



Original Article

A Comparative Study of Proximal Caries Formation and Decay, Missing, Filled Teeth Scores in Clear Aligners and Fixed Orthodontic Treatments

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Main Points

- The total number of caries lesions increased with the use of fixed and clear aligner treatments.
- Clear aligners had no significant effect on reducing the risk of proximal caries compared with fixed orthodontic appliances.
- Fixed orthodontic treatment significantly increased the Decay, Missing, Filled Teeth (DMFT) score, whereas clear aligner therapy caused no statistical change in the DMFT scores.

ABSTRACT

Objective: This study aimed to evaluate proximal caries formation and Decay, Missing, Filled Teeth (DMFT) scores during clear aligner (CA) therapy compared with fixed orthodontic treatment.

Methods: A total of 50 patients with a mean age of 19.9 years were divided into two equal groups (n=25) according to treatment method. Both CA and fixed appliance (FA) patients had low-to-medium levels of crowding. Caries formation and DMFT scores were assessed via radiographic and clinical examination before treatment (T0) and at the end of a six-month observation period (T1). The numbers of caries lesions and fillings was analyzed using a Two-Way Analysis of Variance with a significance level of 0.05.

Results: Significant statistical differences were found for both groups ($p<0.001$). The amount of proximal caries significantly increased in both groups, whereas the increase in non-proximal caries was only statistically significant in the FA group. DMFT scores also increased significantly in both groups, with the FA group showing a higher increase at the end of the observation period.

Conclusion: Although CAs had an advantage in decreasing the overall risk of caries, no distinct advantage was found in reducing the risk of proximal caries lesions. The DMFT index was significantly higher in fixed orthodontic treatment patients than in CA treatment patients.

Keywords: Removable appliances, clear aligners, demineralization, fixed appliance, orthodontics

INTRODUCTION

Fixed orthodontic treatment with brackets, wires, and ligatures is associated with an increased risk of caries because it promotes saliva bacteria and plaque accumulation. Kiliçoğlu et al.¹ found that fixed devices, especially on molar surfaces, hinder proper oral hygiene, leading to an elevated risk of caries in inaccessible proximal areas. The proximal area is inaccessible for physiological cleansing, and the risk of caries lesions is elevated in this area when the patient lacks proper oral hygiene.²

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Difficulty in mechanical cleaning contributes to increased plaque accumulation. Consequently, neighboring teeth may experience demineralization on their contact surfaces.³

In contrast, clear aligners have a significant benefit in reducing the formation of new caries during orthodontic therapy. A recent review about the effects of different orthodontic appliances on periodontal health and oral flora stated that the majority of the literature showed that biofilm formation on clear aligners was less than that on fixed appliances because clear aligners could be removed and changed after a time period and patients treated with aligners showed better compliance in oral hygiene.⁴

Clear aligners, which require 20-22 hours of daily use, impede natural cleaning and remineralization mechanisms by preventing saliva flow onto teeth. Consequently, plaque accumulation occurs under the aligners, thereby affecting the oral flora.⁵⁻⁷

Although clear aligners reduce demineralization risk on buccal surfaces compared with fixed appliances, they may still lead to severe decay, periodontal issues, and even tooth loss. Proximal areas require thorough hygiene and may carry an increased caries risk.⁸

Previous studies mostly focused on white spot lesions and the total amount of caries lesion formations during clear aligner therapy,⁹ but no study has assessed the risk of proximal caries in patients using clear aligners.

The present study aimed to evaluate proximal caries formation and Decay, Missing, Filled Teeth (DMFT) scores during the first six months of clear aligner treatment compared with fixed orthodontic treatment. The null hypothesis is that approximal caries formation and DMFT scores do not differ between the two treatment modalities.

METHODS

This prospective study included 50 patients who sought orthodontic treatment at an Orthodontic Clinic of Kırıkkale University Faculty of Dentistry. Sample size estimation was performed using G-Power (Version 3.1.2., Franz Faul, Universitat-Kiel, Germany) based on a previous study investigating the effect of orthodontic treatment on the DMFT index and caries formation. With equal group sizes, an effect range of 0.40, and a significance level of 0.05, the power analysis indicated a power level of 0.80 for 50 patients.

