European Journal of Orthodontics, 2015, 297–307
doi:10.1093/ejo/cju044
Advance Access publication 22 September 2014

Systematic review

Efficacy of professional hygiene and prophylaxis on preventing plaque increase in orthodontic patients with multibracket appliances: a systematic review

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Summary

Background: Plaque increase is a troubling side-effect of fixed orthodontic therapy. This generally arise as a consequence of long-term difficulty in maintaining adequate oral hygiene while wearing multibracket appliances. Demineralization, also known as white spot, causes particular concern as it spoils the aesthetic outcome of the treatment itself, not to mention the integrity of the enamel.
Objectives: To collate the existing literature by evaluating the efficacy of dental hygienist intervention on plaque increase in fixed orthodontics patients.
Materials and methods: A targeted search of the Medline database (Entrez PubMed), EMBASE, and CENTRAL using relevant Medical Subject Headings was performed. The articles selected were all published before June 2013 and comprised randomized clinical trials, prospective longitudinal controlled clinical trials, and before/after studies onto the plaque increase of fixed appliances.
Results: The search strategy yielded 630 articles. Following the application of inclusion and exclusion criteria, 10 articles qualified for the final review.
Conclusion: The quality of the retrieved researches ranged from low (one study) to high (one study). Six controlled trials were considered at unknown risk of bias. Data showed that regular patient motivation sessions and mechanical tooth cleaning by a professional dental hygienist help maintaining good oral hygiene during fixed orthodontics.

Introduction

Orthodontic treatment with a multibracket (MB) appliance has been associated with a troubling side-effect: development and retention of plaque (1–3).

Demineralization and caries occur when plaque remains on the tooth surface for a critical length of time (4, 5); according to the literature caries incidence could increase during orthodontic treatment (6), as well as the incidence of these so-called white spot lesions (WSLs) in orthodontic patients ranges from 2 to 97% (7–11). As

plaque could cause biological damage and poor aesthetic outcomes, which may even require restorative treatment, its prevention or reduction is essential during orthodontic treatment.

When a patient is fitted with fixed appliances, this brings about an alteration of the oral environment along with difficulties keeping the teeth clean (12), leading to an increase in plaque accumulation (13) and a change in composition of the bacterial flora (14). In the absence of effective prevention programs, gingival inflammation and enamel demineralization around fixed appliances (3, 15) are therefore a common occurrence (16). With regard to plaque increase side-effects, particular emphasis has been placed on prophylaxis and different strategies have been proposed to prevent this iatrogenic lesion (17). These strategies can be divided into two groups: methods related to the subject and those related to the appliance. The first group comprises strategies such as patient motivation, plaque staining (18), chlorhexidine rinses, and professional tooth cleaning (19), whereas the second group includes fluoride-releasing adhesives, varnishes, and laser therapy (20–26). Although numerous articles on these issues have been published to date, findings have been fairly inconclusive and contrasting results have been reported. With a view to shedding some light on this issue, we set out to conduct a systematic review of the literature in order to answer the question of whether it is clinically possible to avoid plaque increase and prevent permanent teeth lesions in orthodontics patients, and in particular, whether prophylactic procedures performed by the dental hygienist are efficacious in reducing the risk of demineralization in orthodontics patients fitted with MB appliances.

Materials and methods

This review has been registered in the PROSPERO international prospective register of systematic reviews as number CRD42012002549. The PRISMA statement was used as a framework for this research.

Clinical studies in which different preventative approaches were used against plaque increase during full MB therapy were selected. Their study designs comprised randomized clinical trials (RCTs), controlled clinical trials (CCTs), prospective studies, and multi-centred RCTs. Only published papers written in English were assessed. Pilot studies, interviews, reviews, *in vitro* studies, animal studies, and those featuring removable appliances or specially designed bands were excluded from the research; only studies with at least six teeth examined were included.

Eligibility criteria for scientific papers were as follows:

Population: orthodontics patients of either gender, any age and any type of malocclusion (Class I, II, or III) and crowding treated with fixed MBs on both arches with first molars included over the course of at least 12 months.

Intervention: only *in vivo* studies on human participants involving different oral health motivation strategies, and oral and dental hygiene techniques and procedures.

Comparison: no treatment or usual care (the gold standard), or inactive control.

Outcome: as a primary outcome, the following data were evaluated: plaque index (PI) and gingival index (GI). The secondary outcomes considered were carious lesions and the presence/absence of white spot.

A literature search was performed on the Medline database (Entrez PubMed), EMBASE, and CENTRAL. The research papers covered the period leading up to June 2013, and were retrieved using the following Medical Subject Headings: orthodontic brackets, fixed appliance, PI, tooth demineralization, white spots, decayed missing filled teeth. A full electronic search strategy for one database is reported in Table 1.

Authors were contacted in two cases to clarify data missing and in case of doubt concerning appropriate eligibility of studies.

