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Caries outcomes after orthodontic treatment with fixed appliances: do lingual brackets make a difference?

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Orthodontic treatment with fixed appliances is considered a risk factor for the development of white spot caries lesions (WSL). Traditionally, brackets are bonded to the buccal surfaces. Lingual brackets are developing rapidly and have become more readily available. Buccal surfaces are considered to be more caries prone than lingual surfaces. Furthermore, lingual brackets are shaped to fit the morphology of the teeth and seal almost the entire surface. In the present study we tested the hypothesis that lingual brackets result in a lower caries incidence than buccal brackets. We tested this hypothesis using a split-mouth design where subjects were allocated randomly to a group receiving either buccal or lingual brackets on the maxillary teeth and the alternative bracket type in the mandible. The results indicate that buccal surfaces are more prone to WSL development, especially when WSL existed before treatment. The number of WSL that developed or progressed on buccal surfaces was 4.8 times higher than the number of WSL that developed or progressed on lingual surfaces. When measured using quantitative light-induced fluorescence (QLF), the increase in integrated fluorescence loss was 10.6 times higher buccally than lingually. We conclude that lingual brackets make a difference when caries lesion incidence is concerned.

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The introduction of fixed appliances meant a step forward in the treatment of orthodontic anomalies, yet is also considered a concern as a result of the high caries incidence rates seen in patients who have undergone orthodontic treatment with such fixed appliances (1–4). Nevertheless, to date, the use of fixed orthodontic appliances plays a key role in orthodontic practice. The main reason for caries development is plaque stagnation around the brackets, mostly underneath the arch wires and between the bracket and gingiva.

Many studies have been performed to find the solution to prevent caries lesions from developing during orthodontic treatment with fixed appliances. Whilst some of these studies have focused on the materials used for bonding the brackets to the tooth surface, or the brackets themselves (5–8), the majority of research aimed at the prevention of caries using topical fluoride or antibacterial agents in the form of rinses, varnishes or gels (9–13). More recent work has focused on fully sealing the buccal surfaces (14, 15). No studies have been reported thus far discussing the placement of brackets on the lingual surfaces, which are considered to be less caries prone.

In 1979 one of the first papers on the lingual placement of brackets for fixed orthodontic treatment was published (16). Lingual brackets were initially merely considered for esthetic reasons (17) and because of the extra costs involved are mostly used in the adult patient population (18, 19). The lingual placement of brackets may also have a positive effect on caries outcome. The lingual surfaces simply are less prone to caries in comparison to the buccal surfaces (20). This may be explained by differences in surface morphology, plaque retention, salivary flow, and mechanical cleaning of surfaces by the tongue. The amounts of plaque found are higher for buccal or labial surfaces than for lingual or palatal surfaces (21, 22). Also, higher caries counts were reported for buccal or vestibular surfaces than for lingual or palatal surfaces (23, 24). It is assumed therefore that the development of caries on the lingual or palatal surfaces with fixed brackets adhered is slower than on buccal and vestibular surfaces undergoing similar treatment.

Another difference between buccal brackets and lingual brackets (as commonly used in orthodontic practice) is the shape and size of the brackets. Buccal brackets are produced *en masse* and are small in order to fit most surfaces. Lingual brackets are custom-made (25) to fit the shape and contour of the individual teeth. These lingual brackets are large and cover nearly the entire lingual aspect of the teeth. The nearly complete seal of the lingual surfaces may be an advantage when caries prevention is considered as long as cementation is effective.

The aim of this study was to test the hypothesis that lingually placed brackets result in a lower caries

incidence on the bracketed surfaces than buccally placed brackets during orthodontic treatment with fixed appliances.

Material and methods

The effect of buccally or lingually placed brackets on caries development on the bracketed surfaces was tested in a caries clinical trial, using a split-mouth design with buccal brackets in either the maxilla or the mandible and lingual brackets in the opposite jaw. The caries incidence in subjects undergoing treatment with fixed orthodontic appliances was assessed by determining the increase in caries on the bracketed smooth surfaces from before treatment to immediately after treatment. The caries incidence on the opposing, unbracketed, surfaces was assessed to check that caries incidence during orthodontic treatment is a local problem initiated by bracket placement.

