Lingual appliances reduce the incidence of white spot lesions during orthodontic multibracket treatment

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Introduction: The aim of this study was to assess the incidence of white spot lesions (WSLs) in subjects treated with customized lingual multibracket appliances—separately for maxillary anterior teeth 12 to 22 (according to the Fédération Dentaire Internationale numbering system) as well as for tooth groups 15 to 45, 16 to 46, and 17 to 47—and to determine the impact of patient-related and treatment-related variables on the frequencies of new WSLs. **Methods:** Of 214 subjects comprehensively treated between June 1, 2011, and May 31, 2014, in 1 orthodontic center (Bad Essen, Germany) with a completely customized lingual appliance (WIN; DW Lingual Systems, Bad Essen, Germany), 174 (47% boys, 53% girls; mean age, 14.35 ± 1.23 years [minimum, 11.35 years; maximum, 17.91 years]) were recruited with inclusion criteria of completed lingual multibracket treatment of their maxillary and mandibular permanent teeth 17 to 47 (4582 teeth in the study), and age less than 18 years at the initial appointment. WSL assessment was accomplished using standardized digital high-resolution maxillary and mandibular occlusal photographs taken before bracketing and after debonding. Nonparametric analysis of variance was performed, taking into account the subjects' grouped ages (≤16 or >16 years), sexes, and treatment durations. **Results:** Of the total population of subjects, 41.95% developed at least 1 new WSL when all teeth, 17 to 47, were considered, and this incidence was 27.01% for tooth group 16 to 46, or 10.59% of subjects and 4.74% of the maxillary incisors (12 to 22). Of all teeth under consideration, 3.19% developed a WSL during treatment. The frequencies of decalcification were not significantly increased in preadolescents (≤16 years) compared with adolescents (>16 years). Treatment duration had a significant adverse impact on WSL formation in tooth groups 15 to 45 and 16 to 46, and in complete dental arches (teeth 17 to 47). **Conclusions:** Subject-related and tooth-related WSL incidences of both single tooth groups and complete dental arches in subjects treated with the lingual WIN appliance were distinctly reduced when compared with previous reports of enamel decalcification after conventional labial multibracket treatment. (Am J Orthod Dentofacial Orthop 2015;148:414-22)

Multibracket (MB) treatment is a routine and frequent procedure used currently in orthodontics because it is the only noncompliance treatment approach for 3-dimensional dental arch adjustments. However, its downside is the increase in the risks of white spot lesion (WSL) formation and incipient caries.[1] Despite the general tendency of WSL surfaces to remineralize and harden after debonding, the esthetic aspect in maxillary anterior teeth affected by WSLs and decalcifications remains highly problematic,[2-4] even 12 years after treatment.[5] Therefore, prevention and treatment of WSLs have become matters of concern among orthodontists, and a health care market has emerged in recent decades to respond to this situation, including new microinvasive approaches for WSL infiltration and camouflage.[6] Nonetheless, it is undeniable that even thorough oral hygiene is not sufficient for preventing WSLs in many patients.[1,7] Moreover, further preventive strategies, such as the application of fluoride-releasing sealants and bonding materials, daily rinsing with sodium fluoride mouth rinse, or

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The first author invented the WIN system, which is manufactured by DW Lingual Systems, Bad Essen, Germany; he is the CEO of the company.
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Table I. Definition of specific tooth groups with the Fédération Dentaire Internationale (FDI) numbering system used in the text and the universal numbering system (UNS)

Tooth group	*Maximum number of teeth per subject*	*Definition by FDI numbering system (universal numbering system)*
12-22	4	Maxillary incisors: 22, 21, 11, 12 (UNS: teeth 7, 8, 9, 10)
15-45	20	Maxillary and mandibular incisors, canines, first and second premolars: 11-15, 21-25, 31-35, 41-45 (UNS: teeth 4-13 and 20-29)
16-46	24	Maxillary and mandibular incisors, canines, first and second premolars, and first molars: 11-16, 21-26, 31-36, 41-46 (UNS: teeth 3-14 and 19-30)
17-47	28	Maxillary and mandibular incisors, canines, first and second premolars, and first and second molars: 11-17, 21-27, 31-37, 41-47 (UNS: teeth 2-15 and 18-31)

chlorhexidine applications, have failed to prevent WSL formation.[8-11] An additional source of frustration is the finding from previous research of increased WSL susceptibility in preadolescents, who are also a major age group for MB interventions.[12,13]