Methodological quality of the included controlled trials was evaluated by means of the standard methods adopted from Cochrane Collaboration considering the following parameters: generation of the random sequence, allocation concealment, blinding of outcomes assessment, incomplete outcome data (attrition), and selective reporting of the outcomes cited in the methods (27).

For time series and before/after studies quality assessment the EPOC scale was used (28), whereas the Newcastle-Ottawa was used for assessing the quality of cohort studies (Tables 2–4) (29).

Where possible, the mean/median and standard deviations of the effects of the different treatments on PI and GI were calculated and compiled in a table for data-matching purposes. The trend in the side-effects of fixed MB appliances was either calculated as a percentage change between two observation periods for each examined group or defined as a qualitative value, or as a positive or negative trend. A paper published by Boersma *et al.* (5) reported that up to 97% of the patients treated with MB therapy had WSL after treatment, thus in this study, if oral hygiene status indices had not worsened at the end of an observation period, their trend was considered positive. Data from the retention phase were not considered.

Table 1. Search history.

#22 Search 'Orthodontic Brackets'[Mesh]	items: 2912
#23 Search 'edgewise bracket'[All Fields] OR 'edgewise brackets'[All Fields] OR 'ribbon arch brackets'[All Fields] OR 'universal bracket'[All Fields] OR 'multibrack- et'[All Fields] OR 'fixed appliance'[All Fields] OR 'fixed appliances'[All Fields] OR 'fixed orthodontic appli- ance'[All Fields] OR 'fixed orthodontic appliances'[All Fields] OR 'fixed orthodontic brack- ets'[All Fields] OR 'fixed orthodontic devices'[All Fields] OR 'fixed orthodon- tic therapy'[All Fields] OR 'fixed orthodontic treat- ment'[All Fields] OR 'fixed orthodon- tics'[All Fields]	items: 1916
#24 Search #22 OR #23	items: 4,486
#29 Search 'Tooth Dem- ineralization'[Mesh] OR 'Dental Caries Susceptibili- ty'[Mesh] OR 'Den- tal Deposits'[Mesh] OR 'Dental Health Surveys'[Mesh]	items: 60 394
#31 Search (gingival OR gingiva* OR plaque OR periodontal) AND (index* OR in- dices OR score*)	items: 15,901
#33 Search 'white spot'[All Fields] OR 'white spots'[All Fields] OR 'decayed missing filled'[All Fields] OR 'dmft'[All Fields] OR 'dmfs'[All Fields] OR 'decayed missing'[All Fields] OR 'dfs'[All Fields] OR | caries[All Fields] OR carious[All Fields]	items: 56 207
#34 Search #29 OR #31 OR #33	items: 85 917
#35 Search #24 AND #34	items: 630

Table 2. Methodological quality of included controlled trials (27).

Study	Population	Random sequence generation	Allocation concealment	Blinding of outcome assessment	Incomplete outcome data	Selective reporting	**Overall evaluation**
Zimmer and Rottwinkel (30)	Control 1 (RR), *N* = 20 Intervention 1 (RR/EP), *N* = 20 Control 2 (ER), *N* = 20 Intervention 2 (ER/EP), *N* = 20	Unknown	Unknown	Unknown	Low	Low	**Unknown**
Dènes and Gábris (6)	Control, *N* = 70 Intervention 1, *N* = 70 Intervention 2, *N* = 70	High	Unknown	Unknown	High	Low	**High**
Lundström *et al.* (31)	Control, *N* = 15 Intervention 1, *N* = 15 Intervention 2, *N* = 15 Intervention 3, *N* = 15	Unclear	High	Unclear	Low	Low	**Unknown**
Boyd and Rose (32)	Control, *N* = 35 Intervention 1, *N* = 30 Intervention 2, *N* = 25	High	Unknown	Low	Low	Low	**Unknown**
Boyd and Chun (33)	Control, *N* = 35 Intervention, *N* = 30	High	Unknown	Unknown	Low	Low	**Unknown**
Jiang *et al.* (34)	Control, *N* = 50 Intervention, *N* = 50	Low	Low	Low	Low	Low	**Low**
Kronenberg *et al.* (35)	Control, *N* = 200 Intervention 1, *N* = 100 Intervention 2, *N* = 100	Low	Unknown	Unknown	Low	Low	**Unknown**
Boyd *et al.* (36)	Control, *N* = 20 Intervention, *N* = 20	Unknown	Unknown	Unknown	Low	Low	**Unknown**

EP, extended prophylaxis; ER, elevated risk; RR, reduced risk. Bold words underline the overall quality assessment.

Table 3. Methodological quality evaluation of time series and before/after studies (28).

