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Incidence of Mucosal Lesions and Pain During Orthodontic Treatment with Fixed versus Removable Orthodontic Appliances

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Abstract

Aim: This study aimed to compare the incidence of mucosal lesions and pain during orthodontic treatment with fixed versus removable orthodontic appliances.
Methods: This cross-sectional study involved 58 patients with fixed orthodontic appliances and 58 patients with removable orthodontic appliances, all aged between 15 and 30 years. The presence and location of lesions were recorded at two time points: two weeks and four weeks after the start of the study. Additionally, the level of pain experienced by the patients was quantified at these same time points using a Visual Analog Scale (VAS). The Chi-square test was used to compare the frequency of oral lesions between the two groups at the onset of treatment. The Kruskal-Wallis test was used to compare the pain score at the onset of treatment between the two groups. The level of significance was set at 0.05.
Results: The frequency of traumatic lesions at two and four weeks was significantly higher in the fixed group (P<0.050). The frequency of traumatic and allergic lesions increased with time in both groups (P<0.050). Lichenoid reactions, candidiasis, and exophytic lesions were only detected in the removable treatment group. At two and four weeks, the frequency of lesions in the buccal mucosa was significantly higher than in other areas in the fixed group (P<0.050). At four weeks, the pain score of patients was higher in the fixed treatment group (P<0.050).
Conclusion: At four weeks, the frequency of lesions was higher in the fixed group. Buccal mucosa was the most common location of lesions in both groups. Pain in the fixed group was higher than the removable group at four weeks.

Keywords: Orthodontic appliances, removable, orthodontics, corrective, mouth mucosa, pain

Background

Orthodontic patients may require fixed or removable orthodontic appliances according to the clinical judgment of their clinician and severity of their malocclusion. It has been reported that 40% to 62.4% of the general population require orthodontic treatment (1, 2). Due to enhanced public knowledge about the advantages of orthodontic treatment, the number of individuals seeking orthodontic treatment has considerably increased in the past two decades (2). Orthodontic treatment significantly enhances both physiological and mental health, improves masticatory function, and boosts dental and facial aesthetics. Furthermore, it contributes positively to an

individual's psychosocial well-being. Nonetheless, it may lead to complications such as root resorption, caries, gingival/periodontal problems, allergic stomatitis, systemic metal accumulation, and iatrogenic damage during bracket removal and elimination of residual adhesive from the enamel surface (3). Components of fixed orthodontic appliances such as brackets may have an unesthetic appearance and cause functional limitations, discomfort, and pain in the course of treatment, adversely affecting the oral health related quality of life of patients (4-6).

Pain and discomfort are the most common, yet challenging, complications of orthodontic treatment (7). The severity of orthodontic pain is comparable to pain due to a bee sting or foot strain (8). It has been reported that 87% to 95% of adolescents experience pain in the course of fixed orthodontic treatment especially in the first 24 hours. Moreover, 39% to 49% of orthodontic patients experience pain after each step of appliance activation or after appliance removal (9). Thus, pain is a main inhibiting factor in orthodontic treatment, which decreases patient cooperation and can even lead to discontinuation of treatment (7, 8). Despite its significance, orthodontic pain has not been paid sufficient attention in research and practice (10). Orthodontists usually underestimate orthodontic pain and are not often sure whether and when they should prescribe analgesics for their patients (7-10).

Oral ulcers and lesions may develop on the oral mucosa and lips following the orthodontic treatment onset due to the presence of orthodontic brackets, bands, archwires, and long-term use of elastics with no wire support (11). Moreover, mucosal irritation may occur due to unwanted muscle movements in the buccal mucosa and tongue (12). Although such lesions are temporary and may be insignificant to orthodontists, they can decrease patient compliance to treatment and cooperation.

Clinical and historical features surround the diagnosis profile of oral lesions, making them identifiable to clinicians and orthodontists. However, these symptoms can make an accurate diagnosis difficult, potentially explaining the frequent delay in early treatment (13, 14). The psychosocial properties of pain are more noticeable in patients who are reluctant to undergo orthodontic treatment (15). Active patient cooperation in all steps of orthodontic treatment is imperative for a successful outcome (16).

The available literature on the pain and discomfort of orthodontic patients is limited and not free from methodological errors (17). Some studies had a small sample size (8, 18, 19), and some had a retrospective design (20) or had a short duration (8, 21). Also, controversy exists regarding the magnitude and duration of orthodontic pain reported in short-term and long-term studies (17). Impellizzeri et al. (22) found that over 75% of patients with orthodontic appliances had oral ulcers and aphthous or traumatic lesions. Baricevic et al. (23) reported a higher frequency of oral mucosal lesions in orthodontic patients compared with a control group with malocclusion. Another study; however, indicated a higher rate of oral mucosal inflammation in the control group with malocclusion than in the patient group with orthodontic appliances (24). Mainali (25) demonstrated that the majority of oral ulcers in orthodontic patients were traumatic ulcers, which could be largely prevented by the correct use of orthodontic appliances.