Subjects

The study was approved by the medical ethics committee of the Medical School Hannover, Germany (registration number: 3892). Subjects between 12 and 18 yr of age, who were patients at the orthodontic clinic in Bad Essen, in general good health, and scheduled to start orthodontic treatment with fixed appliances from May 2005 were eligible to participate in the study. The study recruitment period was set to 12 months with possible extension to allow the inclusion of at least 22 subjects. An exclusion criterion for the study was cavitated lesions or smooth surfaces with white spot caries lesions (WSL) (26). Subjects should have nearly fully erupted permanent premolars and cuspids at the start of treatment with a fixed appliance. Subjects were included only after informed consent was obtained from the subject and, in the case of minors, also their parents. Recruitment, including visual assessment for caries, was performed by the treating orthodontist. To gain experience with two treatment modalities in one mouth, recruitment was started at a slow pace, of one subject every 4 wk, and then speeded up after inclusion of the first 10 subjects. Twenty-eight subjects participated in the study. All subjects participated in the German individual prevention program, comprising oral hygiene check-ups, dental check-ups and fluoride applications twice per year, and fissure sealing of all permanent molars (27, 28).

Study outline

The study used a randomized split-mouth design. Subjects were randomly appointed to one of two groups: buccal brackets in the maxilla and lingual brackets in the mandible, or the reverse (25). Study participants drew a lot from a jar to ascertain which jaw was to be bracketed with buccal brackets and which was to be bracketed with lingual brackets. Before fixed appliance treatment, all subjects enrolled were screened, by the treating orthodontist, for WSL already present, and this was recorded by overview photographs of the oral cavity as well as by quantitative light-induced fluorescence (QLF) images (29) on all smooth surfaces. During treatment, caries progression was monitored visually and by QLF images. Suspect dentinal caries was the reason to terminate orthodontic treatment. Immediately after debracketing, at the conclusion of the treatment phase, the number of WSL was recorded again by overview photographs of the oral cavity and by QLF images.

Orthodontic treatment

All subjects in the study were treated with commercially available bracket systems (buccal: Orthos; Ormco, Glendorra, CA, USA) (lingual: TOP Service for Lingualtechnik, Bad Essen, Germany). Cement remnants after debracketing were removed using a tungsten carbide bur and polishing with a bonding adhesive remover (Pelz and Partner, Lindenberg, Germany).

White light photographs

Clinical photographs were obtained by D.W. using a Digital SLR camera (Nikon D200, AF Mikro Nikkor 105 mm, Nikon Macro Speedlight SB-29s; Nikon, Tokyo, Japan). Images were taken from the front, and from the left and right sides, of the face (Fig. 1), as well as from the occlusal aspect of the upper jaw and the lower jaw. Distances were standardized to 35 cm for the frontal view, to 30 cm for lateral views, and to 42 cm for occlusal/lingual views. Cheek retractors were used to obtain a non-obstructed view of the teeth. Clinical photographs were judged for caries presence by D.W.

QLF imaging

Quantitative light-induced fluorescence images were captured by the treating dental assistants of the orthodontic practice using an Inspektor Pro system (Inspektor Research Systems, Amsterdam, the Netherlands) comprising an intraoral fluorescence camera and a personal computer (PC) with dedicated software for image capturing and analysis (Inspektor Pro 3.0.0.37). To avoid the influence of ambient light in the QLF images, the camera handpiece was equipped with a disposable ambient light shield. The dental assistants of the orthodontic clinic were trained in image capture and repositioning by M.V. Quantitative light-induced fluorescence images were captured sequentially, one quadrant and surface type at a time. Immediately before image capture, the whole quadrant was briefly dried, using a two-way syringe, for 2 s per surface. Images were judged for the presence of WSL and were analyzed for fluorescence loss, integrated fluorescence loss over the WSL area, and WSL area by M.V. after completion of the study by all participants.

Power analysis

Power analysis was based on a previous observational study at the orthodontic department at ACTA reporting 7.5 [standard deviation (SD) 5] lesions on the buccal surfaces at debracketing (2). In this study we aimed to achieve a reduction to three lesions per person, giving an effect size of 0.39. Power analysis was performed using G*-power 3.1.0 (30). To reach a power of 0.8, 19 subjects were required. To allow for drop-outs, the minimum inclusion was set at 22 subjects.

