Research Square

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Comparing Aligner and Multibracket Therapy in The Evaluation of White Spot Lesions

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Research Article

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Abstract

Background: This study used the Enamel Decalcification Index (EDI) by Banks and Richmond (1994) to investigate the severity and development of white spot lesions (WSL) before and after multi bracket (MB) and aligner (Invisalign teen®) therapy. The extent of WSL was recorded using the newly developed evaluation aid crosshair.

Methods:

Photographs of 121 subjects before and after MB therapy (58 female and 63 male) with an average age of 12.5 ±2.1 years and of 42 aligner therapy subjects (18 female and 24 male) with the average age of 14 ±1.8 years were examined. All subjects received standardized oral hygiene instructions. The vestibular tooth surfaces of the incisors, canines, and premolars were examined with the Enamel Decalcification Index (EDI) of Banks and Richmond (grades 0-3), and the extent of WSL was assessed with the graticule using circle segments in percent. All statistical analysis was performed using frequency tables, cross-tabulations, and logistic regression.

Results:

69% of subjects had at least one WSL before MB therapy, while 98% had WSL after MB therapy. 98% of subjects had at least one WSL, which is an incidence of 29%. 17% of subjects had WSL before aligner therapy, and 52% had WSL after aligner therapy. This concludes an incidence of 43%. 18% of tooth surfaces had WSL before MB therapy and 52% had them after. 99% of tooth surfaces examined before aligner therapy had no WSL, and 91% of tooth surfaces stayed free of WSL after therapy. The prevalence of WSL was higher on the canines and premolars than on the incisors before and after both MB and aligner therapy. Aligner therapy had a significantly higher WSL prevalence and incidence on the maxillary teeth. The oral, mesial, and distal surfaces were significantly more likely to have WSL after MB therapy (prevalence) than the gingival tooth surface. The tooth surfaces most notably affected by WSL, in order from highest to lowest impact, were the distal tooth surfaces, the mesial tooth surface and the gingival tooth surfaces (incidence). Areas around rectangular attachments are more likely to be affected by WSL compared to tooth surfaces without. The study on gender distribution in MB therapy showed that the development of WSL was far higher in adolescent males than in females, though age did not prove to be an influencing factor.

Conclusion: This study concludes that the treatment with aligners can successfully reduce the formation of white spot lesions in comparison to MB treatment.

Introduction

The Fifth German Oral Health Study (DMS V) articulates that Oral health has significantly improved in recent decades. It states that the number of caries-free children doubled from 1997 to 2014. Today, 81.3% of 12-year-old adolescents are caries-free, and one in two children are taught about proper dental hygiene.

Although a progressive decrease in caries has been observed, it still remains to be one of the most common chronic diseases [1]. Enamel demineralization, so-called white spot lesions (WSL), are a preliminary stage in the development of caries [2]. Orthodontic treatment most often occurs in adolescents at the end of the second dentition, between the ages of 10 and 14 [3, 4]. The focus of this study is to examine the development of WSL in comprehensive orthodontic treatments on adolescents, specifically aligner and MB therapy. A 2–96% prevalence of WSL in MB therapy is reported in literature [5, 6]. This vast difference in results its attributed to the different assessment methods, the inconsistencies in the study group sizes, and the selection of examined teeth [7]. Some studies examined only the anterior teeth [6, 8] while others examined the maxillary anterior teeth [6, 9]. Some study guidelines even included fluoride application counseling, which presents yet another variable between studies [7]. These aspects must be taken into account when comparing results (Tab 1).

The results of the investigated studies on WSL prevalence before MB treatment, showed various results in a range of 3% in Lovrov et al. [10] to 72% in Mizrahi et al. [11].

