (3). Before the use of mini-screws, which are prevalent today, osteosynthesis plates, osseointegrated implants, onplants, and the distraction method used in severe maxillary constrictions were employed to expand the upper jaw by obtaining support from bone. However, these methods, being invasive and expensive and requiring a waiting period for osseointegration of implants, have been replaced by immediately loadable, inexpensive, and clinically easy-to-apply mini-screws (4). Clinically, the ease of application, the absence of surgical procedures, and cost-effectiveness have led to bone support being provided with mini-screws applied to the palatal bone (5).

The enamel is a porous and semi-permeable mineral structure that allows partial or complete passage of various fluids, ions, and low-molecular-weight substances. Biological factors such as saliva, dental plaque, and the physicochemical structure of the tooth are crucial in demineralization and subsequent caries formation (6). Numerous studies have assessed the impact of orthodontic treatment on mineral loss in enamel (7-9). Orthodontic attachments or appliances, owing to their prolonged contact with tooth structures, reduce the cleansing and neutralizing effect of saliva, and increase plaque accumulation. This situation induces a risk of mineral loss in the hard tissues of the teeth, thereby reducing enamel hardness (10). Increased demineralization and reduced remineralization lead to structural degradation, surface dissolution, and demineralization of the superficial enamel layer (11). In the literature, surface hardness measurements have frequently been used to detect demineralization and remineralization (12-14). Changes in the mineral content of enamel influence its hardness; hence, hardness measurements can be applied as accurate and feasible methods for assessing demineralization and remineralization. The Vicker's hardness test is the most commonly used method for this purpose (13).

The aim of this study is to compare the Vicker's hardness values of premolar teeth extracted after a 3-month retention period in patients who underwent conventional (bonded) expansion and those who received a modified rapid maxillary expansion appliance, supported on one side by bone and on the other by tooth-tissue, following the extraction of two premolars indicated for therapeutic purposes after maxillary expansion.

Materials and Methods

This study was approved by the Necmettin Erbakan University Dentistry Non-Medical Device and Drug Research Ethics Committee (Number: 2024/391). The study included a total of 20 patients, comprising 11 females and nine males, who participated in a study conducted by Yıldırım and Akın in 2019 (15). A total of 40 upper right and left first premolar teeth, extracted for treatment purposes, were used. The extracted teeth were first analyzed for root resorption using a micro-CT device (Scanco Medical mCT 50; Bassersdorf, Switzerland), followed by hardness testing of the crowns to evaluate changes in mineralization. The inclusion criteria are listed in Table 1.

Table 1. Inclusion criteria
Patients aged 11-16 years
No previous orthodontic treatment
Insufficiency in the transverse direction in the maxillary apical base
Indication for extraction of the upper first premolar teeth during fixed treatment to be performed after rapid maxillary expansion
Indication for extraction of upper first premolar teeth during fixed treatment to be performed after rapid maxillary expansion
Good oral hygiene
Absence of any oral or systemic disease
Absence of a history of continuous drug use and smoking

A modified rapid maxillary expansion appliance was applied to the individuals included in the study. The modified appliance was designed to be tooth-supported on one side with bone support provided by a palatal mini-screw on the other side. Before manufacturing the modified appliance, Neoanchor Plus (KJ Meditech, Seoul, South Korea) mini-screws were inserted at a distance of 6-8 mm from the palatal gingival margin of the second premolar and first molar, at an angle of 15-20 degrees to the occlusal plane. Although the teeth in the tooth-supported area were covered with acrylic on their occlusal surfaces, the tooth surfaces in the mini-screw-applied area were left exposed (Fig. 1).

To prevent elongation of the teeth in this area, a unilateral occlusal elevated mandibular essix plate was applied to the patients (Fig. 2).