Data analysis

White-light photographs were judged for the absence or presence of WSL. All QLF images were judged for WSL, and lesions were then analyzed for average and integrated fluorescence loss in the lesion and the lesion area with the

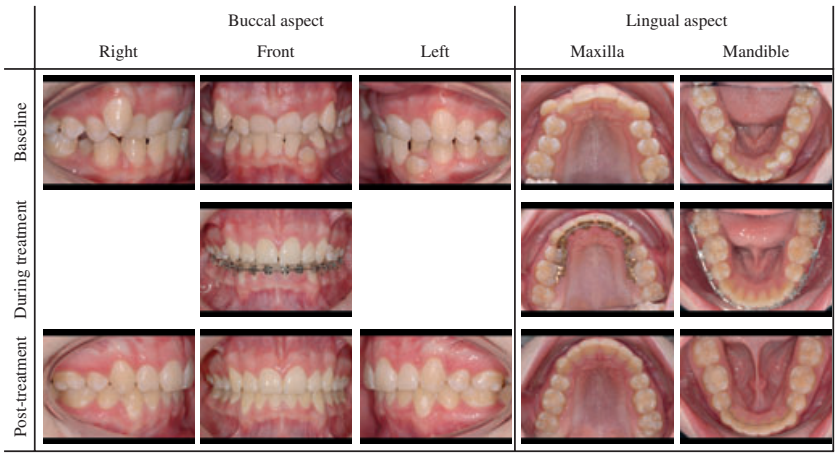

Fig. 1. Photographs showing the dentition of one of the study participants before, during, and after orthodontic treatment with fixed appliances. This subject was allotted to the group with lingual appliances in the maxilla and buccal brackets in the mandible. Note how the lingual brackets follow the shape of the teeth and provide a nearly complete seal of the tooth surfaces, while the buccal brackets are small. Furthermore, the wire in the lingual aspect is positioned closer to the teeth than on the buccal side. This subject clinically had no white spot caries lesions (WSL) on the smooth surfaces before treatment. Using quantitative light-induced fluorescence (QLF) images, small WSL were found before treatment at the buccal surfaces of teeth no. 42 and 45. After orthodontic treatment, WSL were found both visually and using QLF on the buccal surfaces of teeth 42, 43, and 45, and in the lingual groove of tooth 12.

fluorescence loss threshold set at 5% (31). Total integrated fluorescence loss (describing caries extent) and lesion area were calculated separately for the buccal surfaces and lingual surfaces in each subject. The total integrated fluorescence loss and lesion area of treated buccal and lingual surfaces in a subject were compared using a paired-samples *t*-test (SPSS 15, SPSS, Chicago, IL, USA).

Results

Subjects

During the recruitment phase 385 subjects received orthodontic treatment with fixed appliances (see the CONSORT flowchart in the Supporting Information). Of these, 46 desired lingual treatment only and 48 were already scheduled to receive brackets. Ten subjects received fixed appliances in one jaw only. A further 103 subjects did not have fully erupted premolars. Forty subjects did not want to volunteer. A total of 110 possibly eligible subjects were not asked to participate because they started fixed appliance treatment in the first recruitment phase where only one subject every 4 wk was enrolled.

Therefore, 28 subjects were enrolled into the study. The subjects were between 12.75 and 17.25 yr of age (mean age: 15.3 ± 1.2 yr) upon starting the treatment with fixed appliances. Fourteen subjects received buccal appliances in the maxilla and lingual appliances in the mandible, and the other 14 subjects received lingual appliances in the maxilla and buccal appliances in the mandible. The subjects were treated with fixed appliances for an average of 18.1 months (± 5.5 months). One subject was debracketed prematurely after 10 months as a result of severe caries development noticed by the treating orthodontist. The data for this subject are included.

White-spot caries lesions

All subjects were considered to be free from WSL on the smooth surfaces at baseline after visual inspection. Twenty subjects were also considered to be free from WSL on the smooth surfaces before orthodontic treatment, as determined by QLF images. Of these subjects, 15 were still WSL-free on

Table 1

Newly developed and progressing white spot caries lesions (WSL) counts as determined by quantitative light-induced fluorescence (QLF) on surfaces treated with brackets

Treatment group (bracketed surface, jaw)		No WSL	Only new WSL		Existing WSL			Total	
		Subjects	Subjects	New WSL	Subjects	New WSL	Progressing WSL	Subjects	WSL
Buccal	Maxilla	10	1	1	3	5	12	14	18
Lingual	Mandible	13	0	0	1	0	1	14	1
Buccal	Mandible	8	2	4	4	11	9	14	24
Lingual	Maxilla	6	3	3	5	1	6	14	10
Total	Buccal	18	3	5	7	16	21	28	42
	Lingual	19	3	3	6	1	7	28	11
All bracketed surfaces*		15	5	8	8	17	28	28	53