Patients included in the study had permanent dentition, demonstrated the ability to maintain oral hygiene, and showed no signs of plaque buildup, inflammation, or spontaneous gingival bleeding. Additionally, they had moderate dental crowding between 2 and 5 mm. Patients were excluded if they exhibited increased caries activity, xerostomia, periodontal tissue loss, or advanced periodontal disease. Those with systemic diseases affecting oral tissues and saliva

flow, craniofacial syndromes, poor oral hygiene, or those who refused to provide informed consent were also excluded from the study.

This study was approved by Kırıkkale University Clinical Research Ethics Committee (approval no.: 05/01, date: 29.04.2021). Patients were informed about the study and treatment details before beginning treatment and signed informed consent forms, which were approved by the institutional review board. Patients were selected according to inclusion/exclusion criteria from two groups who consulted the Kırıkkale University Faculty of Dentistry, Clinic of Orthodontics for orthodontic treatment between the years 2021 to 2023:

Fixed Orthodontic Appliances (FA) Group: Twelve males and thirteen females (n=25) with a mean age of 17.7 years. Standard 0.022-inch slot metal brackets with MBT prescription (Master Series, American Orthodontics, Sheboygan, WI, USA), bondable molar tubes on first and second molars were used, along with standard wire sequencing. 0.016 and 0.019x0.025-inch heat activated thermal nickel-titanium and stainless-steel wires were used in order.

Clear Aligners (CA) Group: Twelve males and thirteen females (n=25) with a mean age of 21.8 years. Attachments were used selectively for tooth movements. Aligners were worn for at least 20 h per day with specific usage instructions.

Attachments were used only for specific tooth movement needs and for anchorage control in the CA group. Patients were asked to use their aligners for at least 20 h per day. The first two aligners were used for 15 days, and the rest of the single aligners were used for 10 days. Patients in both groups had mild to moderate crowding. None of the patients underwent orthodontic extractions or interproximal enamel reduction on the canines, premolars, or molars.

Pumice prophylaxis was administered, and standard oral hygiene instructions, including brushing three times a day, were given before appliance placement for all patients. The FA group used orthodontic toothbrushes and interdental brushes. They were advised to avoid foods that could damage fixed appliances.

The CA group avoided chewing while wearing aligners, brushed their teeth after meals, and cleaned the aligners with toothbrushes under running tap water. A single expert planned treatment for both groups, informing patients of the restrictions and disadvantages associated with each treatment system.

Records and Time Points

Before treatment (T0), we obtained cephalometric, panoramic, and bite-wing radiographs, intraoral and extraoral photographs, and 3D intraoral scanning models. Radiographs obtained at T0 and at the end of the observation period (T1) were used for caries assessment. The same phosphor-plate bite-wing radiographs (Primax RDX-58, Film Speed E, Berlin, Germany), panoramic device (Op 2D Panorex, Kavo, Germany), and

patient positioning were used for radiographic records. Only radiographs without irradiation, positioning, or procedural errors were used in this study.

The post-treatment records were collected with brackets and attachments, and treatment was continued after the observation period.

Radiographic Analysis

Radiographic classification was used for caries assessment. All radiolucent demineralization areas on radiographs were considered caries. An expert examiner randomly assessed all radiographic images and re-analyzed some of the radiographs to evaluate intraclass correlation coefficient (ICC). The assessment included decalcifications and fillings in the canines, premolars, and first and second molars. However, the mesial proximal faces of the canines and distal proximal sides of the second molars were excluded due to bite-wing film size limitations and inexact contact with the third molar teeth. The number and location of caries lesions were recorded and classified as proximal or non-proximal caries/fillings. Lesions observed at T0 were treated and considered fillings at T1. Secondary lesions around or under existing fillings were not recorded at T1; only newly formed lesions were included. To assess caries formation differences between groups, we used the World Health Organization-recommended DMFT index system as follows:

$$[DMFT = \{untreated\} + \{filling\} + \{missing\} + \{teeth\}]^{10}$$

Twenty percent of the total radiographs were reassessed after one month by the same examiner to analyze the methodological error.