The rotation protocol was terminated after sufficient expansion and overcorrection were achieved, and the Hyrax screw was stabilized with a ligature. The appliance was left in the mouth for three months for retention. Extractions of the first premolars, which were indicated for extraction in the study, were performed. However, the teeth of five patients who broke during extraction were excluded from the study, along with the opposing arch teeth. Therefore, 30 upper first premolar teeth were examined in this study. tissues and debris on the teeth were cleaned with distilled water and a sponge. The extracted teeth were stored in distilled water at +4 degrees Celsius. The crowns and roots of the extracted teeth were separated at the enamel-cement junction under water cooling using an aerator and diamond bur, and the crowns were embedded in rings of standard thickness using cold acrylic (Panacryl, Kent Dental, Türkiye) (Fig. 3).

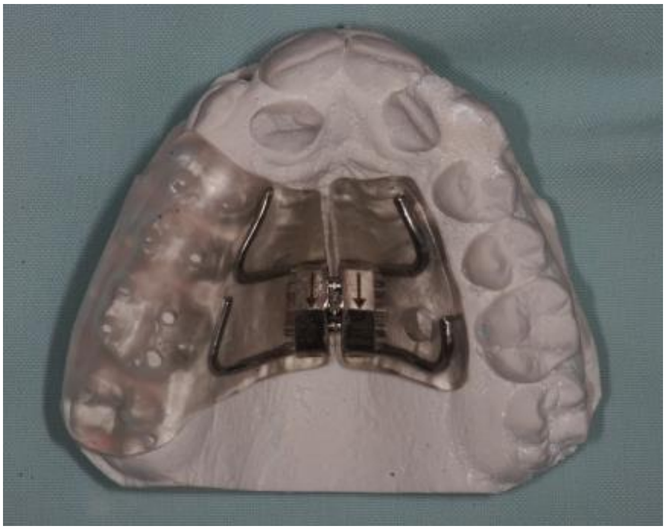

Figure 1. Modified rapid maxillary appliance design.

Figure 2. Mandibular Essix appliance.

For the hardness measurement, a Vickers hardness testing device (Microbul-30-N, Micro Vickers Hardness Tester, Bulut Machine, Istanbul, Türkiye) was used. The enamel samples obtained from the patients were placed under a test microscope and moved until a clear image was obtained at X40 magnification. A load of 200 g was applied for 10 s on 30 enamel samples. The diagonal length of the indentation created by the diamond tip on the enamel was measured in microns, and the microhardness value relationship was automatically calculated by the device and recorded as the Vickers Hardness Value (VHV) on the device screen. Subsequently, the values were compared.

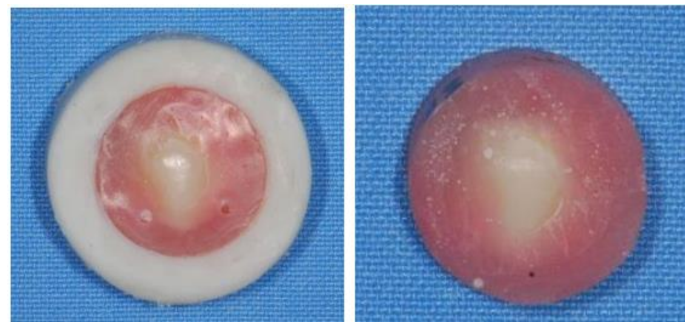

Figure 3. Embedding teeth in acrylic

Statistical analysis

Data were analyzed using IBM SPSS V23 software (SPSS version 23, IBM, Armonk, NY, US).

In this study, the Shapiro-Wilk normality test was conducted to assess the normality of the data between the two groups. Test results confirmed that the data were normally distributed. Based on this, an independent samples t-test was performed to determine the differences between the two groups. The point of statistical significance was determined at the $p<0.05$ level.

Results

The mean age of the individuals included in the study was 14.31 ± 1.36 years. Teeth treated with the hybrid maxillary expansion appliance demonstrated slightly lower hardness values (258.28 ± 57.78) compared to those treated with the conventional appliance (262.56 ± 32.05). This difference was found to be statistically significant (p = 0.038; Table 2). The standard deviation was notably higher in the hybrid group, indicating greater variability in hardness values within this group.

