

Fixed appliances orthodontic therapy as a risk factor for caries development: Systematic review

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Abstract

Orthodontic treatment is often mandatory to improve the patient's health condition. However, the fixed appliance can create additional plaque retention areas, which can increase the risk of caries development. Clinically, one can observe various effects of fixed appliance treatment on caries prevalence. This study aims to analyze to what extent orthodontic therapy with fixed appliances is a risk factor for developing caries in pediatric and adult patients. The keywords used in the search strategy were as follows: ("caries" AND "caries risk" AND "caries experience" AND "orthodontic treatment" OR "fixed appliance") and ("caries experience" AND "orthodontic treatment").

From 808 potential articles, 15 were included in the review. In individuals undergoing fixed orthodontic therapy, several factors can increase the risk of caries during fixed orthodontic treatment, such as salivary composition, oral dysbiosis and plaque accumulation. On the other hand, factors that reduce caries risk are, i.e., oral hygiene self-awareness and previous orthodontic treatment. In most studies which used the Decayed, Missing, and Filled Teeth (DMFT) index, there were no significant differences between the values obtained before orthodontic treatment and after the treatment. Moreover, it is easier for a patient with aligned teeth to remove plaque.

In the young population, fixed orthodontic treatment appears to reduce the incidence of caries. In the adult population, fixed orthodontic treatment increases the risk of dental caries. However, education on proper oral hygiene during orthodontic treatment can reduce the risk of dental caries. The study protocol was registered in the PROSPERO database (PROSPERO CRD42022356628).

Key words: risk factor, prophylaxis, orthodontics, caries, fixed appliances

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Introduction

Caries is a multifactorial disease affecting the tooth's hard tissues, resulting from the demineralization of enamel and dentin. Even today, it is one of the most common diseases, especially in the pediatric population.¹ In addition to the well-known factors that can affect the promotion of demineralization of the tooth's hard tissues, such as the presence of bacteria,² the presence of a substrate for bacterial metabolism (carbohydrates),³ host susceptibility,^{3,4} and time,^{2,3} many patients undertake orthodontic treatment, especially to resolve functional and/or cosmetic problems, which can cause psychosocial distress and affect their quality of life and self-esteem.^{5,6} Therefore, orthodontic treatment is often mandatory to improve the patient's health condition. However, fixed appliances can create additional plaque retention areas, which can cause various spots of demineralization around the bracket.⁷ Initially, the carious lesion is reversible, without loss of substance, devoid of painful symptomatology, and presents clinically on the enamel as a chalky-white area of decalcification called a white spot. Although it is a non-cavitated lesion, if not diagnosed and treated with an appropriate prevention plan, it can further progress and turn into an irreversible cavitated lesion, which requires invasive treatment.⁸ Clinically, one can observe various effects of fixed appliance treatment on the prevalence of caries. The factors that may influence the occurrence and progression of caries are: patient's hygiene and dietary habits, patient's cooperation with both the orthodontist and dental hygienist, and self-awareness.⁹ Therefore, an interesting question arises: How does orthodontic treatment affects the prevalence of caries?

Objectives

This study aims to analyze to what extent orthodontic therapy with fixed appliances is a risk factor for developing caries in growing and adult patients.

Materials and methods

Search strategy

The study protocol was registered after the screening phase in the PROSPERO database (PROSPERO CRD42022356628). The review process was conducted in accordance with the Preferred Reporting Items for Systematic reviews and Meta-Analyses (PRISMA) statement^{10,11} and PRISMA reporting guidelines.^{10,11} Literature searches of free text and MeSH terms were conducted using MEDLINE (PubMed) and Google Scholar (2000 to 2022). All searches were conducted using a combination of thematic titles and accessible text terms. The final

search strategy was determined through several pre-selections. The keywords used in the search strategy were as follows: ("caries" AND "caries risk" AND "caries experience" AND "orthodontic treatment" OR "fixed appliance") and ("caries experience" AND "orthodontic treatment"). The search string presented here refers to the MEDLINE (PubMed) search engine. The search strings associated with the search engines used in this systematic review are shown in Fig. 1. The PICO (Problem/Population, Intervention, Comparison, Outcome) question was: How does orthodontic treatment with fixed appliances influence the risk of caries?¹²

Inclusion criteria

The following inclusion criteria were applied for this systematic review: clinical studies on growing and adult subjects with fixed orthodontic therapy. The following were the exclusion criteria: 1) *in vitro* studies, 2) animal studies, 3) randomized clinical trials (RCTs), and 4) case-control studies. There was no language restriction applied.