Statistical Analysis

We performed statistical analyses using SPSS 24 (IBM Systems, USA). The normal distribution of data was verified using a Shapiro-Wilk test. Two-way analysis of variance (two-way ANOVA) with Bonferroni’s post-hoc test was used to assess the changes in proximal and non-proximal caries amounts and the DMFT score between the two groups at different time points. The ICC method was used to assess observer reliability. The significance level was set at 0.05.

RESULTS

The mean ICCs were 0.84 for the fixed treatment group (FA) and 0.88 for the clear aligner group (CA), indicating high consistency in radiographic assessment.

At the time of T1 examinations: Patients in the FA group had undergone orthodontic therapy for 15.7±13.9 months. Patients in the CA group had undergone orthodontic therapy for 15.2±14.1 months. Table 1 presents the sex-specific incidence. Table 2 presents the descriptive and statistical significance.

The increase in proximal caries amounts and the time-group interaction were statistically significant: [F (1, 48)=14.59, p<0.001]. Specifically, only the FA group exhibited a significant

increase after the observation period (p<0.001). No significant main effect of group was found: [F (1, 48)=0.785, p=0.38].

The number of non-proximal caries increased significantly in FA group: [F (1, 48)=24.3, p<0.001]. There was no significant interaction between time and group or main effect of group on parameters: [F (1, 48)=0.568, 0.455].

The mean DMFT score of the CA group increased by 0.52 points, whereas that of the FA group increased by 1.68 points after the observation period. The overall increase in DMFT scores was significant: [F (1)=30.250, p<0.001]. Both time and group had a significant effect on DMFT scores: [F (1, 48)=8.410, p<0.001]. The FA group exhibited a higher overall increase in DMFT scores after the observation period. For visual reference, Figure 1 illustrates the patterns of all analyzed parameters.

DISCUSSION

The current study revealed that clear aligners were not effective in decreasing the risk of proximal caries when

Table 1. Ratio of the number of new caries formations and fillings through the observation period to the total number of examined subjects (incidences) according to sex

Group	Caries type	Gender	N	Incidence
CA	Proximal	F	13	2.84
	Non-proximal	M	12	4
	Proximal	F	13	2.46
	Non-proximal	M	12	3.41
FA	Proximal	F	13	2.84
	Non-proximal	M	12	2.91
	Proximal	F	13	4.92
	Non-proximal	M	12	3.16

N, Number; CA, Clear Aligners;; FA, Fixed Orthodontic Appliances; F, Female; M, Male

Table 2. Caries lesion numbers according to time points and statistical significance

Variable	Group	Time	Mean	SD	p-value
Proximal caries + fillings	CA	T0	3.04	3.95	
		T1	3.4	4.09	
	FA	T0	2.16	2.44	**
		T1	2.88	2.32	
Non-proximal caries+ fillings	CA	T0	2.84	2.81	
		T1	2.92	2.9	
	FA	T0	3.28	3.54	**
		T1	4.08	3.55	
DMFT*	CA	T0	5.24	5.61	**
		T1	5.76	5.83	
	FA	T0	6.08	4.99	**
		T1	7.76	4.44	

*Significant main effect of the group (p<0.05)
 **Statistical significance between time points (p<0.05)
 SD, standard deviation; DMFT, Decay, Missing, Filled Teeth; CA, Clear Aligners; FA, Fixed Orthodontic Appliances