Intensive clinical studies of WSL formation on maxillary incisors and canines as a side effect of buccal MB treatment have found subject-related incidences of at least 1 new WSL of 46% within 12 months,[14] or 36% for maxillary and mandibular incisors,[12] whereas other authors have even reported 60.9% for maxillary incisors considered alone.[2] For all maxillary and mandibular anterior and posterior teeth, including the first molars, 16 to 46 (according to the Fédération Dentaire Internationale numbering system), WSL incidences up to 72.9% can be expected during MB interventions.[3]

As a totally different approach to preventing WSL formation during orthodontic treatment, the use of lingual MB appliances has recently been reconsidered as a method that is potentially superior to conventional labial fixed orthodontic treatment because of the reduced occurrence of decalcifications on lingual enamel surfaces.[15] However, detailed information derived from clinical studies is limited. Although there are many studies or systematic reviews available regarding the incidence of WSL formation during labial bracket treatment as a function of location, subject age and sex, and even as an iatrogenic side effect of surplus orthodontic etching, there is not enough equivalent information concerning lingual-bracket induced WSLs that would enable us to support or reject the hypothesis of improving WSL prevention during comprehensive orthodontic treatment simply by choosing lingual appliances instead of conventional fixed labial approaches.[2,3,14,16-18]

A potential disadvantage of lingual orthodontic treatment is that additional costs compared with conventional MB treatment may be incurred initially. However, if the hypothesis of a decreased incidence of WSLs is valid, these costs may be balanced against the costs of preventive measures against WSLs, such as the use of enamel sealants, as needed when using conventional MB appliances, or potential costs that may be incurred for treatment of labial WSLs, such as microabrasion or resin infiltration.[6]

The objective of this study was to assess the incidence of WSL formation in subjects treated with completely customized lingual MB appliances (WIN; DW Lingual Systems, Bad Essen, Germany), separately for the maxillary incisors (12-22; Table I), as well as for tooth groups 15 to 45, 16 to 46, and 17 to 47, to allow comparisons with existing data on labial WSL formation and consider the impact of patient variables (age, ≤16 or >16 years; and sex) and treatment duration on WSL formation.

MATERIAL AND METHODS

Our report is based on a single-center retrospective study of the incidence of WSL induced by lingual MB appliances.

Of 214 patients comprehensively treated from June 1, 2011, to May 31, 2014, in 1 orthodontic center (Bad Essen, Germany) with completely customized lingual WIN appliances, 174 participants (82 boys [47%], 92 girls [53%]; mean age, 14.36 ± 1.23 years [minimum, 11.35 years; maximum, 17.91 years]) were recruited. We adopted the following inclusion criteria: (1) lingual MB treatment of the maxillary and mandibular permanent teeth (from central incisor to second molar) with the WIN appliance; (2) age less than 18 years at the initial appointment; (3) debonding completed; and (4) high-quality initial and final intraoral top-view photographs. The exclusion criterion was missing or low-quality photographs.

Accordingly, of the 214 potentially eligible subjects, 40 (18.69%) were excluded from analysis because they were 18 years of age or older. None was excluded because of missing or low-quality photographs.

Single deciduous teeth and teeth with restorations in the area of the palatal or lingual bracket bases were excluded from the analysis, as were teeth whose lingual surfaces were not clearly visible or could not be judged

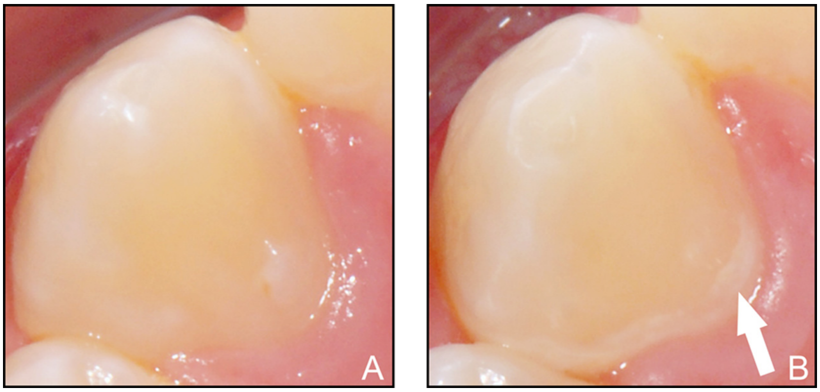

Fig 1. Example of a maxillary right canine: **A,** before treatment and **B,** directly after debonding. A typical lingual WSL is indicated. Each enamel surface was enlarged to full-screen size to enable an accurate judgment of decalcifications. As with all lingual postorthodontic WSLs found in this trial, no preventive or invasive dental care was required subsequently.