Considering the flaws of the available literature on this topic, and limited studies available on pain and discomfort in patients using removable orthodontic appliances, this study aimed to evaluate the frequency of oral mucosal lesions in wearers of fixed orthodontic appliances in comparison to those wearing removable orthodontic appliances.

Methods

1.1. Study design

This cross-sectional study was conducted on orthodontic patients presenting to the School of Dentistry, Mazandaran University of Medical Sciences in 2021-2022. The study protocol was approved by the ethics committee of the University (IR.MAZUMS.REC.1401.14510). The participants were selected from among those treated with both fixed and removable orthodontic appliances. After obtaining the ethical consent form to participate in the study from either the patient or the patient's parents, they were included in the study.

1.2. Setting

The study included all orthodontic patients aged between 15 and 30 years who used fixed or removable orthodontic appliances for treatment at the Mazandaran University of Medical Sciences between 2021-2022. Orthodontic treatment was conducted by experienced orthodontists according to standard protocols tailored for each patient.

1.3. Participants

The criteria for inclusion were as follows: individuals aged between 15 and 30 years, no presence of systemic diseases such as disorders of

the hematological or immune systems, no autoimmune or connective tissue diseases, no consumption of any medications, and non-use of tobacco.

Patients were assigned to two groups for either fixed or removable orthodontic treatment based on the clinical judgment of their orthodontist. Written informed consent was obtained from all patients or their parents/legal guardians (for those under 18 years), and they were assured about the confidentiality of their information. Orthodontic treatment was conducted by experienced orthodontists according to standard protocols, with strict adherence to the principles of adaptation of orthodontic wires and springs. Measures were also taken to prevent mucosal lesions during orthodontic treatment, such as smoothing the surface of appliances using special waxes and prescribing soothing mouthwashes (26). An oral medicine specialist clinically examined the oral mucosa of patients at the onset of treatment and at two and four weeks later using a dental mirror and an explorer. Clinical diagnoses of lesions, including aphthous ulcers, traumatic ulcers, allergic ulcers, recurrent intraoral herpetic lesions, oral mucosal lichenoid reactions, candidiasis, and exophytic lesions (reactive fibroma, pyogenic granuloma), were made according to clinical criteria and guidelines at the onset of treatment and at two and four weeks later, and recorded. The location of lesions was also recorded. If a lesion did not resolve after two weeks, further investigations were carried out.

1.4. Data sources/ measurement

The patients' levels of pain and discomfort were evaluated using a 10 cm Visual Analog Scale (VAS), where a score of zero indicated no pain and a score of 10 represented maximum pain. The VAS pain scores were documented at the beginning of the treatment, and then again at two weeks and four weeks after the onset of treatment. The results were subsequently recorded (26).

1.5. Study size

A group of 116 orthodontic patients who underwent both fixed and removable treatments was selected for this study. This sample size was determined based on an alpha error probability of 0.05, power of 0.80, allocation ratio of 0.271, and effect size of 0.58, which are the requirements for the Wilcoxon-Mann-Whitney test.

1.6. Statistical methods

Data were analyzed using the software SPSS, version 22 (SPSS Inc., IL, USA). The normal distribution of data was evaluated using the Kolmogorov-Smirnov tests. Based on these results, the chi-square test was used to compare the frequency of oral lesions between the two groups at the onset of treatment. The Kruskal-Wallis test was used to compare the pain score at the onset of treatment between the two groups. The level of significance was set at 0.05.

Results

A total of 116 patients participated in this study including 49 males (42.2%) and 67 females (57.8%). The Mean±SD age of participants was 21.62±4.36 years (range: 15 to 30 years).

According to the results of the Kolmogorov-Smirnov test, all the data studied exhibited a non-normal distribution (P<0.050).

Table 1 presents the frequency of various oral lesions and pain scores in the two groups at the onset of treatment, as well as two and four weeks after treatment.

The results showed no significant difference between the two groups in the frequency of oral lesions and pain score at the onset of treatment (P>0.050).

At two weeks after the onset of treatment (Table 1), a significant difference was found between the two groups regarding the frequency of traumatic ulcers and their location (P>0.050). No other significant difference was noted (P>0.050). Absence of lesion had a significantly higher frequency in the removable treatment group (P>0.050). In both groups, the majority of lesions were located in the buccal mucosa. However, the prevalence of lesions was significantly higher in the fixed treatment group (P>0.050). Absence of traumatic lesions had a significantly higher frequency in the removable treatment group (P>0.050).

At four weeks after the onset of treatment (Table 1), significant differences existed between the two groups regarding the location and frequency of traumatic ulcers and pain score (P<0.050). No other significant differences were found (P>0.050). The mean pain score was significantly higher in the fixed treatment group (P<0.050). Absence of traumatic lesions had a significantly higher frequency in the removable treatment group (P<0.050).