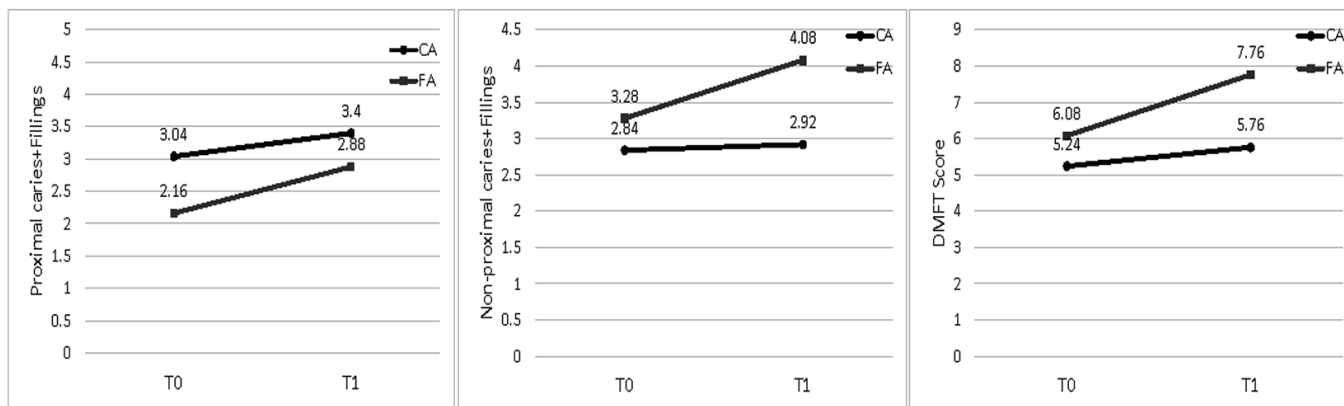


Figure 1. Changes in proximal and non-proximal caries and DMFT scores with the time DMFT, Decay, Missing, Filled Teeth; CA, Clear Aligners; FA, Fixed Orthodontic Appliances

compared with fixed orthodontic appliances. While previous studies highlighted the key advantages of clear aligners for reducing caries risk, most studies focused solely on buccal surfaces. However, the proximal areas pose greater challenges during oral hygiene applications, and the impact of the type of orthodontic appliance on these surfaces remains unclear.

The alteration of buccal enamel surface characteristics during fixed orthodontic treatment, including etching and resin bonding procedures, contrasts with clear aligner therapy.⁵ Unlike composite resin attachments placed only when needed in clear aligner therapy, fixed appliances exhibit a different pattern of bacterial colonization. This discrepancy may have contributed to the observed differences in caries risk between the two approaches.

The surface and chemical characteristics of adhesive materials used in traditional fixed orthodontic appliances and clear aligners significantly affect bacterial retention in the buccal areas.¹¹ As a result of microbiota changes, enamel demineralization, manifesting as white spot lesions, occurs in 2-97% of patients undergoing fixed orthodontic treatment.¹² Consistent with our findings, the fixed treatment group exhibited a significant increase in non-proximal caries due to plaque accumulation around appliances on the buccal surfaces. Several researchers have evaluated the concentrations of *Streptococcus mutans* and Lactobacilli in saliva, revealing that these bacterial counts peak around 12 weeks after the start of fixed orthodontic treatment.¹³⁻¹⁵

Mummolo et al.¹⁶ found that 40% of fixed appliance patients experienced increased demineralization after 6 months of treatment, necessitating more remineralization agents. In contrast, patients who underwent clear aligner implantation exhibited demineralization in only 10% and patients who underwent removable appliance implantation in 13.3% after the same duration.¹⁵

Interestingly, our findings indicated that fixed treatment increased the risk of non-proximal caries, whereas the risk of proximal caries remained relatively stable regardless of the

appliance used. Similarly, Sifakakis et al.¹⁷ no difference in the salivary counts of cariogenic bacteria was observed between adults treated with clear aligners or fixed appliances. Good oral hygiene likely played a role in the present study, as our study included only patients with favorable hygiene practices.

Orthodontic appliances, such as brackets and bands, pose challenges for thorough proximal cleaning. Although cleaning agents are effective for anterior teeth during full-arch fixed orthodontic treatment, they are less efficient for difficult-to-reach posterior areas. Posterior teeth inherently carry a higher risk of caries even without orthodontic intervention.¹⁷ The oral environment relies on natural cleaning mechanisms facilitated by saliva, tongue movement, and cheek motion. Aligners covering tooth surfaces can disrupt this natural cleaning process.¹¹

Saliva plays a crucial role in oral health. Decreased saliva flow contributes to gingival diseases and caries.¹⁸ Patients with xerostomia and advanced periodontal diseases were excluded from the study due to their impact on DMFT scores and tooth loss.