Data extraction

After retrieving the results from the search engines to create a database, the duplicates were removed. Literature was selected following the inclusion criteria by reading the titles and abstracts by 2 authors (SP and MM). The full text of each identified article was then read to determine if it was suitable for inclusion. Whenever a disagreement occurred, it was resolved by the study supervisor (AN). Data were sought regarding the changes in care experience before and after therapy with fixed orthodontic appliances. The authors extracted the values regarding caries severity and dental hygiene from the papers included to find the ones that were used in most of the studies and thus could be compared. The Cohen's K coefficient for the agreement between the authors in study selections indicates a high agreement between the authors, as it was equal to 0.98. Authorship, year of publication, type of each eligible study, and the main results regarding the caries occurrence were extracted by one author (SP) and examined by another author (MM). The data sought were different oral hygiene and caries prevalence indices which reflect changes that would promote the development of caries.

Quality assessment

According to the PRISMA statement,¹¹ the assessment of methodological quality indicates the strength of the evidence provided by the study, as methodological flaws can cause bias. The Newcastle-Ottawa Scale (NOS) has been used for quality assessments of cohort, case-control, and cross-sectional studies. Each study type has its own, specific criteria. This scale has 7 items and a maximum of 10 stars in cases involving cross-sectional

studies, and 9 in cases involving cohort studies can be distributed. In the cohort studies spreadsheet, the quality of the selection of groups under study (4 questions), comparability of the groups (1 question) and outcomes of interest (2 questions) are assessed. Up to 5 stars can be given to the selection section, a maximum of 2 for comparability, and 3 stars for the outcome of interest section.¹³ In the cross-sectional studies spreadsheet, there are 3 main categories: selection (5 questions and 5 stars maximum), comparability (1 question and 2 stars maximum) and outcome (2 questions and 3 stars maximum).¹⁴ The Jadad scale was used to assess the quality of RCTs. There are 5 questions, and the first 3 are characterized by a binary response (yes = 1 point; no = 0 points), and cover details on the randomization of subjects, description of patients and operator blinding, and description of the proportion of subjects lost to follow-up. One point will be subtracted or added from the total of the first 3 questions for each of these questions on the appropriateness of randomization and double-blinding. This procedure provides a total score ranging from 0 to 5, where 0 indicates a low-quality study and 5 indicates the highest possible quality. A study is considered good quality when it scores at least 3.¹⁵

Results

Search results

A systematic literature review was conducted for studies published from 2010 to 2022. The search strategy identified 808 potential articles from PubMed and Google Scholar. After the removal of duplicates, 538 articles were analyzed.

Afterward, 201 articles were excluded because they were not relevant to the topic, author debates, lack of effective statistical analysis, case reports, incomplete studies, reviews, and in vitro studies. Of the remaining 337 articles, 322 were excluded because they were not relevant to the full-text analysis. The remaining 15 articles were included in the review, and are represented in Table 1. Figure 1 presents the search strategy and the final number of studies included.