*Please note that not all subjects developing buccal WSL also developed lingual WSL, and vice versa.

the smooth surfaces at the conclusion of the orthodontic treatment, while five subjects had developed WSL (Table 1). Eight subjects already had WSL, visible by QLF images, at baseline on their smooth surfaces, of which 38 were on buccal surfaces (23 treated with brackets) and 14 were on lingual surfaces (7 treated with brackets). In these subjects existing lesions on the bracketed surfaces were found to progress, whilst new lesions also developed (Table 1). Existing lesions on non-bracketed surfaces remained stable, although a total of three new buccal lesions and one lingual lesion developed in three of these subjects during orthodontic treatment on surfaces not treated with brackets.

In Fig. 1, white-light photographs show the dentition of one subject before, during, and after orthodontic treatment from both the buccal and lingual aspects. The baseline data for WSL on bracketed surfaces (Table 1) suggest that the buccal surfaces were more often affected by caries than the lingual surfaces. However, the difference between buccal and lingual surfaces in the number of WSL found at baseline was not statistically significant (paired *t*-test, $P = 0.07$). Also, the total lesion area or caries extent (expressed as integrated fluorescence loss) within the subjects was not different for buccal and lingual surfaces at baseline (paired *t*-test, $P > 0.1$).

Although five of the subjects who were caries-free at baseline developed caries during treatment, 65.2% of new WSL developed in subjects with caries already existing at baseline, and all but one (4.3%) developed caries on buccal surfaces (60.9%). The number of buccal caries lesions that formed or progressed during orthodontic treatment was higher than the number of lingual lesions that formed or progressed during orthodontic treatment (paired *t*-test, $P = 0.01$). We did not find differences in incidence between the maxilla or mandible regarding buccal caries for the group as a whole. The number of buccal lesions that formed or progressed during orthodontic treatment in the maxilla (18) was not significantly different from that in the mandible (24) (*t*-test equal variance, $P = 0.7$). Also, when only newly developed lesions were considered, the difference between the maxilla (6) and the mandible (13) was not significant (*t*-test equal variance, $P = 0.3$). The number of lingual lesions that formed or progressed in the maxilla for all lesions and new lesions (10; 4 respectively) was statistically significantly higher than that in the mandible (1; 0 respectively) (*t*-test equal variance, $P = 0.02$ and 0.04, respectively).

The results for QLF analysis of lesions at baseline and post-treatment are given in Fig. 2. An overall increase in caries extent, expressed as integrated fluorescence loss over a lesion, existed. At baseline and after debracketing we found an average integrated fluorescence loss of 8.2%.mm^2 (range 0–141.9%.mm^2) and 58.4%.mm^2 (range 0–436.6%.mm^2), respectively, for the buccal surfaces, while these values for lingual surfaces were 0.9%.mm^2 (range 0–12.5%.mm^2) and 5.7%.mm^2 (range 0–43.7%.mm^2), respectively. The extent of caries increased more for buccal surfaces in a subject than for lingual surfaces (paired *t*-test, $P = 0.03$; effect size 0.4). Also, the increment in total lesion area or average fluorescence loss of all buccal surfaces in a subject was higher than for lingual surfaces (paired *t*-test, $P = 0.02$ and 0.03, respectively).

Early debracketing

We found a total of seven buccal and one lingual WSL in the subject who was debracketed prematurely after