Table 1 presents the frequency of different lesions at the onset of treatment and at two and four weeks later in the two groups of fixed and removable orthodontic treatment. As shown, the frequency of traumatic and allergic lesions increased with time in both groups. Candidiasis,

exophytic lesions, and lichenoid reactions were only seen in the removable treatment group.

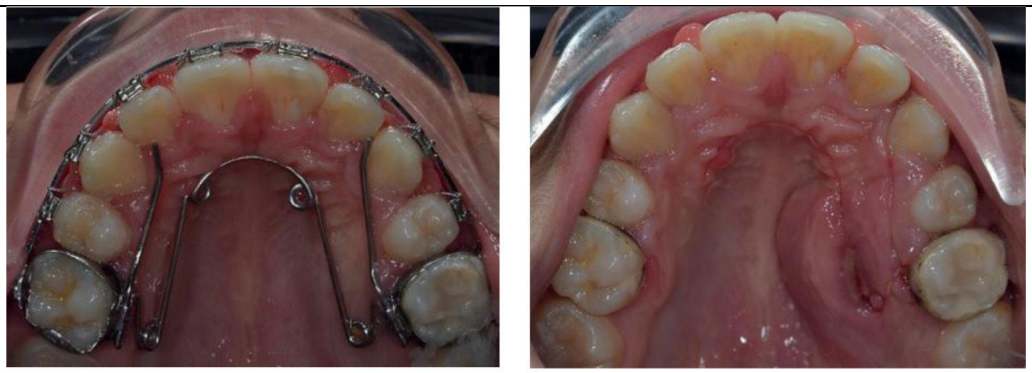
Figure 1 shows the mean pain score in the two groups at different time points. As shown, the mean pain score in the removable treatment group was the highest at two weeks after the onset of treatment. The mean pain score in the fixed treatment group was almost the same at two and four weeks after the onset of treatment. Figures 1 to 4 show clinical intraoral manifestations of some of the lesions.

Table 1. The frequency of various oral lesions and pain scores in the two groups

Variable		Fixed group (n=58)			Removable group (n=58)			P-value		
		Onset of treatment	Two weeks	Four weeks	Onset of treatment	Two weeks	Four weeks	Onset of treatment	Two weeks	Four weeks
Location N (%)	No lesion	52 (89.65)	21 (36.20)	21 (37.93)	54 (93.10)	36 (62.06)	28 (48.27)	0.577	0.001	0.003
	Gum	1 (1.72)	4 (6.89)	3 (5.17)	0 (0.00)	6 (10.34)	4 (6.89)			
	Buccal mucosa	1 (1.72)	7 (12.06)	20 (34.48)	4 (6.89)	24 (41.37)	7 (12.06)			
	Palate	1 (1.72)	0 (0.00)	0 (0.00)	0 (0.00)	5 (8.62)	8 (13.79)			
	Oral floor	0 (1.72)	1 (1.72)	2 (3.44)	1 (1.72)	2 (3.44)	3 (5.17)			
	More than one lesion	1 (1.72)	7 (12.06)	11 (18.96)	3 (5.17)	3 (5.17)	8 (13.79)			
	P-value		0.352			0.502				
Aphthous N (%)	Absence	54 (93.10)	53 (91.37)	54 (93.10)	56 (96.55)	56 (96.55)	53 (91.37)	0.679	0.437	0.999
	Presence	4 (6.89)	5 (8.62)	4 (6.89)	2 (3.44)	2 (3.44)	4 (6.89)			
	P-value		0.999			0.999				
Traumatic N (%)	0	57 (98.27)	23 (39.65)	25 (43.10)	57 (98.27)	47 (81.03)	46 (79.31)	0.999	0.001	0.001
	1	1 (1.72)	35 (60.34)	33 (56.89)	1 (1.72)	11 (18.96)	12 (20.68)			
	P-value		0.003			0.001				
Allergic N (%)	0	58 (100.0)	52 (89.95)	51 (87.93)	57 (98.27)	55 (94.82)	50 (86.20)	0.999	0.490	0.999
	1	0 (0.0)	6 (10.34)	7 (12.06)	1 (1.72)	3 (5.17)	8 (13.79)			
	P-value		0.409			0.999				
Herpetic N (%)	0	56 (96.55)	57 (98.27)	57 (98.27)	57 (98.27)	56 (96.55)	53 (91.37)	0.999	0.999	0.206
	1	2 (3.44)	1 (1.72)	1 (1.72)	1 (1.72)	2 (3.44)	5 (8.62)			
	P-value		0.469			0.342				
Lichenoid reaction N (%)	0	58 (100.0)	58 (100.0)	58 (100.0)	58 (100.0)	56 (96.55)	55 (94.82)	0.999	0.496	0.243
	1	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	2 (3.44)	3 (5.17)			
	P-value		0.999			0.075				
Candidiasis N (%)	0	58 (100.0)	58 (100.0)	58 (100.0)	58 (100.0)	57 (98.27)	53 (91.37)	0.999	0.999	0.057
	1	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	1 (1.72)	5 (8.62)			
	P-value		0.999			0.999				
Exophytic N (%)	0	58 (100.0)	58 (100.0)	58 (100.0)	58 (100.0)	56 (96.55)	57 (98.27)	0.999	0.496	0.999
	1	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	2 (3.44)	1 (1.72)			
	P-value		0.999			0.999				
Pain	Mean±SD	1.07±0.37	4.21±2.05	4.24±1.79	1.12±0.49	4.19±1.70	2.74±1.35	0.129	0.961	0.001
	P-value		0.129			0.001				