	Zimmer (38)
Was the intervention independent of other changes?	Y
Was the shape of the intervention effect prespecified?	Y
Was the intervention unlikely to affect data collection?	Y
Was knowledge of the allocated interventions adequately prevented during the study?	N
Were incomplete outcome data adequately addressed?	Y
Was the study free from selective outcome reporting?	Y
Was the study free from other risks of bias?	Y

Results

The search strategy described above yielded 630 articles. After double citations elimination, 483 papers remained. The above inclusion and exclusion criteria were applied, and this selection process left us with 17 full-text articles. Quality analysis led to the exclusion of further seven articles, leaving a final selection of 10 full-length articles deemed fit for review (Figure 1): 8 were RCT, 1 was CCT, and 1 was before/after study. The characteristics of the indices the papers used to describe oral health are reported in Table 5.

Online supplementary table 1 shows the efficacy of different prophylactic procedures evaluated, describing the trend in different indices after orthodontic treatment. Online supplementary table 2 shows the same results coupled with the oral hygienist intervention (OHI).

All reviewed studies described both which teeth were observed and all the prophylactic procedures undertaken. Data on the various indices were extracted, considering values measured before treatment and after debonding only. Four of the eight studies used the Silness and Loe index (1964) to measure plaque levels, while four different indexes were used to measure gingival bleeding.

Demineralized spot lesion were assessed either clinically using the WSL index (2), either using a standardized photographic technique or a laser light fluorescence reading. In online supplementary table 3 observation period extracted for each study is reported.

Quality of the studies

Although RCTs are relatively few in orthodontics, the sample papers considered in this review included seven trials (30–36) in addition to one CCT (6), one cohort study (37), before/after study (38). Only one of the included trials was classified as low risk of bias (in this study outcomes were assessed blind). The most part of the trials were considered to be at unknown risk of bias since the parameters considered for evaluation were described with a detail that do not allow a precise evaluation. CCT study has been considered to be at high risk of bias (allocation is not adequate, a many subjects excluded from follow-up) (6). The remaining two included studies were a cohort observational study and a before/after research and were evaluated with an overall good quality.

Discussion

This systematic revision only included articles on orthodontic treatment by means of fixed MB appliances. In this area many intervention studies suffer for the problem of clustering of teeth in the mouth: teeth within a mouth will respond similarly because they are exposed to a similar environment; this means that data from

Table 4. Methodological quality evaluation of the cohort study of Hadler-Olsen *et al.* (37) (Wells *et al.* (29)).

Selection
1) Representativeness of the exposed cohort
a)Truly representative of the average _____ (describe) in the community*
b)Somewhat representative of the average young patients needing orthodontic treatment in the community*,**
c)Selected group of users, e.g. nurses, volunteers
d)No description of the derivation of the cohort
2) Selection of the non-exposed cohort
a)Drawn from the same community as the exposed cohort*,**
b)Drawn from a different source
c)No description of the derivation of the non exposed cohort
3) Ascertainment of exposure
a)Secure record (e.g. surgical records)*,**
b)Structured interview*
c)Written self-report
d)No description
4) Demonstration that outcome of interest was not present at start of study
a)Yes*,**
b)No
Comparability
1) Comparability of cohorts on the basis of the design or analysis
a)Study controls for bitewings taken, dental stage, decayed-missed-filled tooth, gender, age (select the most important factor)*,**
b)Study controls for any additional factor* (this criteria could be modified to indicate specific control for a second important factor)
Outcome
1) Assessment of outcome
a)Independent blind assessment*,**
b)Record linkage*
c)Self-report
d)No description
2) Was follow-up long enough for outcomes to occur
a)Yes (select an adequate follow-up period for outcome of interest)*,**
b)No
3) Adequacy of follow up of cohorts
a)Complete follow up—all subjects accounted for*,**
b)Subjects lost to follow-up unlikely to introduce bias—small number lost—>____ % (select an adequate %) follow-up, or description provided of those lost*
c)Follow-up rate <____% (select an adequate %) and no description of those lost
d)No statement

*The lowest bias risk option for cohort study.
**The quality evaluation conferred to this study.

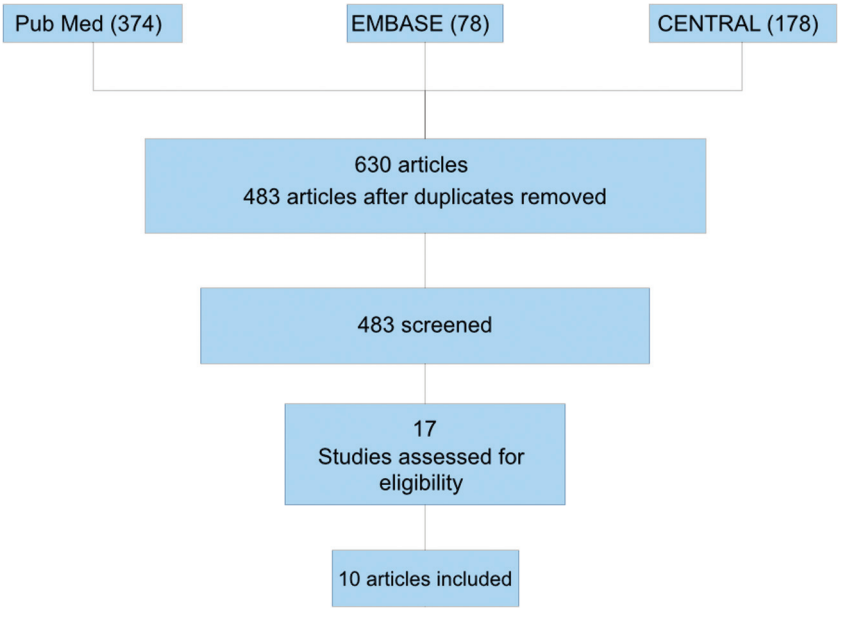

Figure 1. PRISMA 2009 flow diagram.