Extracted data

The data extracted from the included articles are presented as follows: authors, year, location, study setting, number of subjects studied, duration of therapy, and

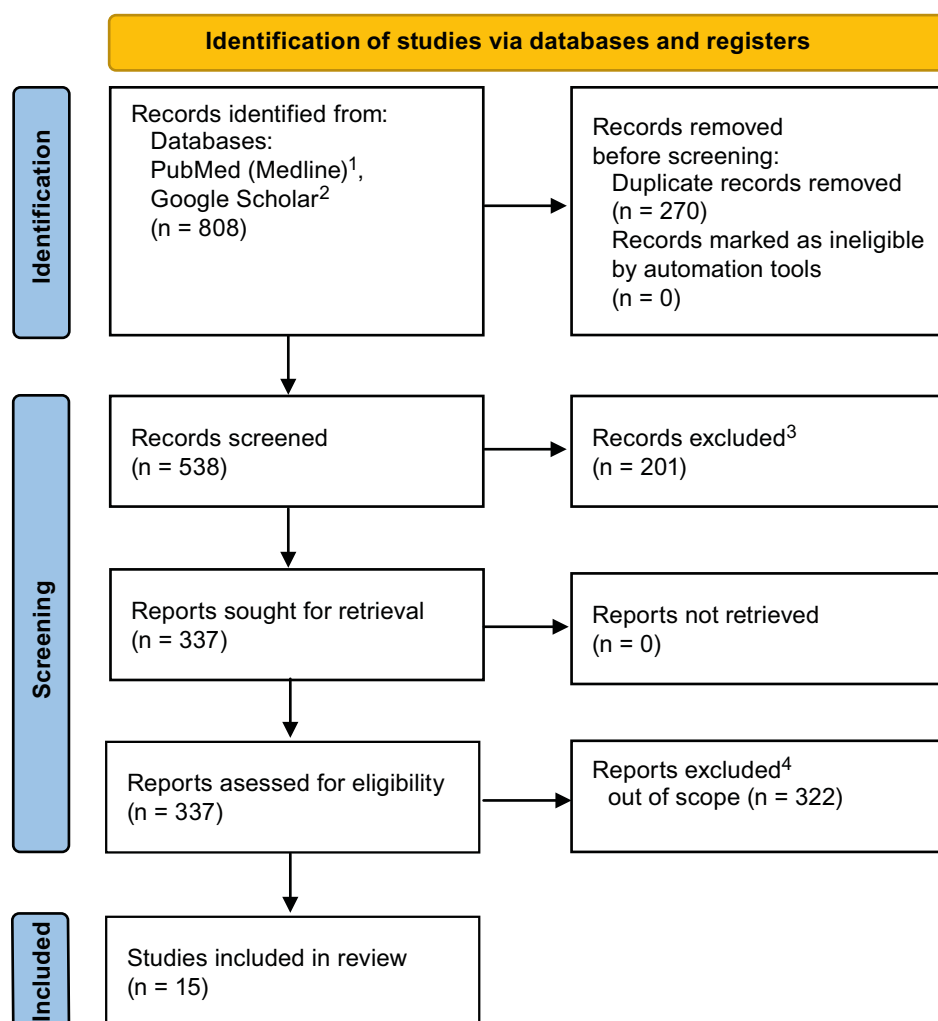


Fig. 1. Preferred Reporting Items for Systematic reviews and Meta-Analyses (PRISMA) 2020 flow diagram

¹ search string "caries experience"[All Fields] AND "orthodontic treatment"[All Fields]

² search string: "caries" AND "caries risk" AND "caries experience" AND "orthodontic treatment" OR "fixed appliance"

³ because not relevant to the subject, author's debates, lack of effective statistical analysis, case reports, incomplete studies, reviews, in-vitro studies

⁴ because not relevant to the full-text analysis

indices used. Table 1 presents the summary of data provided from the included studies.

The included studies were published between 2010 and 2022 and were conducted in North America ($n = 2$), South America ($n = 1$), Asia ($n = 7$), Europe ($n = 4$), and Australia and Oceania ($n = 1$). Thirteen studies were conducted at universities, 3 in hospitals (1 both at a university and in a hospital), and 1 of them was partially conducted in private practice.

The total number of subjects examined was 23,943, with an average of 1,596 subjects per study. The total number of growing subjects was a clear minority of the total, $n = 1,633$ (6.8%). The total number of adult subjects was 22,310 (93.2%). The average age of the total number of subjects examined was 20.15. The average age of growing subjects was 13.37, while the average age of adult subjects was 33.7. The average duration of orthodontic therapy was approx. 23 months.