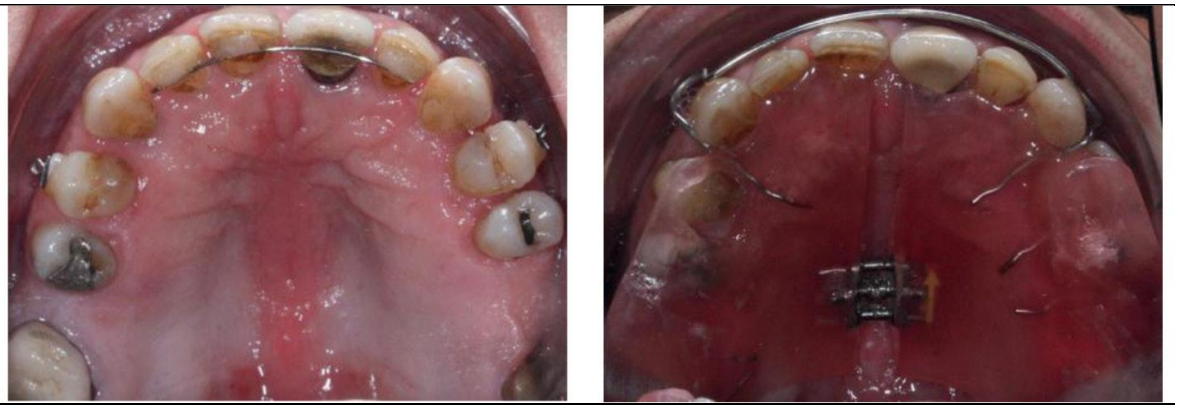
The average pain experienced at three specific times (at the start of treatment, two weeks post-treatment, and four weeks post-treatment) is categorized by the type of orthodontic treatment used. The group that received removable orthodontics reported the highest average pain two weeks after the start of treatment. In contrast, the group that received fixed orthodontics reported a relatively consistent level of average pain at both two and four weeks after treatment began.

Figure 1. Reactive keratosis at the end of a NiTi archwire



a b

Figure 2. Traumatic ulcer due to a quad-helix at the site of tooth #26; (a) appliance at the site; (b) traumatic ulcer in the left side of the palate



a

Figure 3. Hyperplasia and erythema caused by a palatal plate

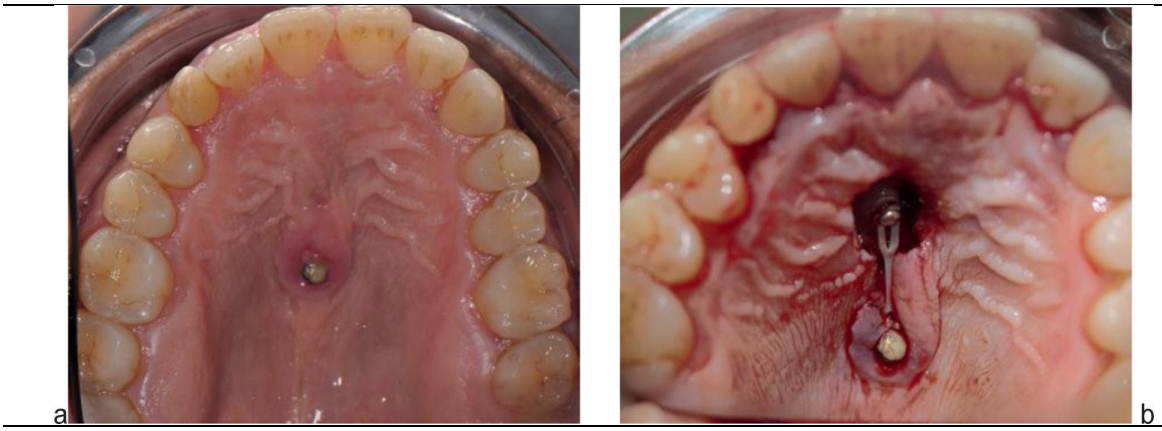


Figure 4. (a) Hyperplasia around the head of a miniscrew; (b) hyperplasia is aggravated after the placement of the elastic

Discussions

This study compared the incidence of mucosal lesions and pain during orthodontic treatment with fixed versus removable orthodontic appliances. The results showed no significant difference in the frequency of lesions at the treatment onset between the two groups. At two and four weeks, the frequency of traumatic lesions in the fixed treatment group was significantly higher than that in the removable group. The incidence of both traumatic and allergic lesions increased over time in both groups. Additionally, lichenoid reactions, candidiasis, and exophytic lesions were observed exclusively in the group receiving removable treatment.