Table 5. Indexes utilized among different articles.

Article	Plaque index	Gingival index	Carious lesion index	White spot lesion index	Other
Lundström *et al.* (31)	Plaque index (Silness and Loe (48))	Gingival index (Loe and Silness (53))	Initial carious lesions on the smooth surfaces[a]	—	—
Dénes and Gábris 1991 (6)	Quigley–Hein index	Sulcus bleeding index (Mühlemann and Son (55))	DMFT/DMFS	—	Lactobacillus counts and Candida albicans test
Zimmer and Rottwinkel (30)	—	—	—	WSL index	—
Hadler-Olsen *et al.* (37)	Plaque index O'Leary *et al.* (50))	Gingival bleeding index (Ainamo and Bay (54))	Caries scores (Amarante *et al.* (58))	WSL index (Gorelick *et al.* (2))	—
Boyd and Rose (32)	Plaque index (Silness and Loe (48))	Gingival index (Loe and Silness (53)); bleeding tendency (Armitage *et al.* (69))	—	WSL index (Gorelick *et al.* (2))	Tongue staining; tooth staining; mucosal irritation
Boyd and Chun (33)	Plaque index (Silness and Loe (48))	Gingival index (Loe and Silness (53)); bleeding tendency (Armitage *et al.* (69))	—	—	Coronal staining (Loe *et al.* (70))
Jiang *et al.* (34)	—	—	—	WSL index (Gorelick *et al.* (2))	—
Kronenberg *et al.* (35)	Visible plaque index (Turesky *et al.* (49))	—	—	White spot index (Gorelick *et al.* (2))	—
Zimmer (38)	Aproximal plaque index (API); plaque index (Silness and Loe (48))	Gingiva index (Löe and Silness (53))	DMFT/dmft initial lesions	WSL index	—
Boyd *et al.* (36)	Plaque index (Silness and Loe (48))	Gingival index (Loe and Silness (53)); bleeding tendency (Armitage *et al.*, (69))	—	—	—

DMFS, decayed, missing, filled surface; DMFT, decayed, missing, filled teeth; WSL, white spot lesion.
[a]Koch *et al.* (71).

each tooth cannot be assumed to be independent of each other. In statistical terms, the patient is the sampling unit (or unit of investigation) and should therefore be the unit of analysis. However, in some situations, e.g. development of caries during orthodontic treatment, useful information about which teeth and which sites on individual teeth undergo demineralization, is lost if we only look at the number of patients affected (39). Therefore, while conducting a clinical trial regarding preventive procedures during orthodontic treatment, could be useful to address this problem reporting both data, i.e. plaque accumulation and WSLs incidence, considering both patient and tooth as sampling unit.

Oral health and MB therapy

A series of studies have highlighted the association between fixed orthodontic appliances and the unwanted accumulation of bacterial plaque around the brackets, which, along with the other components of such devices, tend to hinder its removal *via* normal home hygiene procedures (40–47). Flossing is particularly difficult, thereby making the onset of periodontal tissue inflammation all the more likely.

Not only does the subgingival bacterial flora increase in number during fixed orthodontics, but a change in its composition has also been documented, specifically a shift from aerobic to anaerobic populations, that is the major culprits in gum disease and periodontal problems (40, 41). Fixed appliances also increase the likelihood of enamel demineralization, as evidenced by the appearance of WSLs and caries, and orthodontic treatment by these means is therefore considered a risk factor for both soft and hard tissue damage.

Plaque index

It is well known that full plaque control through mechanical and chemical prevention can efficaciously reduce the progression of soft tissue and enamel damage. The PI is therefore an accepted means of judging oral health. In the papers considered (31–33, 36), plaque was generally measured by means of the Silness and Loe index (48). However, in one study (6), plaque was scored according to Quigley and Hein (49), in an other O'Leary *et al.* PI was used (50), and one research used the cisible PI (35).