Table 2. Comparison of hardness values between hybrid and conventional side teeth

	N	Mean	SD	*p*-value
Conventional	15	262.56	32.05	0.038
Hybrid	15	258.28	57.78	

Student's t-test, Mean, SD: Standard deviation, *p*: significance value

Discussion

Considering the potential risks that a mini-screw applied to the palatal region may pose to unerupted teeth, individuals aged between 11 and 16 years who were in their permanent dentition phase were included in this study. Upper jaw constriction, which disrupts the transverse relationship between the jaws, is a common and correctable orthodontic anomaly (16). To enhance the orthopedic impact and prevent the tipping of teeth in the buccal segment, researchers have developed fully bonded appliances that entirely encase the teeth and palatal tissues with acrylic (17). This modification allows for an adjusted force application, in terms of both magnitude and duration. Recently, appliances that facilitate bone-supported expansion through the application of mini-screws solely to the palatal bone, thus eliminating reliance on dental support, have been used (18-20). Ludwig et al. noted that mini-screws are particularly well-suited for placement in the palatal area between the fifth and sixth teeth because of their wide spacing and sufficient cortical bone structure (21). Lin et al. employed the C-expander, a device supported by four mini-screws, and an acrylic plate designed to expand the upper jaw (22). This appliance utilizes screws positioned between the canine and first premolar, and between the second premolar and first molar. Akin et al. have developed a palatal expander that can be implemented with two mini-screws, named the "Hybrid Expander" (20). This device, comprising two mini-screws and acrylic in the palatal region, provides additional support from a mini-screw placed between the fifth and sixth teeth, enhanced by acrylic pads to bolster palatal tissues. The appliance utilized in this study featured a fully bonded appliance on one side and a Hybrid Expander on the other.

The hardness value of enamel varies from individual to individual and between different tooth groups (23). Consequently, this study compared the hardness values of the right and left first premolars of the same patients. Half of the participants had their right first premolar randomly left within the appliance, while the other half had the left. Orthodontic treatment is recognized as a significant risk factor for the demineralization of hard dental tissues, and the design, manner of use, and duration of appliances employed influence enamel demineralization (7,10). It has been documented in the literature that demineralization can be detected by a reduction in enamel microhardness (24). Therefore, a hardness test was utilized in our study as an effective method to assess changes related to both demineralization and remineralization events in the enamel (12). Various studies have employed hardness tests to evaluate changes in the mineral content of enamel, with enamel surface hardness typically measured using Vickers and Knoop hardness tests (12-14). In this study, a Vickers hardness test was performed. Owing to the in vitro applicability of microhardness tests, our study included patients who required fixed treatment after tooth extraction during the retention period following Rapid Maxillary Expansion (RME) treatment. Assuming no initial differences in the right and left teeth of the same patient at the start of treatment, the hardness values of the teeth extracted after the retention period were compared.

For accurate microhardness measurements, the sample surfaces must be flat and polished (25). Therefore, following the RME treatment, the buccal surfaces of the extracted teeth were polished using silicon carbide sandpapers. Similar to the protocol described by Zheng et al., the extracted teeth were stored in distilled water at +4 degrees Celsius until the day of the study (26). Herkströter et al. were referenced for sample preparation, and enamel samples were embedded in acrylic blocks within rings of standard thickness (27). Before the hardness test, the teeth were dried with tissue to prevent erroneous readings caused by light refraction of the wet enamel. If acrylic coverage is not maintained correctly, it forms a potential retention area harboring plaque, affecting oral hygiene and appliance care (10). Birdsall and Robinson reported severe mineral losses in hard dental tissues using an Essix retainer throughout the day (excluding meals) (28). They reported that the Essix retainer created an environment conducive to the accumulation of acidic beverages around the teeth, thereby limiting saliva flow and reducing its cleaning and buffering capabilities (28). Due to variations in enamel hardness, our study compared the hardness values of the upper first premolar teeth both inside and outside the RME appliance to detect potential demineralization due to appliance use. The findings of this study revealed that maxillary first premolars not covered by the acrylic coating exhibited lower hardness value.