Rodríguez-Rentería et al. (27) assessed the load of pathogenic microorganisms on the oral mucosa of 55 patients between 6-12 years with removable orthodontic appliances and found that the frequency of candida species increased at four weeks after using removable orthodontic appliances. A direct correlation was also found between the use of removable appliances and an increased count of periodontal pathogens. Their results were in line with the present findings. The higher frequency of candidiasis lesions can be attributed to the structure of removable appliances, which provides a surface for greater retention of microorganisms and is in continuous contact with the oral mucosa. Gupta et al. (28) evaluated the prevalence of oral lesions in 60 Indian patients under fixed orthodontic treatment and 60 patients using removable appliances (aged 15 to 30 years). They found that ulcers and desquamation were mainly due to fixed orthodontic appliances such as brackets, bracket hooks, trans-palatal arch, lingual arch, and distal end of wires while inflammation and atrophic lesions were more common under the acrylic parts of removable orthodontic appliances. Similar to the study by Gupta et al., (28) traumatic lesions were more prevalent in fixed orthodontic patients in the present study while the frequency of lichenoid, candidiasis, and exophytic lesions was higher in the removable treatment group. Rashidi et al., (26) in their study on 56 orthodontic patients in Iran assessed the frequency of aphthous ulcers, allergic ulcers, lichenoid reactions, exophytic lesions, traumatic ulcers, recurrent intraoral herpetic lesions, and candidiasis at the onset of treatment and two and four weeks later. They reported an increase in the frequency of lesions after two weeks, and this increase in frequency was significant for all lesions, except for the lichenoid reactions, recurrent intraoral herpetic lesions, and candidiasis. The frequency of allergic ulcers, exophytic and traumatic lesions, and recurrent aphthous ulcers increased at four weeks after treatment compared with before treatment, and this increase was significant for exophytic and traumatic lesions (26). Consistent with their results, the frequency of traumatic and allergic lesions increased in fixed orthodontic patients at four weeks after the treatment onset in the present study. However, in contrast to the study by Rashidi et al., (26) no exophytic or lichenoid lesion was seen in fixed orthodontic patients, and the frequency of herpetic lesions decreased in the present study. Differences in the results can be due to different sample sizes.

At the onset of treatment, no significant difference existed between the two groups in the frequency of lesions at different locations (gingiva, buccal mucosa, palate, floor of the mouth, multiple sites) in the present study. At two weeks, a significant difference existed in this regard between the two groups. In both groups, buccal mucosa was the most common site of involvement but in the

fixed treatment group, the frequency of lesions in the buccal mucosa was significantly higher than that in other areas. The difference in the location of lesions was also significant between the two groups at four weeks. In the fixed treatment group, the buccal mucosa was the most commonly involved site. Baseer et al., (29) in Saudi Arabia assessed oral indices during fixed and removable orthodontic treatment. They assessed 150 adults in fixed (n=118) and removable (n=32) treatment groups one week after activation of appliances. The frequency of tongue and buccal ulcers was significantly higher in the fixed orthodontic treatment group, which can be due to greater contact of the mucosa with fixed orthodontic appliances such as metal brackets, distal end of archwires, and bands at these sites, which irritate the mucosa and causes ulceration (28). Similarly, the majority of lesions were noted in the buccal mucosa in the present study. This finding was in agreement with the results of Baricevic et al., (23) and Travess et al., (30) who reported that ulcerative lesions develop in fixed orthodontic patients due to mucosal irritation by orthodontic appliances.