According to the findings of Lundström *et al.* (31), the introduction of a specific oral hygiene education program a month and a half before treatment led to a reduction in PI. These values then increased slightly as treatment progressed, but not to a significant degree. At the end of the treatment, the scores had fallen to their initial levels, which appeared to demonstrate that continual reinforcement by the dental hygienist of preventive procedures brings about no further improvement in oral hygiene levels. Nevertheless, the results of this study do show, confirming and extending observations reported by Lundström *et al.* (31), that it is possible to get school-age children to learn and use high-level plaque control techniques, and thereby maintain an adequate standard of oral hygiene and dental health. Dénes and Gábris (6) set out to show that fluoride gel is

also able to improve oral health, by comparing the plaque indices of a group treated using topical application of amine fluorides with those who received oral hygiene instruction alone. This revealed that there is indeed a significant improvement in plaque indices correlated with the use of fluoride gel, greater than that seen following instruction alone.

Boyd *et al*. conducted 3 different studies on plaque increase and decalcifications during orthodontic treatment evaluating two different preventive approaches: the use of a rotary electric toothbrush instead of a manual toothbrush, and the use of 0.4% stannous fluoride gel together with conventional toothbrushing (32, 33, 36); both the use of the gel and the electric toothbrush showed significantly lower plaque increase, gingival inflammation, and less calcification. In particular, the use of electric toothbrushing led to an improvement of plaque level at the end of orthodontic treatment when compared to baseline; these results are similar to those obtained by another RCT published in 2010 (51).

This systematic review included researches including a dental hygienist intervention only; Buck *et al*. (52) compared conventional elastomeric ligature with self-ligating bracket evaluating the microbial quantity and quality colonization during orthodontic treatment only on four teeth (four lateral incisors); results showed no differences in plaque quantity among two different ligature methods. The possibility that a dental hygienist could change ligature on orthodontic patient is not allowed thorough all the states and depend on national regulation. For this reason this study was not included in this review. Kronenberg *et al*. (35) studied the protective effect of ozone and Cervitec/Fluor Protector during MB appliance therapy. This 26 months long research concluded that none of the selected preventive approaches lead to a better plaque control, with a PI at the end of observation period between 54 and 57.1%.

Gingival index

To evaluate the degree of gingival inflammation, the gingivitis index introduced by Loe and Silness (53) was employed in five studies (31–33, 36, 38), while the Ainamo and Bay gingival bleeding index (54) was used in Hadler-Olsen *et al*. research (37). In one of the remainders (6), periodontal health status was assessed by means of the sulcus bleeding index (55), which is used to classify gingival bleeding.

A study by Lundström *et al*. (31) demonstrated that during active orthodontic treatment, the state of gingival inflammation increases in both experimental and control subjects, returning to initial levels, or even improving, once the active phase was completed.

Boyd conducted different researches on plaque control during orthodontic treatment; in 1983 compared the gingivitis scores between a control group (56), and two experimental groups, which had the benefit of plaque control instruction and plaque disclosure instruction. During the 10 months observation period he observed a worsening (+64.3%) in the control group, whereas in the experimental groups saw a reduction in the high pre-treatment levels of gingivitis during the first 5 months of the observation, and then a gradual increase during the following 5 months, after which regular reminders and training about plaque control arrested this increase, and in fact, brought the levels back down to around baseline (−0.8%).

Statistical analysis of the intergroup differences in gingival inflammation was only carried out for groups 1 and 3, as the patients in these groups had similar levels of gingivitis at the beginning of the study. The result of this analysis showed statistically significant differences at the vestibular surfaces of both the upper ($P = 0.003$) and lower ($P < 0.01$) teeth, but not on the lingual sides of the same teeth ($P = 0.14$). Boyd et al. successively study the effect of the rotary electric toothbrush on GI and he found that the percentages for the treatment group were significantly lower ($P < 0.001$) than those for the control group (36); similar findings were found when he clinically tested the use of 0.4% stannous fluoride gel (33).

Dénes and Gábris (6) measured the gingival bleeding score using the sulcus bleeding index. In the group given the fluoride gel (G2), this value was invariably lower than those measured in the other two groups.

Hadler-Olsen *et al*. (37) compared 40 orthodontic patients with the same number of untreated subject with a mean observation period of 18 months. A statistically significant difference in gingival bleeding index among two groups were described: the orthodontic patients showed an increase of 4.4% while the untreated subjects showed a mean decrease of 0.5%.

Oral hygienist intervention

Boyd observing orthodontic patients for 10 months emphasized the importance of a structured program aimed at keeping bacterial plaque under control (56), and revealed the necessity of reinforcing oral hygiene procedure instruction to the patient every 4–7 weeks. The beneficial effect of plaque removal, particularly in terms of the GI, has mainly been observed at the vestibular surfaces of the upper teeth, presumably because these are easier to see and reach. Indeed, the authors show that the teeth in the anterior sector are generally kept much freer of plaque by patients.