Conclusion

The absence of an acrylic-covered surface in the hybrid maxillary expansion appliance allows direct contact between the teeth and saliva, thereby promoting remineralization. This was considered an advantage over fully acrylic-covered appliances by our research team. However, contrary to expectations, teeth treated with the hybrid appliance exhibited lower hardness values compared to those treated with the fully acrylic-covered appliance, indicating a greater degree of demineralization. Therefore, individual preventive measures should be taken to minimize mineral loss during orthodontic treatment.

Disclosures

Acknowledgments: This study has been presented at the Necmettin Erbakan University 3rd International Dentistry Congress in Konya, Türkiye, held between May 24-26, 2024.

Ethical Approval: Ethics committee approval was received for this study from the Necmettin Erbakan University, Faculty of Dentistry Non-Drug and Medical Device Research Ethics Committee, in accordance with the World Medical Association Declaration of Helsinki, with the approval number: 2024-391.

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Conflict of Interest: No conflict of interest was declared by the authors.

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References

1. McDonald RE, Avery DR. Dentistry for the child and adolescent. 6th ed. St Louis, MO: Mosby-Year Book Inc; 1994.
2. Graber TM, Vanarsdall RL Jr, Vig KWL. Orthodontics: current principles and techniques. 4th ed. St Louis, MO: Elsevier; 2005.
3. Bishara SE, Staley RN. Maxillary expansion: clinical implications. Am J Orthod Dentofacial Orthop. 1987;91(1):3-14. https://doi.org/10.1016/0889-5406(87)90202-2
4. Miyawaki S, Koyama I, Inoue M, Mishima K, Sugahara T, Takano-Yamamoto T. Factors associated with the stability of titanium screws placed in the posterior region for orthodontic anchorage. Am J Orthod Dentofacial Orthop. 2003;124(4):373-378. https://doi.org/10.1016/S0889-5406(03)00565-1
5. Kang S, Lee SJ, Ahn SJ, Heo MS, Kim TW. Bone thickness of the palate for orthodontic mini-implant anchorage in adults. Am J Orthod Dentofacial Orthop. 2007;131(4 suppl):S74-S81. https://doi.org/10.1016/j.ajodo.2005.09.029
6. Robinson C, Shore RC, Brookes SJ, Strafford S, Wood SR, Kirkham J. The chemistry of enamel caries. Crit Rev Oral Biol Med. 2000;11(4):481-495. https://doi.org/10.1177/10454411000110040601
7. O'Reilly MM, Featherstone JDB. Demineralization and remineralization around orthodontic appliances: an in vivo study. Am J Orthod Dentofacial Orthop. 1987;92(1):33-40. https://doi.org/10.1016/0889-5406(87)90293-9
8. Alexander SA. The effect of fixed and functional appliances on enamel decalcifications in early Class II treatment. Am J Orthod Dentofacial Orthop. 1993;103(1):45-47. https://doi.org/10.1016/0889-5406(93)70103-U
9. Gorton J, Featherstone JD. In vivo inhibition of demineralization around orthodontic brackets. Am J Orthod Dentofacial Orthop. 2003;123(1):10-14. https://doi.org/10.1067/mod.2003.47
10. Dixon M, Jones Y, Mackie IE, Derwent SK. Mandibular incisal edge demineralization and caries associated with Twin Block appliance design. J Dent Res. 2005;32(1):3-10. https://doi.org/10.1179/146531205225020724
11. Shimpo Y, Nomura Y, Sekiya T, Arai C, Okada A, Sogabe K, et al. Effects of the dental caries preventive procedure on the white spot lesions during orthodontic treatment-an open-label randomized controlled trial. J Clin Med. 2022;11(3):854. https://doi.org/10.3390/jcm11030854