At the onset of treatment and also after two weeks, the pain score was not significantly different between the fixed and removable treatment groups in the present study. However, after four weeks, the pain score was significantly higher in the fixed treatment group. Within-group comparison of pain scores revealed the highest pain at two weeks in the removable treatment group. In the fixed treatment group, the pain score was almost the same at two and four weeks. Literature is controversial regarding the pain score of patients under fixed and removable orthodontic treatment. Baseer et al. (29) reported that fixed orthodontic patients had a significantly higher pain score one week after activation of appliances compared with the removable treatment group. Consistent with their findings, the present study showed a significantly higher pain score in the fixed treatment group at four weeks. Baseer et al., (29) also found that the perceived pain in the fixed orthodontic patients in the first three days following the treatment onset was the highest, and maximum pain was experienced on day two. However, in contrast to their study, Alajmi et al. (31) reported similar levels of pain in fixed and removable orthodontic treatment groups. Wiedel and Bondemark (32) reported mild to moderate pain in both fixed and removable orthodontic treatment groups. Differences in the results can be due to several factors. The level of pain is often measured by a VAS or a similar tool, which are all subjective measures and are self-reported by patients. Also, the pain perception threshold of patients may vary, and is affected by racial and cultural factors. Thus, controversial results may be reported regarding perceived pain in different populations. Moreover, differences in sample size and sex distribution may affect the results since males may experience lower levels of pain than females. Rakhshan and Rakhshan (17) in their study on 67 Iranian patients between 18 to 32 years under fixed orthodontic treatment reported variable levels of pain in different areas at four weeks after the treatment onset. Rashidi et al., (26) also reported an increase in pains core at four weeks after the treatment onset compared with baseline (before the initiation of treatment). Similarly, the present study reported pain at both two and four weeks after the treatment onset in the fixed orthodontic treatment group. The research conducted by Bahrami et al. demonstrates a significant reduction in polymicrobial periopathogenic biofilms when subjected to treatments that utilize reactive oxygen species (ROS) and 0.2% chlorhexidine (CHX), in comparison to a control group. It is crucial to acknowledge that while CHX treatment is patient-centric, it can result in several side effects (33). These side effects may encompass discoloration of teeth and the top of the tongue, a sensation of oral dryness, and a feeling of burning (34). Broadly speaking, the results of research indicate that all treatments, including aSDT, aPDT, aPSDT, and CHX, are classified as anti-biofilm. These treatments have been found to decrease the quantity of periodontal pathogen bacteria biofilms by a minimum of 3 Log10 steps in comparison to the control group. Considering the limited surface area of the miniscrew head, a reduction of 2 Log10 is considered to be acceptable (35). On the other hand, research conducted by Pourhajibagher et al. suggests that removable orthodontic appliances made from polymethylmethacrylate (PMMA) and enhanced with nanoresveratrol (NR) could potentially serve as an effective new type of orthodontic acrylic resin. This material has been observed to be particularly effective against multispecies microbial biofilms, especially when subjected to light-emitting diode (LED) and ultrasound waves (UW) (36). Research has demonstrated that the expression of pro-inflammatory cytokine genes and the antibacterial activity of antimicrobial photo-sonodynamic therapy (aPSDT) are influenced by NR against multispecies microbial biofilms (37-40). These findings underscore the need for comprehensive research using an animal model. Future experiments with animal models and clinical trials will further elucidate the relationship

between the anti-biofilm and anti-inflammatory effects of new devices utilized in orthodontics.

The small sample size, unequal sex distribution, and unequal age distribution of patients in the two groups were the main limitations of the present study. Similar future studies with a larger sample size and standardized age and sex distribution in the two groups are recommended for other races and ethnic groups. Also, oral hygiene status and gingival health status of patients should be considered in future studies.

Conclusion

Over time, both the fixed and removable treatment groups experienced an increase in the frequency of traumatic and allergic lesions. By the 4-week mark, the fixed group had a higher frequency of lesions compared to the removable group. The most common location for lesions in both groups was the buccal mucosa. Furthermore, at four weeks, the level of pain reported in the fixed group was greater than that in the removable group.