on either photograph—eg, because of labiolingual inclination. Thus, a total of 279 teeth (5.7%), including 40 maxillary incisors (12-22), 46 mandibular incisors (32-42), 88 maxillary canines and posterior teeth (13-17 and 23-27, respectively), and 105 mandibular canines and posterior teeth (33-37 and 43-47, respectively), were excluded because they could not be judged from either of the photographs, taken before treatment or at debracketing. The final number of trial teeth was 4582.

The records included each subject's age, sex, and time points of bracketing and debracketing. After subjects aged 18 or more years were excluded, the sample was further divided into 2 age groups: 16 years of age and less, and more than 16 years. Ninety percent (n = 156) of the subjects were 16 years old or less, and 10% (n = 18) were older than 16 years.

They received identical, standardized oral hygiene instructions, including the advice to brush their teeth at least 3 times daily with typical commercially available 1400 to 1450 ppm fluoridated dentifrices; otherwise, oral hygiene was not considered as a cofactor in our analysis.

To be able to compare our findings with previous research on WSL incidence after labial bracket treatment, analyses were performed separately for specific tooth groups (Table 1).

This study received full ethical approval from the ethics committee of Hannover Medical School in Germany (number 1189/2011), and all patients or their guardians gave informed consent before the study.

For the WSL and enamel cavitation assessments, standardized high-resolution intraoral maxillary and mandibular occlusal photographs were taken of the dental arches before bracketing and directly after debracketing by the same operator (D.W.) using a digital camera (D-200, AF Mikro Nikkor 105 mm 1:2.8D, Makro Speedlight SB-29s; Nikon, Tokyo, Japan) and intraoral mirrors. Before the WSL screenings, the mirrored images were swiveled back to their true sides for an unambiguous assignment of quadrants and teeth. Screenings of the lingual enamel surfaces were performed in a darkened room by an assessor (E.K.) on a high-resolution screen (VP950 b; screen diameter, 19 in; maximum resolution, 1280 × 1024; ViewSonic, Walnut, Calif) and by another assessor (M.K.) (MacBook Pro Retina 2013; Apple, Cupertino, Calif) by enlarging each enamel surface to full-screen size (Fig 1).

One assessor (E.K.) was trained and calibrated in assessing lingual WSLs. The primary outcome measures were sound enamel and the numbers of WSLs. A WSL was defined as the "first sign of a caries lesion on enamel detected with the naked eye"[19]: ie, demineralized, slightly rough or chalky enamel opacities on smooth surfaces at or near the area of the former orthodontic brackets. To differentiate between these and other white discolorations of enamel, such as dental fluorosis, the latter was defined as a white to yellowish lesion blending with normal enamel and without well-defined margins or with blurred outlines, in contrast to WSLs, which have more defined outlines and are well differentiated from the surrounding enamel.[20] As an additional aid in distinguishing between WSLs and fluorosis, we checked whether there was a symmetrical distribution of those opacities when considering the complete dental arches as is typical for fluoride opacities, or whether they were randomly distributed as is typical for WSLs.[20]

All lingual orthodontic MB treatments were carried out at the same orthodontic center (Bad Essen, Germany) with a standardized indirect bonding routine and the WIN appliance (Fig 2). For indirect bracket bonding,