Clear aligners, when worn for 20-22 hours per day and removed only during eating and brushing, have demonstrated effectiveness. However, previous studies have suggested that clear aligners may negatively impact oral hygiene, potentially leading to bacterial colonization and biofilm formation, both intricately linked to caries and periodontal diseases.^{4,19,20} While clear aligners prevent some pH-balancing effects of saliva enzymes during full-time use, their ease of mechanical cleaning contributes to overall better oral hygiene. Abu Ebaid and Acar's²¹ research supports this, showing that clear aligners minimally affect saliva pH and dental plaque accumulation compared to several fixed orthodontic appliances. Fernley et al.²² found an inverse relationship between saliva carbonic anhydrase concentration and caries prevalence, highlighting the importance of salivary factors in oral health.

Our study revealed no significant main effect of the appliance used on the increase in the number of caries lesions over time. However, the DMFT scores significantly increased in both groups. Clear aligners did not effectively reduce the risk of proximal caries, possibly because of their limited impact on saliva cleaning effects.

Interestingly, fixed appliances increased the DMFT index more than clear aligners. This difference can be attributed to easier cleaning and reduced plaque accumulation on the buccal surfaces in patients with clear aligners.

In our study, bite-wing radiography was used to assess proximal caries. These radiographs demonstrated higher sensitivity than both panoramic radiographs and visual-tactile examination for diagnosing proximal caries.²³ Newman et al.²⁴ combined panoramic and bite-wing radiographs for successful proximal caries diagnosis. We adhered to this approach by utilizing both radiographic techniques. Periapical radiographs were intentionally avoided to minimize unnecessary X-ray exposure while assessing the same area. Gribben²⁵ emphasized the importance of error-free radiographs for valid evaluations, and we followed World Health Organization criteria²⁶ in evaluating diagnostically excellent radiographs.

Dental crowding complicates oral hygiene, increasing the risk of plaque accumulation and caries.²⁷ To standardize the sample, we excluded patients with excessive crowding. Only individuals with good oral hygiene were included to minimize the impact of oral hygiene on the study results. The interproximal reduction (IPR) of enamel tissue can lead to surface irregularities and plaque accumulation.²⁷ To eliminate this potential effect, we excluded patients who required IPR of their canines, premolars, and molars.

Study Limitations

The distal surfaces of the second molars, where caries formation is more common, were not included in our study because of the absence of universally present third molars for proximal contact. Additionally, nutritional content was not controlled because this parameter is challenging to regulate. Instead, patients with similar hygiene and caries activities were included for standardization.

Future randomized controlled trials that carefully monitor pretreatment complexity and treatment outcomes are necessary to minimize variations among pre-treatment groups and provide a comprehensive understanding of the effects of aligners on proximal caries formation. In clinical practice, thorough monitoring of proximal caries formation throughout orthodontic treatment remains crucial, regardless the type of appliance used.

CONCLUSION

New caries formed in non-proximal areas were more common during fixed orthodontic treatment. Clear aligners provide an advantage in reducing the risk of non-proximal caries

compared with fixed appliances. However, no significant difference was observed in proximal caries formation between the two treatment modalities, indicating that clear aligners do not significantly reduce the risk of proximal caries. Patients undergoing fixed orthodontic treatment experienced a significantly greater increase in the DMFT index compared to those receiving clear aligner treatment. Despite the overall decrease in caries risk with clear aligners, the possibility of proximal caries formation remains and should not be overlooked. In clinical practice, vigilant monitoring of proximal caries formation throughout orthodontic treatment is essential, regardless of the appliance used.

Ethics

Ethics Committee Approval: This study was approved by Kırıkkale University Clinical Research Ethics Committee (approval no.: 05/01, date: 29.04.2021).

Informed Consent: Patients were informed about the study and treatment details before beginning treatment and signed informed consent forms, which were approved by the institutional review board.

Footnotes

Author Contributions: Surgical and Medical Practices - S.Ç., B.S.A.; Concept - B.S.A.; Design - S.Ç.; Data Collection and/or Processing - S.Ç.; Analysis and/or Interpretation - B.S.A.; Literature Search - S.Ç., Writing - S.Ç., B.S.A.

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

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