As patient compliance cannot be wholly relied upon to resolve the problem, the onus is firmly on the dental hygienist and on a regular exposition to low levels of fluoride, since the risk of plaque increase and demineralization linked to MB appliances can be mainly eliminated by thorough prophylaxis (11, 30), whether patients feature a normal or high risk of developing the same. As expected, the recommended procedures are those performed professionally, namely, gingival pocket irrigation and fluoride and chlorhexidine application, which result in a significantly better improvement than relying on regular patient-performed brushing, and flossing. This is in agreement with the observations of Ullsfoss *et al*. (57) and Øgaard *et al*. (58), according to whom, among other demineralization-related parameters, the use of fluoride combined with other procedures improves the outcome in comparison to the use of fluoride alone.

Communication techniques

With this in mind, various authors have set out to determine which communication strategies (written, visual, verbal) are most effective in motivating patients and improving demineralization risk. Although a study of Lees and Rock (59) found no statistically significant difference between the various educational strategies, other studies (Ay *et al*. (60)) report that the most efficacious means of reducing inflammation markers (PI, GI, bleeding on probing) was verbal instruction of how to brush and floss with the aid of illustration, followed, in young children, by a practical real-life 'test', closely monitored by an experienced professional, who was on hand to correct any errors the children might make. Likewise, Thomson *et al*. (61) suggested that verbal instruction is best supported by written or visual information.

Interestingly enough, Ay *et al*. (60) found that two-dimensional images, rather than three-dimensional models, brought about the greater improvement in PI and bleeding on probing scores, which they explained by stating that adolescents are more familiar with such teaching aids, which are widely used in schools. In any case, the

most important advantage of verbal instruction is its usefulness in engaging the patient in dialogue and thereby helping to build a trusting relationship. According to Ay *et al.* (60), this is also true if young patients are unaccompanied by their parents, although Thomson *et al.* (61) maintained that unaccompanied adolescents should not be given information verbally.

From a study by Lees and Rock (59), it is apparent that video is also an extremely efficacious tool for improving patient awareness of oral hygiene and honing their practical technique, encouraging them to reverse any bad habit. The advantage of this approach with respect to the other techniques is that it lends itself to autonomous learning in private, comfortable surroundings. Indeed, this study showed that the most efficacious motivation techniques are video aids and dental hygienist-led instruction.

Caries

Three out of the 10 articles attempted to measure carious lesions. Dénes and Gábris (6) to determine the prevalence and severity of the caries found in the study, the epidemiological index decayed, missing, filled teeth/decayed, missing, filled surface (DMFT/DMFS) was employed, while Lundström *et al.* (31) counted the initial number of carious lesions on the smooth surface of the teeth to use as a point of reference. Dalessandri *et al.* (62) report the number and severity of caries at the end of observation period, while Hadler-Olsen *et al.* (37) used method reported from Amarante *et al.* (63) to measure caries scores. The number of carious lesions in Lundström *et al.* study was found to increase during the treatment periods (31), between 0.1 and 1.8 in patients who underwent plaque prevention procedures, and the control group showing an even greater increase. Statistical analysis showed that in the patients treated with a chemical plaque control, there was a significant difference in the number of lesions that reached the status of deep caries upon removal of the bands.

Dénes and Gábris (6) evaluated the variations in caries and gingivitis in orthodontic patients who maintained their normal oral hygiene routine with those who additionally applied topical amine fluoride. In all three groups evaluated (Table 5), DMFT and DMFS values were measured at four time-points during the treatment: at the beginning, halfway through, upon bracket removal, and in the final phase of retention. The DMFT scores increased during the 3 years of the study period in all three groups. Nonetheless, this increase was not so pronounced in the two experimental groups with respect to the control. DMFS values showed a similar trend, although in this case a significant lower value was found in patients provided with fluoride gel for self-application with respect to the control group (G1).

In Hadler-Olsen et al. research orthodontic patients who received a comprehensive prophylactic regimen (test group) did not statistically differ from the control group in dentine caries increase (mean increase was 0.5 lesions) and 0.7 lesions for test and control group respectively) (37); authors observed a common trend for both group in which a high increase was registered for few patients, underlining the concept of 'high risk' patient in caries development.

White spot lesions

Six studies focused on white spot lesions during orthodontic treatment (30, 32, 34, 35, 37, 38). Independently from preventive procedures, in all the studies examined the incidence of increased after orthodontic treatment, even if specific treatment reduced the risk compared to orthodontic patients without any preventive approach. Different factors can affect the development of WSL during fix appliance treatment: gender, age, treatment length, use of fluoride, diet, and oral hygiene level (64, 65).

Zimmer conducted a study in 1999 to compare various prophylactic methods in reducing decalcification during fixed appliance therapy (38). The author proposed a optimized prophylaxis by selecting patient on their oral hygiene risk. The most effective preventive procedure was professional and regular cleaning of teeth and bonded appliance with rotating instruments by a dental hygienist after removal of the arch wire in addition to regular application of chlorhexidine trays. Later on the same author (Zimmer and Rottwinkel (30)), studying patients at high risk of demineralization, emphasized the importance of a prophylactic regime during orthodontic treatment with MB appliances in order to reduce the risk of demineralization. By comparing the two groups of patients, one at low risk of demineralization and one at high risk, it was found that the second group showed a total increase in demineralization equal to 150 during the course of the study, whereas the low-risk group showed only an increase of 17 demineralizations. The difference between the two groups is evidently statistically significant. Hence, in patients with a low risk of demineralization, an initial program of prophylaxis is a sufficient preventive measure, while in high-risk patients, this prophylaxis regime needs to be extended throughout the duration of treatment.