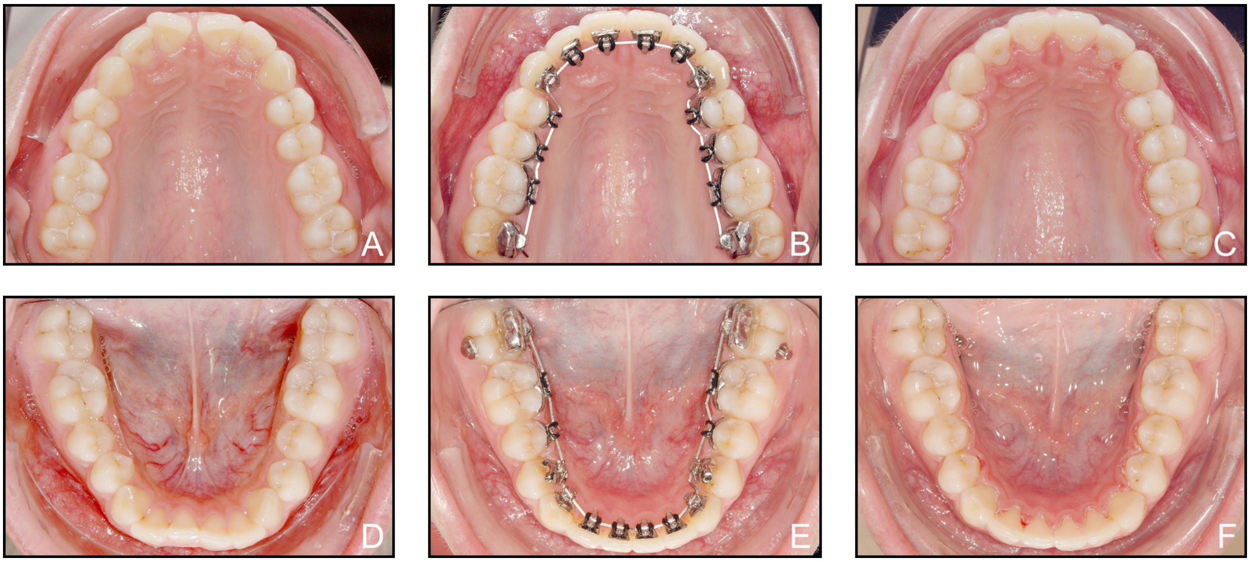

Fig 2. A-F, Example of a patient treated with the WIN appliance, as used in both dental arches of all patients of this trial. Top-view photographs taken before bonding (**A** and **D**) and after debracketing (**C** and **F**) were used for the WSL assessments, and photographs taken during treatment (**B** and **E**) were used for determining the former locations of the bracket margins.

Table II. Interoperator and intraoperator method error assessment results for reassessments of a random sequence of 40 participants

		Frequencies of unequal WSL classifications/valid teeth, n (%)	
Time point	*Subjects (n)*	*Interoperator error (assessors M.K. vs E.K.)*	*Intraoperator error (assessor E.K.1 vs E.K.2)*
Before treatment	40	25/1035 (2.42)	9/1039 (0.87)
After treatment	40	86/1036 (8.3)	49/1032 (4.75)
Total	80	111/2071 (5.36)	58/2071 (2.80)

the chemically cured resin Maximum Cure (Reliance Orthodontic Products, Itasca, Ill) was applied to both bracket bases and lingual enamel surfaces, after the application of a thin layer of a fluoride-releasing dual-cure, single-component bonding agent to the enamel (ExciTE F DSC; Ivoclar Vivadent, Ellwangen, Germany).

Statistical analysis

The features of the 174 subjects (4582 teeth) such as treatment time and age distribution were descriptively analyzed (means and standard deviations). Nonparametric, multifactorial analysis of covariance (ANCOVA) was used to assess the impact of the factors "sex" (female, 0; male, 1) and "age group" ($\leq$16, 0; $>$16, 1), adjusted by the covariable "treatment duration" on the incidence of WSLs for the specific tooth groups. Both tooth-related and subject-related incidences of WSLs were calculated for each tooth group shown in Table I. The significance level was set at $\alpha = 5\%$. Statistical software packages (SAS version 9.3; SAS Institute; Cary, NC; and STATISTICA version 10; StatSoft, Tulsa, Okla) were used for the statistical analyses.

Four weeks after the trial assessments, both intraoperator and interoperator method errors were calculated on the basis of reassessments of a random sequence of 40 participants in the study (80 assessments; 2071 teeth; random sequence generator, www.random.org) by 2 raters (E.K. and M.K.) for both assessments. This was done to assess the validity of the method as well as possible. Both operators were calibrated and trained in assessing WSLs. The intraoperator assessment deviation in WSL classification was 2.8%. Table II gives the detailed method error assessment results.