12. Featherstone JDB, Ten Cate JM, Shariati M, Arends J. Comparison of artificial caries-like lesions by quantitative microradiography and microhardness profiles. Caries Res. 1983;17(5):385-391. https://doi.org/10.1159/000260692
13. Taher NM, Alkhamis HA, Dowaidi SML. The influence of resin infiltration system on enamel microhardness and surface roughness: an in vitro study. Saudi Dent J. 2012;24(2):79-84. https://doi.org/10.1016/j.sdentj.2011.10.003
14. Montasser MA, El-Wassefy NA, Taha M. In vitro study of the potential protection of sound enamel against demineralization. Prog Orthod. 2015;16(1):12. https://doi.org/10.1186/s40510-015-0080-2
15. Yıldırım M, Akın M. Comparison of root resorption after bone-borne and tooth-borne rapid maxillary expansion evaluated with the use of microtomography. Am J Orthod Dentofacial Orthop. 2019;155(2):182-190. https://doi.org/10.1016/j.ajodo.2018.03.021
16. McNamara JA. Maxillary transverse deficiency. Am J Orthod Dentofacial Orthop. 2000;117(5):567-570. https://doi.org/10.1016/S0889-5406(00)70202-2
17. Memikoğlu UT, İşeri H, Uysal M. Three-dimensional dentofacial changes with bonded and banded rapid maxillary appliances. Eur J Orthod. 1995;16(3):342.
18. Garib DG, Henriques JF, Janson G, de Freitas MR, Fernandes AY. Periodontal effects of rapid maxillary expansion with tooth-tissue-borne and tooth-borne expanders: a computed tomography evaluation. Am J Orthod Dentofacial Orthop. 2006;129(6):749-758. https://doi.org/10.1016/j.ajodo.2006.02.021
19. Baysal A, Uysal T, Veli I, Ozer T, Karadede I, Hekimoglu S. Evaluation of alveolar bone loss following rapid maxillary expansion using cone-beam computed tomography. Korean J Orthod. 2013;43(2):83-95. https://doi.org/10.4041/kjod.2013.43.2.83
20. Akin M, Akgul YE, Ileri Z, Basciftci FA. Three-dimensional evaluation of hybrid expander appliances: a pilot study. Paper presented at: XIII Congress of the Turkish Orthodontic Society; November 3-5, 2013; Istanbul, Turkey.
21. Ludwig B, Glasl B, Bowman SJ, Wilmes B, Kinzinger GS, Lisson JA. Anatomical guidelines for miniscrew insertion: palatal sites. J Clin Orthod. 2011;45(8):433-441.
22. Lin L, Ahn HW, Kim SJ, Moon SC, Kim SH, Nelson G. Tooth-borne vs bone-borne rapid maxillary expanders in late adolescence. Angle Orthod. 2015;85(2):253-262. https://doi.org/10.2319/030514-156.1
23. Cuy JL, Mann AB, Livi KJ, Teaford MF, Weihs TP. Nanoindentation mapping of the mechanical properties of human molar tooth enamel. Arch Oral Biol. 2002;47(4):281-291. https://doi.org/10.1016/S0003-9969(02)00006-7
24. Pascotto RC, de Lima Navarro MF, Capelozza Filho L, Cury JA. In vivo effect of a resin-modified glass ionomer cement on enamel demineralization around orthodontic brackets. Am J Orthod Dentofacial Orthop. 2004;125(1):36-41. https://doi.org/10.1016/S0889-5406(03)00571-7
25. Torres CRG, Rosa PCF, Ferreira NS, Borges AB. Effect of caries infiltration technique and fluoride therapy on microhardness of enamel carious lesions. Oper Dent. 2012;37(4):363-369. https://doi.org/10.2341/11-070-L
26. Zheng J, Huang Y, Qian LM, Zhou ZR. Nanomechanical properties and microtribological behaviours of human tooth enamel. Proc Inst Mech Eng J. 2010;224(6):577-587. https://doi.org/10.1243/13506501JET693
27. Herkströter FM, Witjes M, Ruben J, Arends J. Time dependency of microhardness indentations in human and bovine dentine compared with human enamel. Caries Res. 1989;23(5):342-344. https://doi.org/10.1159/000261203
28. Birdsall J, Robinson S. A case of severe caries and demineralisation in a patient wearing an Essix-type retainer. Prim Dent Care. 2008;15(2):59-61. https://doi.org/10.1308/135576108784000203