Hadler-Olsen *et al.* (37) compared a comprehensive prophylactic approach test group with a control group who did not receive any specific preventive treatment except for routine appointments at the general dentist; even though no differences were observed in caries increase between two groups a statistically difference was described in WSL increase: the control group showed a 0.4 increase after 18 months of observation, while the orthodontic group showed an overall increase of 1.9; authors stressed the use of steel ligature during orthodontic treatment, nevertheless they reported that 60% of the test group patients developed one or more new WSL.

Boyd and Rose evaluated the efficacy of the rotary electric toothbrush on WSL (32). He tested three different groups: the first received only hygiene instructions, the second instruction in toothbrushing and daily use of NaF rinse, while the third group use the NaF rinse in addition to the rotary electric toothbrush. He found that the last group showed an increase of WSL of 0.3% during 27 months of observation, while the other patients showed an increase of 12.7 and 6.6% (first and second group, respectively).

Jiang *et al.* studied the preventive effect of the fluoride foam on orthodontic patients (34). In this double-blinded trial they compared the effect of the professional application of 1.23% fluoride foam compared with a placebo. After 18 months of observation both groups showed an increase in WSL, but the control group (placebo) revealed an incidence of new WSL of 51% while the fluoride foam group showed an increase of 13%.

Kronenberg et al. in 2009 studied the protective effect of ozone (2'100 ppm ± 10%) delivered for 30 seconds on orthodontic patients using a split mouth design (35). The author compared this prophylactic procedure with a control group and an other preventive approach including chlorhexidine and fluoride application. Even in this study WSL at the end of the observation period increased respect to the baseline; nevertheless the quadrants treated with Cervitec/Fluor Protector showed significantly ($P < 0.05$) less WSL than in the quadrants treated with ozone or control.

Similar results were found by Stecksén-Blicks *et al.* (66) in 2007: authors conducted a RCT studying the effect of repeated topical fluoride varnish application during an observation period of at least 6 months; compare to the placebo, fluoride varnish applications every 6 weeks reduced the WSL incidence of 18%.

Prophylaxis regime

One of the main parameter considering a prophylaxis regime is the frequency of the intervention; among all the studies examined there is no uniformity (online supplementary table 2): OHI frequency varied between 3 weeks and 4 months.

In Lundström *et al.* (31) study the children in each of the test groups received initially a specific systematic plaque control program delivered every 3 weeks by a dental nurse . Detailed oral hygiene education was given (clean teeth twice daily using the Bass method supplemented by toothbrush) and motivation was focused to achieve and maintain dental health. Children were also recommended to restrict sugar and candy consumption. During the active orthodontic treatment period the children in each of the test groups were subject to a different plaque control procedures: mechanical plaque control (group A), chemical plaque control using chlorhexidine digluconate (group B), mouth rinsing with placebo (group C). Dénes and Gábris (6) reports the results of a study on children treated with fixed orthodontic appliances where patients were all instructed in oral hygiene maintenance; test group patients had professional cleaning every second or third week followed by fluoridation with a fluid preparation (group 1) or instructed to use a fluoride gel once a week after brushing (group 2). Zimmer and Rottwinkel (30) discerned between initial prophylaxis regimen (IP) and extended prophylaxis regimen (EP); the IP program consisting of patient motivation, instruction in oral hygiene, oral hygiene checkups, and fluoridation. The EP intervention included regular mechanical tooth cleaning by a professional dental hygienist, scaling, and chlorhexidine treatment.

In Buck *et al.* (52) and Dalessandri *et al.* (62) articles plaque reduction was evaluated applying different ligature modalities (conventional versus self ligating bracket) or using an indirect bonding instead of direct bonding; professional oral hygiene protocol was planned every 6 months.

The oral hygiene regimen in Hadler-Olsen *et al.* (37) consisted of brushing teeth three times daily, flossing, fluoride rinse, and plaque disclosing tablets. Patients were also instructed to avoid carbonated soft drinks and acid juices and to restrict the intake of candies to a maximum of once a week. Giannini *et al.* (67) in orthodontic surgical treatment proposed a plaque control program that consists in oral hygiene instructions, patient motivation, professional oral hygiene, local fluoridation, and chlorhexidine mouthwash.