RESULTS

Mean lingual MB treatment duration was 19.02 ± 4.63 months (minimum, 7.67 months; maximum, 29.47 months). The global incidence of new WSLs was

Table III. Tooth-related and subject-related incidences, considering distinctive groups of teeth: frequencies and percentages of teeth and subjects affected by at least 1 new WSL in specific tooth groups (see Table I for definitions of tooth groups)

Group of teeth	*Valid numbers of teeth*	*Tooth-related incidence, n (% all/male/female)*	*Valid numbers of subjects*	*Subject-related incidence, n (% all/male/female)*
12-22	654	31 (4.74/4.44/5.01)	170	18 (10.59/12.2/9.09)
15-45	3317	70 (2.11/2.3/1.89)	174	37 (21.26/24.39/18.48)
16-46	4004	85 (2.12/2.4/1.85)	174	47 (27.01/31.71/22.83)
17-47	4582	146 (3.19/3.2/3.1)	174	73 (41.95/43.9/40.22)

Table IV. Results of nonparametric ANCOVA of tooth-related WSL formation in the tooth groups, with 2 main effects (sex and age group [≤16 and >16 years]), and treatment duration as the covariable

	Incidence of WSL in groups of teeth (P value)			
Effect or interaction	*12-22*	*15-45*	*16-46*	*17-47*
Sex (male, female)	0.87	0.02	0.02	0.12
Age group	0.50	0.31	0.67	0.58
Sex × age group	0.55	0.045	0.09	0.16
Treatment duration	0.07	0.03	0.003	0.01

P <0.05 indicates statistical significance. Frequencies of deterioration in decalcification were not significantly increased in preadolescents (age, ≤16 years) compared with adolescents (age, >16 years). Sex had an influence on tooth groups 15-45 and 16-46.

3.19% for all teeth (17-47); 41.95% of the subjects were affected by at least 1 new WSL. The subject-related incidence was 27.01% for tooth group 16 to 46, or 10.59% when considering the maxillary incisors separately. Further details about subject-related incidence and percentages of affected teeth for specific tooth groups are given in Table III.

Table IV shows the results of the nonparametric ANCOVA of tooth-related WSL formation in the tooth groups, with the main factors of age (≤16 or >16) and sex, as well as treatment duration as the covariable. Frequencies of deterioration in decalcification were not significantly increased in preadolescents (≤16 years) compared with the adolescents (>16 years). Treatment duration had a significant adverse impact on WSL formation in tooth groups 15 to 45 and 16 to 46, and the complete dental arches (teeth 17-47).

DISCUSSION

Although the discussion of the problem of WSLs induced by fixed orthodontic appliances has mostly been focused on the impaired esthetic appearance of the front teeth and smile esthetics,[2,4,6,14] a WSL is an incipient caries caused by an imbalance of natural enamel remineralization and demineralization, and it is prone to progress to a stage of cavitation if adequate oral hygiene measures are not implemented.[19,21]

The aim of this study was to address the assumption of reducing WSL formation using a completely customized lingual appliance system, the WIN appliance, instead of buccal MB appliances. We had a much larger sample than in previous research on lingual WSL formation[15,22] to provide data that were on a par with existing, well-designed reports about WSLs induced by labial MB appliances, in terms of coverage.[2,3,17] In the literature on this topic, a certain inhomogeneity was found in relation to the composition of the tooth groups investigated, with an emphasis on the analysis of the front teeth.[2,14,17] Therefore, we decided to additionally subdivide the data analysis in this study into specific tooth groups, to an extent that allowed comparisons with much of the existing research on WSLs induced by labial MB appliances (Table V).

In this study, only lingual WSLs were assessed. A comparison of our results with published data on post-orthodontic WSL incidences by labial MB appliances is admissible, but it needs to take into account the slight differences in methodology because WSL assessments are done at different sight angles.