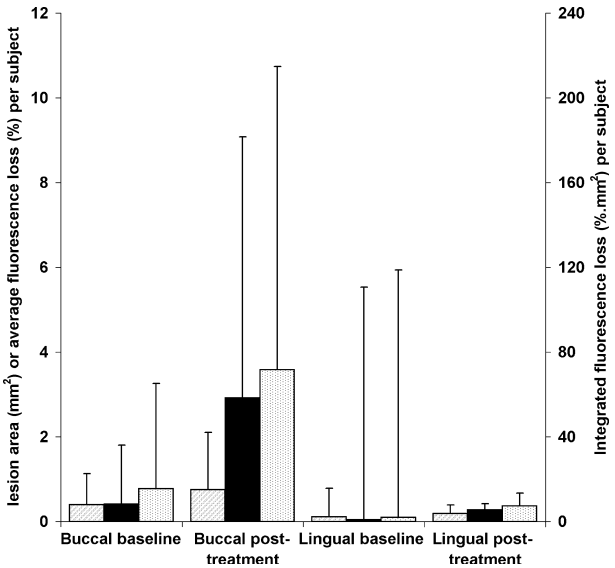

Fig. 2. Baseline and post-orthodontic treatment values from quantitative light-induced fluorescence (QLF) images on the bracket surfaces. Significant differences were found between buccal and lingual surfaces regarding the increment in average (white bars) and integrated (black bars) fluorescence loss and lesion areas (dotted bars) in subjects.

10 months as a result of the development of severe caries. All these lesions were already visible by QLF images taken at baseline. The fluorescence loss in this subject changed from 141.9%.mm^2 to 265.0%.mm^2 for the buccal surfaces and from 8.9%.mm^2 to 24.8%.mm^2 for the lingual surfaces. After exclusion of this subject from the statistical comparisons, the increase in the extent of caries was still significantly higher for buccal surfaces than for lingual surfaces (paired *t*-test, $P = 0.04$; effect size 0.4). Also, the number of buccal caries lesions that formed or progressed during orthodontic treatment remained higher than that of lingual lesions (paired *t*-test, $P = 0.03$).

Bracket failure

In two subjects, one buccal lesion in the buccal pit progressed as a result of leakage of the bracket. In one subject the lingual brackets failed on multiple occasions. Leakage of the lingual brackets occurred, causing lesions on the lingual smooth surfaces. In four subjects lesions in the lingual groove of the upper incisors had progressed as a result of leakage of the bracket. However, there was no statistical difference between lesions caused by leakage of the bracket cement on lingual and buccal surfaces (*t*-test equal variance, $P = 0.09$).

Discussion

Caries incidence in orthodontic subjects is considered to be a problem. In this study we tested a commonly used lingual bracketing system as an alternative to a commonly used buccal bracketing system to prevent caries lesions. In the group of 28 subjects participating in the study, the number of new WSL developing or progressing on bracketed buccal surfaces was 4.8 times

higher than the number of new WSL developing or progressing on bracketed lingual surfaces.

Furthermore, the caries extent, or integrated fluorescence loss, was 10.6 times higher for buccal surfaces than for lingual surfaces. When caries did develop on lingual surfaces, this was primarily in the maxilla, in the lingual pits of the incisors that were already affected by WSL before treatment, and these could be ascribed to leakage. In fact, 56.6% of WSL found after orthodontic treatment already existed before treatment, and 60.9% of new WSL developed on the buccal surfaces of subjects with existing caries lesions at baseline.

It is of concern that subjects undergoing orthodontic treatment already have WSL on their smooth surfaces before the start of treatment, as detected by QLF images. Indeed, existing caries at baseline seems to be indicative of increased caries risk. A more stringent examination for WSL, or a more sensitive detection method (such as QLF) to determine exclusion from orthodontic treatment, could have prevented the development of new WSL. Nevertheless, in this study the overall prevalence of WSL, and the WSL on bracketed surfaces after orthodontic treatment, was lower than recently reported from other orthodontic trials using QLF images (2) or visual assessment including WSL (3).

Whether the low caries incidence on the lingual surfaces is attributable to caries etiological factors, or bracket shape and size, is not known. A study comparing customized buccal brackets covering the whole buccal surfaces may answer this question; however, the acceptance of such brackets is deemed to be low for reasons of esthetics. Hence, in the present study we chose to compare lingual and buccal bracketing systems because they are commonly used without modifications.

The main drawback of lingual brackets used in this study is that they are not as easily applied as buccal brackets and therefore require that all teeth involved in fixed-appliance treatment need to be nearly fully erupted at the start of treatment. Because of this, nearly 27% of the patients at the orthodontic practice in Bad Essen are deemed unsuitable to receive such treatment unless they are willing to postpone the start of treatment.

From this study we concluded that, when properly mounted, lingual brackets are in favor over buccal brackets, when caries outcome on the smooth surfaces is considered. The answer to the initial question is therefore, yes, lingual brackets do make a difference.

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Supporting Information

Additional Supporting Information may be found in the online version of this article:

CONSORT Flowchart and Checklist.

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