Conclusions

An optimal oral health maintenance during orthodontic treatment should be a gold standard in today practice; nevertheless literature on this topic is lacking as well as high quality studies like RCT. Future high quality researches are recommended, in particular is it advisable to follow the CONSORT statement to reduce risk of multiple bias, to perform an accurate sample size calculation before starting trial, and possibly to obtain data considering both the patient analysis and single tooth analysis as well; moreover we suggest to test PI specifically ideated for orthodontic treatment as the aproximal

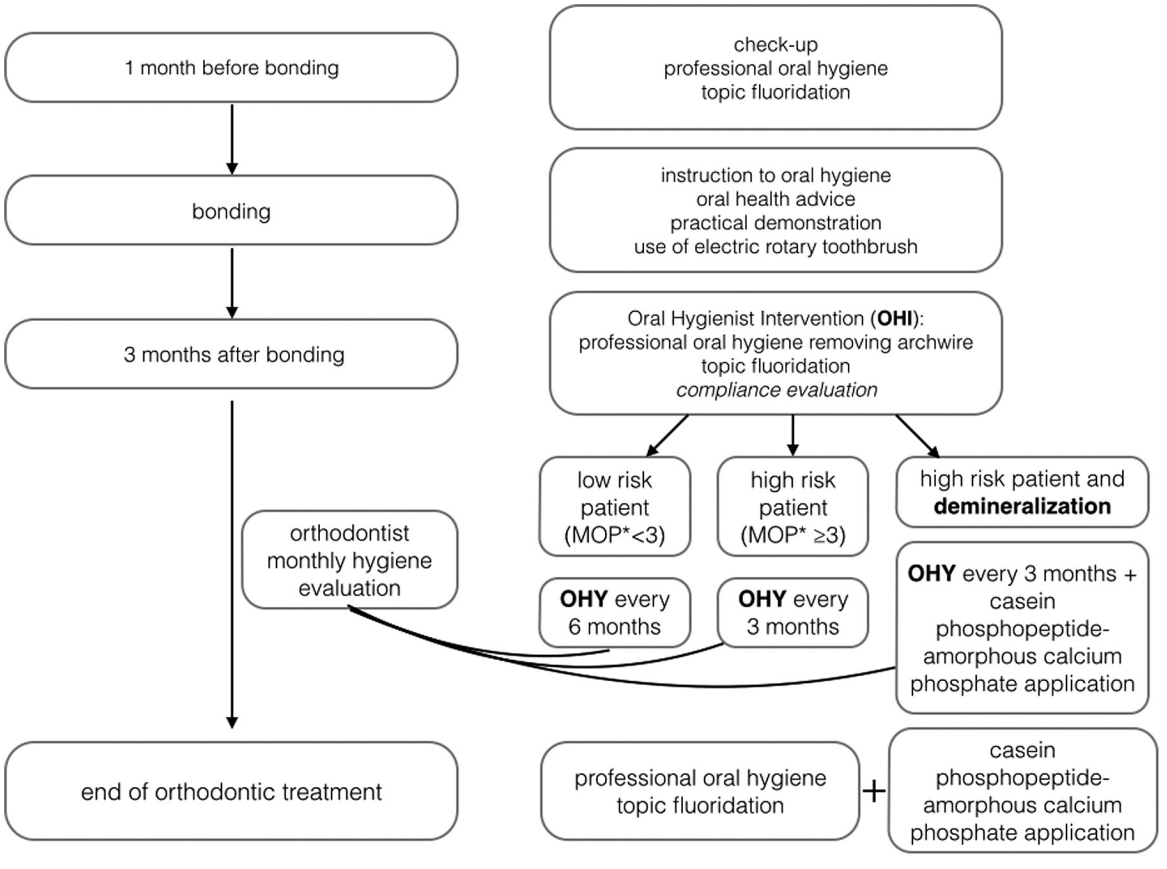

Figure 2. Prophylactic procedure protocol during orthodontic treatment with multi-bracket appliance. *MOP: modified orthodontic plaque index. Plaque scores range from 0 to 4. Code 0: no plaque; code 1: inter-proximal plaque accumulation (mesial and/or distal) of the bracket base; code 2: plaque accumulation inter-proximal, incisal, and/or cervical to the bracket base; code 3: continuous plaque accumulation from the gum line to the bracket base; code 4: complete coverage by plaque.

plaque index or orhtodontic plaque or modified orthodontic plaque index (62, 68). Data obtained from this review indicate the professional hygiene and prophylaxis on preventing plaque increase in orthodontic patients as generally efficient even if does not appear a well-defined rational approach: the present study suggests a prophylactic oral hygiene protocol to be used during orthodontic treatment with fix appliances (Figure 2). The synergic team work between the orthodontist and dental hygienist should lead to a decrease of oral health risks due to the orthodontic treatment. The dental hygienist intervention involves not only the traditional scaling and polish but also thorough and comprehensive instruction and motivation of the patients in terms of patient home oral hygiene routine.

Supplementary material

Supplementary material is available at *European Journal of Orthodontics* online.

Acknowledgment

The authors are grateful to Dr E. Butera and Dr F. Razzetti for their help and support with the article research and evaluation. Systematic review registration number: CRD42012002549.

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