In contrast to several reports on labial WSL formation during fixed orthodontic treatment, no "problematic" subjects were excluded from our analysis because of missing photographs, interrupted documentation, lack of compliance, or debonding ahead of schedule for caries formation.[2,3,12] The subject-related incidence of at least 1 new WSL was 10.59% in our sample when considering the maxillary incisors (teeth 12-22) separately. Compared with labial MB appliance treatment of the same tooth group, Enaia et al[2] reported a subject-related WSL incidence of 60.9% in a cohort of subjects with comparable ages (mean age, 13.7 ± 3.5 years). Comparing both labial and lingual situations as documented, the incidence of lingual WSLs in our study was about 6 (5.75) times smaller. In terms of tooth-related WSL incidence after labial MB treatment, Enaia et al found that 919 teeth (57.4%) had

Table V. Findings of recent studies with visual analysis of WSL frequencies after labial MB treatment

Authors	Subjects (n)	Teeth analyzed	WSL frequencies, % (multiplication factor to our findings) Subject related	Tooth related
Lovrov et al[23] (2007)	53	Maxillary and mandibular front teeth		28.1
		Maxillary and mandibular premolars		34.4
		Maxillary and mandibular dental arches, 16-46		24.9 (11.8 times)
Enaia et al[2] (2008)	400	Maxillary incisors, 12-22	60.9 (5.8 times)	57.4 (12.1 times)
Chapman et al[12] (2010)	332	Maxillary anterior 8 teeth, 14-24	36	
Richter et al[3] (2011)	350	Maxillary and mandibular dental arches, 16-46	72.9 (2.7 times)	17.3 (8.2 times)
Tüfekçi et al[14] (2011)	35	Maxillary 6 anterior teeth, 13-23, after 12 months	46	
Julien et al[17] (2013)	885	Maxillary 6 anterior teeth and mandibular teeth, 13-23	23.4	

Reasons for variations in assessed WSL incidences are likely due to different fluoridation regimens, but also likely to partial exclusions of problematic patients who were debonded ahead of schedule or had incomplete documentation.

postorthodontic WSLs in their sample of 1600 maxillary incisors, compared with 4.74% (more than 12 times less) (Table III) in our study, when considering the same tooth group of maxillary incisors.[2] Also, whereas labial WSLs often compromise smile esthetics, resulting in preventive or camouflage treatments, no lingual WSL assessed in this trial required restorative dentistry or presented an esthetic problem to any patient.

Likewise, Tüfekçi et al[14] investigated maxillary front teeth including canines (teeth 13-23) and found in 46% of subjects at least 1 new WSL after 12 months. The reason for not including premolars was that assessments were performed during MB treatment, whereas premolar enamel surfaces located gingivally to the archwire were "generally covered by inflamed gingiva."[14] They excluded subjects who were on a daily supplemental fluoride regimen from their trial. There was an observational time limit to their study of 12 months, whereas our study assessed WSL incidence during the entire time period of orthodontic lingual bracket treatment for a mean treatment duration of 19.02 $\pm$ 4.63 months. Comparing the reduced WSL incidence findings of Tüfekçi et al with those of Enaia et al,[2] an obvious explanation for the differences is the shorter observational time in the former study. Also, a comparison of that study with our data suggests remarkably reduced frequencies of new WSLs during lingual treatment compared with conventional bracket interventions.

Other studies of both maxillary and mandibular front teeth found MB-induced WSL incidences between 23% and 36%,[12,17,23] which may have been due to fluoridation regimens[23] but were more likely due to the inclusion of the mandibular incisors, which tended to show a lower WSL incidence because of enhanced salivary wetting.[17] It may be hypothesized that in terms of differences between WSL formation of labial and lingual enamel areas, local differences in saliva wetting and distribution by intraoral soft tissue dynamics may play a role.

Although studies with sufficiently large sample sizes for assessing WSL incidences of almost complete dental arches up to the first molars (teeth 16-46) found that 72.9% of the subjects developed new lesions during labial MB treatment, our study established an incidence of lingual lesions about 2.7 times lower (27.01%) than the same group of teeth with the same method of WSL screening.[3]

To the best of our knowledge, WSL incidence evaluations based on sufficiently large sample sizes for complete maxillary and mandibular dental arches including the second molars are lacking. The reasons for this paucity of data can be seen in the inconsistencies of inclusion of the second molars into fixed orthodontic treatment, but even more likely is that those teeth are often difficult to judge with the standard orthodontic documentation images commonly used for assessing WSL prevalence or incidence. We found a global WSL incidence for complete maxillary and mandibular dental arches including the second molars (teeth 17-47) of 3.19% (Table III).