The indices used to detect caries were Decayed Teeth (DT), Filled Teeth (FT), Decayed Surfaces (DS), Filled Surfaces (FS), Decayed and Filled Teeth (DFT), Nyvad, Decayed, Missing and Filled Teeth (DMFT), Decayed and Filled Surfaces (DFS), Decayed, Missing and Filled Surfaces (DMFS), and White Spot Lesions (WSL) indices. In addition, periodontal indices such as gingival index (GI) and plaque index (PI) were also used. The main outcomes included in studies were mean DMFT in growing subjects before therapy, mean DMFT in growing subjects after therapy, mean DMFT in adult participants before therapy, and mean DMFT in adult subjects after therapy. In summary, the DMFT index was used on a total of 13,503 patients and in a total of 15 studies.

No specific information was provided regarding the type of brackets used, except for in the study conducted by Sanpei et al.³⁰

Quality assessment

The evaluation of the RCT with the use of the Jadad scale is presented in Table 2. Moreover, the cohort and cross-sectional studies were evaluated with the use of the corresponding type of NOS, as presented in Table 3,4.

From the conducted risk of bias assessment, it could be stated that a RCT is of low quality, while 4 cohort studies are of high quality and 4 others of medium quality. All cross-sectional studies are of high quality.

Discussion

Influence of fixed orthodontic therapy on the prevalence of caries

This systematic review sought to comprehensively show the available evidence on caries risk during fixed orthodontic therapy in the growing and adult population.

In growing patients undergoing fixed orthodontic treatment, Cardoso et al.¹⁷ showed that salivary composition plays an essential role in the development of active carious

Authors, year, reference	Study location	Study setting	Total number of subjects	Age range [years]	Type of orthodontic treatment	Observation time	Indices used	Results
Alsulaima and Brenann ¹⁶ 2021	all states in the USA	hospital setting	9,486	24–39	not specified	72 months	DT, FT, DFT	Patients who underwent orthodontic treatment before being characterized by lower values of all indices.
Cardoso et al. ¹⁷ 2020	Piracicaba (Brazil)	university setting	22	11–22	fixed orthodontic treatment	6 months	Nyvad	During follow-up, 59% of patients developed at least 1 white spot lesion, but no cavities. The concentration of Ca^{2+} ions in saliva changes during treatment. An increase in their concentration indicates an increased risk of white spot lesion.
Choi ¹⁸ 2020	Uijeongbu (South Korea)	university setting	11,732	>19	fixed orthodontic treatment	36 months	DMFT pre and post orthodontic treatment	DMFT pre: 7.27; DMFT post: 7.55 People who have had orthodontic treatment are less likely to have untreated dental caries than those who have not had orthodontic treatment.
Zabokova-Biliblova et al. ¹⁹ 2020	Skopje (North Macedonia)	university setting	60	young adults (age not specified)	fixed orthodontic treatment	whole treatment time (not specified)	DMFT pre and post orthodontic treatment	DMFT pre: 6.45; DMFT post: 7.50 All patients experienced an increase in DMFT. The introduction of professional fluor prophylaxis did not cause significant changes in the increase of carious lesions.
Baeshen et al. ²⁰ 2019	Gothenburg (Sweden)	university setting	171	11.2–17.3; mean: 14.8	fixed orthodontic treatment	no follow-up	DFS, SD, FS	FS and DS study group: 0.57 ± 1.41 ; FS and DS control group: 0.65 ± 1.38 Adolescents who suffered from different type of malocclusion have higher prevalence of carious lesions than the healthy control group.

Table 1. Summary of findings from included studies

Table 1. Summary of findings from included studies – cont.