Table 1
Literature review investigating the prevalence of WSL before MB treatment

Author (year)	n	Included Teeth	Evaluated Teeth	Index used	Prevalence before MB	Diagnosis	Treatment time (months)	Mean age (years)
Akin et al. (2015)	200	16-46	4.800	Gorelick et al.	19%	Intraoral photographs		18
Enaia et al. (2011)	400	12-22	1.600	Gorelick et al.	32%	Intraoral photographs	22	13,7
Lovrov et al. (2007)	53	17-47	1.414	Gorelick et al.	3%	Intraoral photographs	12-18	13,4
Mizrahi et al. (1982)	527	15-45	10.126	Mod. Index by Curzor and Spector	72%	Intraoral photographs		11,8

n = number of patients included

The results of Akin et al. [12] fall in between these two studies, with a WSL prevalence of 19%, as does Enaia et al. [6] with 32%. With the exception of the study by Lovrov et al. [10], which investigated 53 patients, the other studies examined at least 200 patients. The treatment duration of the young patients (average age less than 20 years) was at least one year. Scientific evidence from studies on WSL prevalence before aligner therapy is currently not available. After MB treatment, Lovrov et al [10] found a WSL prevalence of 26% (Tab 2).

Table 2
Literature review examining the prevalence of WSL after MB treatment.

Author (year)	n	Included Teeth	Evaluated Teeth	Index used	Prevalence before MB	Diagnosis	Treatment time (months)	Mean age (years)
Sundararaj et al. (2015)	1242				69%		mind.12	
Akin et al. (2015)	200	16-46	4.800	Gorelick et al.	54%	Intraoral photo-graphs		14
Lucchese et al. (2012)	191	16-46	4584	Gorelick et al.	40-43%	visual examination		
Tufekci et al. (2011)	37,35,28	6 times 35	6 times 35	Visual classification according to extent of demineralisation score 0-3	38%; 46%	visual examination	6;12	17
Enaia et al. (2011)	400	Dec 22	1600	Gorelick et al.	74% of patients	Intraoral photo-graphs	20	13,7
Lovrov et al.(2007)	53	17-47	1414	Gorelick et al.	26%	Intraoral photo-graphs		
Boersma et al. (2005)	62	16-46	488		ca. 30% of a patients tooth surface 97% of patients	QLF and visual examination	25,4	19,5
Pancherz und Mühlich (1997)	108	15-25	794	Modif. Gorelick	62%	Intraoral photo-graphs		
Øogard et al.(1989)	51	16-46	1224	Modif. Gorelick	96%	visual examination		
Geiger et al. (1988)		1567			34%	visual examination		
Årtun und Brobakken (1986)	120	15-45	2400	cariesindex by Fehr,+ modif. Gorelick	53%	visual examination		
Mizrahi et al. (1982)	269	15-45	5758	Modif. Index by Curzor and Spector	84%	Intraoral photo-graphs		15,4

n = number of patients included

Similar results were obtained by Geiger et al. [13] with 34%, Lucchese et al. [14] with 40-43%, and Tufekci et al. [9] with 38% after 6 months, and with a prevalence of 46% after 12 months (Tab 2). Low values after MB treatment were also reached by Julien et al. [7] with 23%. In contrast, the studies by Boersma et al [15] showed WSL in 97% of patients after MB treatment, where approximately 30% of tooth surfaces were affected (Tab 2). Oogard et al. [16] also showed similarly high results with 96%, Mizrahi et al. [11] with 84%, and Enaia et al. [6] with 74% WSL prevalence. Mean prevalence values after MB therapy were

measured as 53% [17] and 62% [18]. Akin et al [12] also showed a 54% average WSL prevalence. Results were predominantly assessed by visual inspection of intraoral photographs (Tab 3).

Table 3
Literature review investigating the incidence of WSL in aligner and MB treatment

Author (year)	n	Included teeth	Evaluated tooth surfaces	Index used	Incidences	Diagnosis	Treatment time (months)	Mean age (years)	Treatment method
Azeem et al. (2017)	25	16-46			28% of patients 3% of examined surfaces	QLF	18,11		Aligner
Akin et al. (2015)	200	16-46	4.800	Gorelick et al.	32%	Intraoral photo-graphs		10-18-jährige	MB
Sunda-raraj et al. (2015)	2041				46%		mind. 12		
Hadler-Olsen et al. (2012)	40	84?		Gorelick et al.	60%		18	13,6	MB
Enaia et al. (2011)	400	12-22	1600	Gorelick et al.	61%	Intraoral photo-graphs			
Richter et al. (2011)	350	16-46			73%	Intraoral photo-graphs			MB
Chap-man et al. (2010)	332	14-24			36%	Intraoral photo-graphs Evaluation with computer software	32	16,2	MB
Lovrov et al. (2007)	53	17-47	1414	Gorelick et al.	25%	Intraoral photo-graphs	14,9+-2,3		MB
Pan-cherz et al (1997)	108	15-25	794	Modif. Gorelick	17%	Intraoral photo-graphs			MB
Banks et al. (1994)	80	15-45	4728	EDI	74% of test subjects	visual examination			MB
Gorelick et al (1982)	121	15-45	2211	Gorelick et al.	50%	visual examination			MB