Since previous research has reported increased caries activity in preadolescents and adolescents compared with young adults, we made a separate analysis of age groups estimated to be more susceptible to caries formation.[12] Analysis of the factors of age group ($\leq$16 or $>$16 years), sex, and treatment duration (Table IV) confirmed previous research findings, since no significantly increased WSL formation was seen in preadolescents ($\leq$16 years) compared with adolescents ($>$16 years),[24,25] but this is at variance with the findings of other authors because it is obviously due to the exclusion of subjects older than 18 years in our study.[12,13] The reason for excluding subjects in that age group was to match the samples from previous studies of WSL formation in patients treated with conventional labial appliances without creating a bias toward reduced formation of WSL by including subjects who are potentially less susceptible to WSL formation because of their age.[2] However, as a result of focusing on subjects under 18 years, there was an imbalance in our study in the distribution of subjects toward the age group below 16 years of age, compared with the group of subjects between 16 and 18 years of age (90% to 10%, respectively). A reason for it may be that the trial sample represents a typical cross-sectional age distribution of an orthodontic practice, with more underaged patients treated before or during their growth spurts than afterward. This also implies that a majority of the patients in our sample were characterized by even more pronounced caries activity and susceptibility, and a higher risk for WSLs, because of their young age (mean, 14.35 years).[12] Therefore, the incidence of postorthodontic lingual WSLs may be expected to be even more reduced in a sample with a greater mean age.

Tüfekçi et al[14] reported a significantly more pronounced WSL susceptibility in male subjects. Significant sex effects in our trial were only seen for tooth groups 15 to 45 and 16 to 46 (Tables III and IV), with lower WSL incidences in the girls in these groups, thereby partly corroborating most previous reports on cofactors of formation of labial-side WSLs because they did not find significant effects by sex.[12,13]

There is disagreement in the literature concerning whether treatment duration enhances the formation of WSLs significantly[17,23] or not.[12,13] In our study, the cofactor of treatment duration did have a significant impact on WSL formation in tooth groups 16 to 46 and 17 to 47.

Regarding treatment duration with lingual appliances, our results showed that orthodontic treatment using lingual appliances—when provided on a routine basis—is comparable in terms of treatment duration with labial MB treatment (19.02 $\pm$ 4.63 months). Moreover, it has been shown that torque or third-order angle expression is not a problem with modern customized lingual appliances.[26,27]

Assessments of the prevalence or incidence of WSLs after fixed orthodontic appliance treatment is sometimes performed at chairside[14] or using quantitative light-induced fluorescence.[15] However, the most common method in WSL assessments is screening digital dental arch images taken before and after treatment.[2-4] Whereas the method of quantitative light-induced fluorescence seems to be more sensitive, with overall higher numbers of WSLs detected, it is also time-consuming, resulting in lower sample sizes.[4,15,25] Therefore, most research groups screen images that are available as part of routine orthodontic diagnostics. The advantages compared with chairside analysis without images are greater accuracy in the option of magnifying enamel surfaces, as carried out in this study, and also in the option of estimation of method errors.[14] Intraoperator and interoperator errors in our study were 2.8% and 5.36%, thereby corroborating previous reports regarding the validity of the method.[3,17] To standardize WSL assessments as much as possible, high-resolution digital pictures were taken in a standardized setting. However, lingual WSL assessments are more difficult than buccal WSL screening, since distinctively lingually inclined front teeth, canines, or first premolars sometimes cannot be assessed. If this was the case in either of the 2 images obtained per subject, those teeth were excluded from subsequent analysis.