Authors, year, reference	Study location	Study setting	Total number of subjects	Age range [years]	Type of orthodontic treatment	Observation time	Indices used	Results
Doğramacı ²¹ 2019	Adelaide (Australia)	university and hospital setting	632	not specified; mean: 30	fixed orthodontic treatment	12 months	DMFT pre and post orthodontic treatment	DMFT pre: 1.00; DMFT post: 1.12 Orthodontically treated participants had a lower DMFT but statistically insignificant.
Enerbäck et al. ²² 2019	Gothenburg (Sweden)	university setting	255	12–20; mean: 15.4	fixed orthodontic treatment	whole treatment time (not specified)	DMFT pre and post orthodontic treatment	DMFT: 0.89; DMFT post: 0.86 To reduce the likelihood of developing caries while undergoing orthodontic treatment, it is recommended to use toothpaste with a high fluoride content (5,000 ppm F) or a mouth rinse containing 0.2% NaF with regular toothpaste on a daily basis.
Almosa et al. ²³ 2018	Riyadh (Saudi Arabia)	university setting and private clinic	40	mean: 26.4	fixed orthodontic treatment	48 months after the treatment	DMFS and PI	Mean DMFS increased during follow-up from 1.8 to 2.3. Both plaque index and the risk of caries were reduced steadily during the follow-up time.
Morgenstern et al. ²⁴ 2018	Chapel Hill (USA)	university setting	10	13–15	fixed orthodontic treatment	3 months	GI, PI	Both indices during the first 3 months of treatment increased – GI PLI. by several times.
Karabekiroğlu et al. ²⁵ 2017	Konya (Turkey)	university setting	178	14–20	fixed orthodontic treatment	3 months	DMFT after finishing the orthodontic treatment	DMFT pre: 5.8; DMFT post: 7.4 The frequent use of CPP-ACP toothpaste did not improve the appearance of white spot lesions significantly better than regular toothpaste only.
Chen and Zhou ²⁶ 2015	Wenzhou (China)	university setting	60	11–13	fixed orthodontic treatment	18 months	DMFS pre and post treatment	DMFS pre: 139; DMFS post: 158 for 3240 surfaces of treated group; DMFS pre: 149; DMFS post: 179 for 3240 surfaces of control group.
Lucchese and Gherlonez ²⁷ 2013	Milan (Italy)	hospital setting	191	8–12	fixed orthodontic treatment	13 ± 0.9 months	WSL index	WSL index scored 28 in study group compared to 9 in control group. The scores did not differ significantly between 1 st (6 months) and 2 nd (12 months) check-up.
Borzabadi-Farahani et al. ²⁸ 2011	Isfahan (Iran)	university setting	748	11–20; mean age: 15.11	fixed orthodontic treatment	whole treatment time (not specified)	DMFT <8 and >8	The formation of carious lesions is influenced by the size of the family (more than 6 members have a negative impact), as well as lower age.
Tufekci et al. ²⁹ 2011	Richmond (USA)	university setting	100	>12; mean age: 17.4 ± 1.3	fixed orthodontic treatment	6 months and 12 months	WSL index	In the group that was observed for 6 months, 38% of individuals had at least 1 visible white spot lesion. In the group that was observed for 12 months, this percentage was 46%. However, in the control group, it was only 11%. The groups that were observed for 6 and 12 months were significantly different from the control, but there was no significant difference between them.
Sanpei et al. ³⁰ 2010	Niigata (Japan)	university setting	42	mean age: 8.8 ± 0.92	fixed orthodontic treatment with sectional appliances	8 months	DMFT	DMFT pre: 4.53; DMFT post: 4.41 The concentration of <i>Lactobacillus</i> was found to be of special importance while monitoring the risk of caries in pediatric patients.

PI – plaque index; GI – gingival index; DT – Decayed Teeth; FT – Filled Teeth; DS – Decayed Surfaces; FS – Filled Surfaces; DFT – Decayed and Filled Teeth; DMFT – Decayed, Missing and Filled Teeth; DFS – Decayed and Filled Surfaces; DMFS – Decayed, Missing and Filled Surfaces; WSL – White Spot Lesions.