References

1. al-Emran S, Wisth PJ, Böe OE. Prevalence of malocclusion and need for orthodontic treatment in Saudi Arabia. Community Dent Oral Epidemiol. 1990;18(5):253-5. doi: 10.1111/j.1600-0528.1990.tb00070.x. PMID: 2249408.
2. Haralur SB, Addas MK, Othman HI, Shah FK, El-Malki AI, Al-Qahtani MA. Prevalence of malocclusion, its association with occlusal interferences and temporomandibular disorders among the Saudi sub-population. Oral Health Dent Manag. 2014;13(2):164-9. PMID: 24984617.
3. Amini F, Rakhshan V, Mesgarzadeh N. Effects of long-term fixed orthodontic treatment on salivary nickel and chromium levels: a 1-year prospective cohort study. Biol Trace Elem Res. 2012;150(1-3):15-20. doi: 10.1007/s12011-012-9457-y. PMID: 22644664.
4. Doll GM, Zentner A, Klages U, Sergl HG. Relationship between patient discomfort, appliance acceptance and compliance in orthodontic therapy. J Orofac Orthop. 2000;61(6):398-413. English, German. doi: 10.1007/pl00001908. PMID: 11126015.
5. Jawaid M, Qadeer TA. Assessment of the changes in the oral health related quality of life 24 hours following insertion of fixed orthodontic appliance components - An observational cross-sectional study conducted at Bahria University Medical and Dental College Karachi. J Pak Med Assoc. 2019;69(5):677-683. PMID: 31105287.
6. Mansor N, Saub R, Othman SA. Changes in the oral health-related quality of life 24 h following insertion of fixed orthodontic appliances. J Orthod Sci. 2012;1(4):98-102. doi: 10.4103/2278-0203.105880. PMID: 24987635;
7. Krishnan V. Orthodontic pain: from causes to management--a review. Eur J Orthod. 2007;29(2):170-9. doi: 10.1093/ejo/cjl081. PMID: 17488999.
8. Bergius M, Berggren U, Kiliaridis S. Experience of pain during an orthodontic procedure. Eur J Oral Sci. 2002;110(2):92-8. doi: 10.1034/j.1600-0722.2002.11193.x. PMID: 12013568.
9. Xiaoting L, Yin T, Yangxi C. Interventions for pain during fixed orthodontic appliance therapy. A systematic review. Angle Orthod. 2010;80(5):925-32. doi: 10.2319/010410-10.1. PMID: 20578865
10. Sandhu SS, Sandhu J. Orthodontic pain: an interaction between age and sex in early and middle adolescence. Angle Orthod. 2013;83(6):966-72. doi: 10.2319/030113-174.1. PMID: 23705940
11. Kvam E, Bondevik O, Gjerdet NR. Traumatic ulcers and pain in adults during orthodontic treatment. Community Dent Oral Epidemiol. 1989;17(3):154-7. doi: 10.1111/j.1600-0528.1989.tb00012.x. PMID: 2736897.
12. Profit WR. Orthodontic treatment planning: Limitations, controversies and special problems. Contemporary orthodontics. 2007.
13. Shiva A, Sobouti F. Comparative study of histopathological reports and clinical diagnosis of oral biopsies. Journal of Mazandaran University of Medical Sciences. [in persian].2017;26(144):57-64.
14. Shiva A, Nosrati K. A calcifying odontogenic cyst associated with complex odontoma: a case report. [in persian].Journal of Babol University of Medical Sciences. 2015;17(2):57-61.
15. Campos LA, Santos-Pinto A, Marôco J, Campos J. Pain perception in orthodontic patients: A model considering psychosocial and behavioral aspects. Orthodontics & craniofacial research. 2019;22(3):213-21. doi: 10.1111/ocr.12315.
16. Story RI. Psychological issues in orthodontic practice. Am J Orthod. 1966;52(8):584-98. doi: 10.1016/0002-9416(66)90139-4. PMID: 5220745.
17. Rakhshan H, Rakhshan V. Pain and discomfort perceived during the initial stage of active fixed orthodontic treatment. Saudi Dent J. 2015;27(2):81-7. doi: 10.1016/j.sdentj.2014.11.002. PMID: 26082574.
18. Fujita K. New orthodontic treatment with lingual bracket mushroom archwire appliance. Am J Orthod. 1979;76(6):657-75. doi: 10.1016/0002-9416(79)90211-2. PMID: 293135.
19. 19. Sinclair PM, Cannito MF, Goates LJ, Solomos LF, Alexander CM. Patient responses to lingual appliances. J Clin Orthod. 1986;20(6):396-404. PMID: 3461002.
20. Miyawaki S, Yasuhara M, Koh Y. Discomfort caused by bonded lingual orthodontic appliances in adult patients as examined by retrospective questionnaire. Am J Orthod Dentofacial Orthop. 1999;115(1):83-8. doi: 10.1016/s0889-5406(99)70320-3. PMID: 9878962.
21. Ngan P, Kess B, Wilson S. Perception of discomfort