A total of 5.7% of the teeth were excluded because they could not be judged on either photograph, mostly in the areas of the mandibular canines and posterior teeth. For that reason, a decision was made not only to consider the global incidence for all teeth, but also to perform segregated analyses for tooth groups 12 to 22, 15 to 45, 16 to 46, and 17 to 47. In addition, this enabled a comparison of our results directly with those of other research groups, who restricted their analyses and focused on 1 of those specific tooth groups (eg, 12-22) from the beginning.[2] For the tooth group of maxillary incisors (12-22) in our study, there were only 40 teeth that could not be judged at 1 time point because of tooth surface inclination. Although there was a higher dropout rate for the group of mandibular posterior teeth, these data are considered valuable, since they are the first data available on the topic and provide complementary information. Omitting those teeth for both time points that could not be judged at 1 of the assessments because of a spatial inclination may have contributed to either an increase or a decrease in the percentage of teeth affected by WSLs. Therefore, it was considered less as a bias toward 1 side than as a reduction in the numbers of teeth assessed. The general issue that some teeth cannot be judged applies to all reports with photographs for assessment of WSLs: eg, due to hyperplastic gingiva conditions, if photographic assessments are made with the appliances still in situ.[14] However, when attempting to assess lingual WSLs, the problem that some surfaces cannot be determined because of the unfavorable inclination of some teeth may be greater in top-view photographs than when assessing labial WSLs on lateral or front-view images. Despite the complete exclusion of those teeth from both assessments, if they could not be judged at either time point, it is conceivable that both sound enamel areas and WSLs were overlooked. Nevertheless, even though 5.7% of all teeth could not be judged, this report is based on the largest sample size for lingual WSLs currently available.

It has also been claimed in some publications that during assessments of labial WSLs after MB treatment there was a partial exclusion of "problematic" patients who were debonded ahead of schedule or because of incomplete documentation.[2,3,12] This aspect is rarely discussed as a factor generating bias in studies on WSL incidence in orthodontic patients. In our study, there were no dropouts because of incomplete records or low-quality photographs, as is often the case with socioeconomically problematic persons, who tend to use fewer oral hygiene measures and have a higher susceptibility to carious lesions.[28] It can be assumed that in some studies of WSL incidence that reported exclusion of several subjects with incomplete records or low-quality photographic documentation, the true incidence of WSLs in those samples might have been slightly higher than calculated.

It is obvious that each method of WSL assessment—whether clinical scoring, photographic analysis, or quantitative light-induced fluorescence assessment—has advantages and flaws. The drawback of clinical assessments is that they are not verifiable and are more or less subjective, since they are carried out at one moment in time and mostly by one operator. The drawback of the method of screening photographs is that some areas cannot be judged in situations of highly inclined single teeth; ie, single teeth were excluded if the area of the former bracket base could not be judged or fully viewed because of an inclination of the respective tooth surface. This was the case in 5.7% of the teeth. On the other hand, the advantages compared with the typical chairside situation in an orthodontic office include the possibilities of a more diligent assessment with high-resolution screens and magnification, and calculations of method errors. Finally, the large sample sizes distinguish this method from time-consuming chairside quantitative light-induced fluorescence assessments.[15]

Since the technique of lingual MB treatment is not as widespread as that of conventional labial MB treatment, there is currently no clinical report available on the incidence of lingual WSLs nearly as large in terms of sample size. Despite the initial laboratory cost factor that must be weighed against the costs of prevention or treatment of labial WSLs, lingual MB treatment may provide a valuable supplement to the therapeutic spectrum of orthodontists.

The subjects in this study received routine local fluoridation after bracketing, application of a thin layer of a fluoride-releasing bonding as part of the standardized bracketing procedure, as well as standardized oral hygiene instructions, including advice to brush their teeth at least 3 times daily with a typical commercially available fluoridated (1400-1450 ppm) dentifrice. Oral hygiene status, nutritional habits, further fluoridation exposure, and potential local differences in saliva wetting and distribution between the tongue and the circumferential intraoral soft tissues were not considered as cofactors in this study, but they might influence increases or decreases in WSL frequencies.

In our study, subjects older than 18 years at the start of treatment were excluded. Due to an increased susceptibility for incipient caries in preadolescents and adolescents, the inclusion of these older subjects would have reduced the frequencies of WSLs even more.[12]

CONCLUSIONS

Prevention of MB-induced enamel demineralization and incipient caries is still a critical issue in orthodontics. Based on our findings and their comparisons with published data on labial postorthodontic WSLs (taking into account slight differences in assessment methodologies), the following conclusions can be drawn.

1. Subject-related and tooth-related WSL incidences of both single-tooth groups and also complete dental arches in subjects treated with the lingual WIN appliance were distinctly reduced compared with previous reports on enamel decalcification after conventional labial MB treatment.[2,3]
2. In addition, lingual appliances do not involve etching and rotational postprocessing (high or low speed) of adhesive residues on the labial enamel, and lingual WSLs do not compromise smile esthetics.
3. Orthodontic treatment with customized lingual fixed appliances can significantly reduce incipient caries lesions.

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