Table 2. randomized controlled trial (RCT) evaluation using the Jadad scale

Jadad scale for reporting randomized controlled trials	
Author	Enerbäck et al. ²²
1) Is the study described as randomized?	*
2) Is the study described as double blind?	—
3) Is there a description of withdrawals and dropouts?	1 point
4) Is the method of randomization appropriate?	1 point
5) Is the method of blinding appropriate?	—
Total score	2

lesions, and with proper composition monitoring, it is possible to accurately assess the risk of caries development. Moreover, results from the by Morgenstern et al.²⁴ showed that fixed orthodontic appliances could lead to dysbiosis, and those alterations in the oral microbiome are correlated with the development of caries. This relates directly to the results of the research by Lucchese et al.²⁷ and Tufekci et al.²⁹ Both of them found that fixed orthodontic appliances are a risk factor for plaque accumulation and the development of white spots. Both studies also proved

that white spot lesions form primarily at the beginning of treatment (in the first 6 months), and their formation rate significantly decreases after this time. The distribution of white spot lesions is not equal, and a small percentage of patients in the study groups suffered from a large number of them on many teeth.

The study conducted by Enerbäck et al.²² shows that the risk of caries during orthodontic treatment is significantly increased due to the increased number of cariogenic bacteria. However, the regular use of toothpaste with a high fluoride content (5000 ppm F) or a mouth rinse containing 0.2% NaF together with standard toothpaste (1450 ppm) on a daily basis significantly reduces the risk of caries development. What is more, a study by Zabokova-Bilbilova et al.¹⁹ found that the introduction of professional fluoride-containing prophylaxis, as the only additional fluoride agent besides standard toothbrushing, did not cause a significant protective effect in subjected patients. Thus, professional application of fluoride, during follow-up visits only, does not protect the patient from lesion formation.

Another important factor is the type of orthodontic equipment applied by the clinician. Elastic ligatures showed a significantly lower susceptibility to plaque adhesion, in comparison to the stainless steel in the metallic ligatures.³¹ Elastic ligatures, on the other hand, occupy more space around the bracket, therefore requiring the patient

Table 3. Evaluation of cohort studies

Newcastle-Ottawa quality assessment scale cohort studies		Authors							
		Alsulaiman and Brennann ¹⁶ 2021	Cardoso et al. ¹⁷ 2020	Doğramacı ²¹ 2019	Almosa et al. ²³ 2018	Morgenstern et al. ²⁴ 2018	Karabekiroğlu et al. ²⁵ 2017	Chen and Zhou ²⁶ 2015	Sanpei et al. ³⁰ 2010
Selection: (max. 4 stars)	1) Representativeness of the exposed cohort	*	*	*	*	—	*	*	*
	2) Selection of the non-exposed cohort	*	*	*	*	—	*	*	*
	3) Ascertainment of exposure	*	*	*	*	*	*	*	*
	4) Demonstration that outcome of interest was not present at start of study	—	—	—	—	—	*	—	—
Comparability: (max. 2 stars)	5) Comparability of cohorts on the basis of the design or analysis	*	*	*	*	*	*	*	*
Outcome: (max. 3 stars)	6) Assessment of outcome**	*	*	*	*	*	*	*	*
	7) Was follow-up long enough for outcomes to occur	*	*	*	*	*	*	*	*
	8) Adequacy of follow up of cohorts	*	*	—	*	*	—	—	—
Total score		7	7	6	7	5	7	6	6

Table 4. Evaluation of cross-sectional studies

Newcastle-Ottawa Scale adapted for cross-sectional studies		Authors					
		Choi ¹⁸ 2020	Zabokova-Bilbilova et al. ¹⁹ 2020	Baeshen et al. ²⁰ 2019	Lucchese and Gherlone ²⁷ 2013	Borzabadi-Farahani et al. ²⁸ 2011	Tufekci et al. ²⁹ 2011
Selection (max. 5 stars)	1) Representativeness of the sample	*	*	*	*	*	*
	2) Sample size	*	*	*	*	*	*
	3) Non-respondents		*		*		*
	4) Ascertainment of the exposure (risk factor)	*	*	*	*	*	*
Comparability (max. 2 stars)	5) The subjects in different outcome groups are comparable, based on the study design or analysis. Confounding factors are controlled.	*	*	*	*	*	*
Outcome (max. 3 stars)	6) Assessment of the outcome**	**	**	**	**	**	**
	7) Statistical test	*	*	*	*	*	*
Total score		7	8	7	8	7	8