by patients undergoing orthodontic treatment. Am J Orthod Dentofacial Orthop. 1989;96(1):47-53. doi: 10.1016/0889-5406(89)90228-x. PMID: 2750720.
22. Impellizzeri A, Samà R, Di Giorgio R, Barbato E, Galluccio G. Control of oral hygiene in the orthodontic patient: comparison between public facility and private practice. Annali di Stomatologia. 2018;9(1):43-52. doi: 10.59987/ads/2018.1.43-52.
23. Baricevic M, Mravak-Stipetic M, Majstorovic M, Baranovic M, Baricevic D, Loncar B. Oral mucosal lesions during orthodontic treatment. Int J Paediatr Dent. 2011;21(2):96-102. doi: 10.1111/j.1365-263X.2010.01078.x. PMID: 21121986.
24. Baranović M, Stipetić MM, Baričević D, Baranović M, Čimić A, Blažević A. Oral Mucosa Status of Patients Undergoing Orthodontic Treatment. Acta Stomatologica Croatica. 2009;43(2).
25. Mainali A. Occurrence of oral ulcerations in patients undergoing orthodontic treatment: A comparative study. Orthodontic Journal of Nepal. 2013;3(2):32-5. doi: 10.3126/ojn.v3i2.10075.
26. Rashidi MF, Omrani A, Aliyari L, Sarrafzadeh H. Prevalence of Oral Mucosal Lesions in Patients Undergoing Fixed Orthodontic Treatment in The Orthodontic Department of Faculty of Dentistry, Islamic Azad University Isfahan (Khorasgan) Branch During 2010-11.[in persian]. Journal of Isfahan Dental School. 2017;12(4):349-57.
27. Rodríguez-Rentería M, Márquez-Preciado R, Ortiz-Magdaleno M, Bermeo-Escalona J, Sánchez-Vargas LO. Frequency of Pathogenic Microorganisms in Removable Orthodontic Appliances and Oral Mucosa in Children. J Clin Pediatr Dent. 2021;45(2):135-139. doi: 10.17796/1053-4625-45.2.11. PMID: 33951170.
28. Gupta R, Mahajan N, Jandial S, Kotwal B, Kaur S, Kharyal S. Incidence of oral ulcers in patients undergoing orthodontic treatment. International Journal of Preventive and Public Health Sciences. 2017;3(2):31-4.
29. Baseer MA, Almayah NA, Alqahtani KM, Alshaye MI, Aldhahri MM. Oral Impacts Experienced by Orthodontic Patients Undergoing Fixed or Removable Appliances Therapy in Saudi Arabia: A Cross-Sectional Study. Patient Prefer Adherence. 2021;15:2683-2691. doi: 10.2147/PPA.S343084. PMID: 34880603
30. Travess H, Roberts-Harry D, Sandy J. Orthodontics. Part 6: Risks in orthodontic treatment. Br Dent J. 2004;196(2):71-7. doi: 10.1038/sj.bdj.4810891. PMID: 14739957.
31. Alajmi S, Shaban A, Al-Azemi R. Comparison of Short-Term Oral Impacts Experienced by Patients Treated with Invisalign or Conventional Fixed Orthodontic Appliances. Med Princ Pract. 2020;29(4):382-388. doi: 10.1159/000505459. PMID: 31842018.
32. Wiedel AP, Bondemark L. A randomized controlled trial of self-perceived pain, discomfort, and impairment of jaw function in children undergoing orthodontic treatment with fixed or removable appliances. Angle Orthod. 2016;86(2):324-30. doi: 10.2319/040215-219.1. PMID: 26185899.
33. Bahrami R, Pourhajibagher M, Parker S, Esmaeili D, Bahador A. Anti-biofilm and bystander effects of antimicrobial photo-sonodynamic therapy against polymicrobial periopathogenic biofilms formed on coated orthodontic mini-screws with zinc oxide nanoparticles. Photodiagnosis Photodyn Ther. 2023;41:103288. doi: 10.1016/j.pdpdt.2023.103288. PMID: 36640857.
34. Poppolo Deus F, Ouanounou A. Chlorhexidine in Dentistry: Pharmacology, Uses, and Adverse Effects. Int Dent J. 2022;72(3):269-277. doi: 10.1016/j.identj.2022.01.005. PMID: 35287956.
35. Cieplik F, Aparicio C, Kreth J, Schmalz G. Development of standard protocols for biofilm-biomaterial interface testing. JADA Foundational Science. 2022;1:100008. doi: 10.1016/j.jfscie.2022.100008.
36. Pourhajibagher M, Bahrami R, Bazarjani F, Bahador A. Anti-multispecies microbial biofilms and anti-inflammatory effects of antimicrobial photo-sonodynamic therapy based on acrylic resin containing nano-resveratrol. Photodiagnosis Photodyn Ther. 2023;43:103669. doi: 10.1016/j.pdpdt.2023.103669. PMID: 37356699.
37. Al-Thobity AM, Gad MM. Effect of silicon dioxide nanoparticles on the flexural strength of heat-polymerized acrylic denture base material: A systematic review and meta-analysis. Saudi Dent J. 2021;33(8):775-783. doi: 10.1016/j.sdentj.2021.08.008. PMID: 34938017.
38. Pourhajibagher M, Bahador A. Antimicrobial properties, anti-virulence activities, and physico-mechanical characteristics of orthodontic adhesive containing C-phycocyanin: a promising application of natural products. Folia Med (Plovdiv). 2021;63(1):113-121. doi: 10.3897/folmed.63.e52756. PMID: 33650404.
39. Tandra E, Wahyuningtyas E, Sugiatno E. The effect of nanoparticles TiO2 on the flexural strength of acrylic resin denture plate. Padjadjaran Journal of Dentistry. 2018;30(1):35-40. doi: 10.24198/pjd.vol30no1.16110.
40. Pourhajibagher M, Ahmadi H, Roshan Z, Bahador A. Streptococcus mutans bystander-induced bioeffects following sonodynamic antimicrobial chemotherapy through sonocatalytic performance of Curcumin-Poly (Lactic-co-Glycolic Acid) on off-target cells. Photodiagnosis Photodyn Ther. 2020;32:102022. doi: 10.1016/j.pdpdt.2020.102022. PMID: 33038486.