to cooperate reasonably and not avoid follow-up visits. For this reason, in a number of studies, greater amounts of microorganisms are found in patients with elastic ligatures than in those who have arches fixed with metal ligatures.³² Therefore, it can be deduced that the type of ligature applied should be appropriately selected for patients according to their compliance. In addition, it is important to note that an orthodontic band would hold bacterial plaque more quickly than a bracket, which should also be taken into account when planning the placement of the appliance.³³

Phenomena observed in growing patients

The clinical outcomes of the experience of caries in the growing patient are not unequivocal; in fact, Chen and Zhou²⁶ observed a decrease in interproximal caries in patients undergoing fixed orthodontic treatment. However, Sanpei et al.³⁰ did not find a significant change in DMFT during the treatment, but an accumulation of lactobacilli, which is considered a risk factor for caries. In both cases, there was a lack of analysis of potential confounding factors, such as the degree of crowding prior to orthodontic fixed treatment, or subjective factors, such as individual caries risk assessment on a genetic and exposomal basis. Therefore, it is not possible to draw a definitive conclusion on the relationship between fixed appliances and variation in caries experience in growing patients.

Phenomena observed in adult patients

In the study carried out by Choi,¹⁸ it was shown that orthodontic treatment is considered a risk factor for dental caries since fixed orthodontic appliances increase the surface

area on which plaque can adhere. Moreover, the irregular shape of the brackets makes it almost impossible to remove the plaque altogether. Thus, oral hygiene education during orthodontic treatment is vital to reduce the risk of caries. According to Doğramacı et al.,²¹ orthodontic treatment is not considered a risk factor for dental caries in the long term. Furthermore, a relationship between DMFT and orthodontic treatment has not been found. The study by Alsulaiman and Brennann¹⁶ found that patients who have already undergone orthodontic treatment have better hygiene habits, which reduces the risk of caries. What is more, it is easier to remove plaque with properly aligned teeth.

Limitations

From the risk of bias assessment, it can be stated that the results from the studies included are more than likely to translate into actual clinical conditions. The limitation of this study is the fact that there was a limited number of RCTs and time restriction for article search. The other problem is the fact that factors that appear to be most important – patient cooperation and hygiene – are purely behavioral. Therefore, it should be underlined that the patients included in this study may behave differently than the ones clinicians are cooperating with on an everyday basis.

Summary

The studies included convey a distinct message. In most studies in which DMFT was used to assess caries risk, there were no significant differences between the value

obtained before orthodontic treatment and the post-treatment value. Although orthodontic therapy with fixed appliances is commonly associated with the incidence of caries, the crucial factor is proper dental hygiene, which, when adequately maintained by the patient, can exclude the formation of any carious lesions during that time. Doctors and hygienists must constantly support, remind, and encourage proper hygiene practices so that the patient gets through the orthodontic treatment unaffected. From the recent study on the hygiene status of patients undergoing orthodontic treatment, it is known that this applies to all kinds of orthodontic therapy and removable appliances, e.g., aligners.³⁴

Conclusions

Based on the results of this systematic review, it can be concluded that several factors can increase the risk of caries during fixed orthodontic treatment, such as salivary composition, oral dysbiosis and plaque accumulation. It was not possible to establish a direct correlation between the fixed multi-bracket appliance and caries experience in the developmental patient, whereas this is confirmed in the adult patient. Therefore, both age groups need to be addressed to reduce the causative factors of caries risk during treatment, with the benefit of making patients more aware of the importance of biofilm removal, even after the conclusion of fixed therapy.

Data availability

The datasets generated and/or analyzed during the current study are available from the corresponding author on reasonable request.

Consent for publication

Not applicable.

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