n = number of patients included

Patients presenting with WSL for the first time after MB therapy represented 74% of their collective in Banks et al. [19] and 73% in Richter et al. [20] (Tab 3). Somewhat lower results were obtained by Enaia et al. [6] with 61% and Hadler-Olsen et al. [5] with 60% (Tab 3). Gorelick et al [2] diagnosed WSL in 50% of cases. Azeem et al [21] described an incidence of 28% in the patients studied under aligner therapy. 3% of teeth 16-46 were affected by WSL. Lovrov et al. [10] measured a WSL incidence of 25% in their study with MB therapies and Akin et al. [12] an incidence of 32% (Tab 3). Even lower results were obtained by Pancherz and Mühlich et al. [18] with an incidence of 17%. The index according to Gorelick et al [2] was the main evaluation tool used in the various studies.

Methods

In this retrospective study, 489 intraoral digital photographs were examined for WSL. All photos were taken from patients of the Department for Orthodontics of the University Medical Center of the Johannes Gutenberg - University Mainz. The study protocol was approved by the ethics committee of the Medical Chamber of Rhineland-Palatinate (No. 9565). The digital photographs of 42 adolescent subjects were evaluated before and after treatment with aligner therapy. The study participants were divided by gender, 18 female and 24 male subjects. At the beginning of treatment, the mean age of the subjects was 14.0 ± 1.8 years (range: 12-17 years old). Informed consent was obtained from all subjects and their legal guardians. The dental surfaces examined included the labial surfaces of teeth 15 to 45. The average number of aligners was 43.4 ±11.1 (range: 14-69 aligners) in the maxilla and 42.7 ±11 (range: 14-66 aligners) in the mandible. During treatment, different attachment types were applied at different times according to treatment needs. Three standardized intraoral images were taken at T0 and T1 using a digital SLR camera with an RGB CCD sensor (Nikon D80, Nikon Corporation, Chiyoda, Tokyo, Japan). These included a frontal, a right lateral, and a left lateral image. 121 Subjects under MB therapy represented the comparison group. Of the 121 subjects, 63 were male and 58 were female patients who had MB treatment at the Department for Orthodontics of the University Medical Center of the Johannes Gutenberg - University Mainz. MB treatment was performed in the subjects' maxilla and mandible with conventional metal brackets (Mini-Sprint, 0.22 slot, Roth Presription, Forestadent, Pforzheim, Germany). At the start of treatment, the average age of the subjects was 12.5 years (+/- 2.2). The youngest patient was 7.7 years old and the oldest was 17.9 years old. Subjects could not be older than 18 years. Treatment time averaged 3.1 years (+/- 1.4), with the shortest treatment periods lasting 0.9 years and the longest treatment taking 8.3 years. The WSL intensity at T0 and T1, was evaluated using the Enamel Decalcification Index (EDI) according to Banks & Richmond (1994) with severity graded from 0 to 3 per tooth surface. The labial tooth surface was divided into four surfaces. Grade 0 was present when no demineralization was observed. Grade 1 described mild WSL, encompassing less than 50% of the evaluated area. Grade 2 described moderate to severe demineralization, with over 50% occurrence on the assessed area. Grade 3 described the most severe intensity of a WSL, where the entire area under consideration was affected by demineralization, so much so that surface intrusions were possible (Fig. 1).

An evaluation tool (Fig. 2) was created to assess the extent of demineralization. The digital scaled graticule reflects the division of the labial tooth surfaces according to the EDI index. Each segment on the target of the circle represents 20%, as a percentage division of the examined tooth surface. The different attachment types used in treatment depending on the indication were taken into consideration in the evaluation. Attachments represent plaque retention sites [22]. Thus, the question arose whether, and to what extent, each attachment favored WSL. Statistical analysis was performed in collaboration with IMBEI Mainz using frequency tables, cross-tabulations and logistic regression. After plausibility checks of the data, the programs IBM SPSS Statistics 22 for Windows (IBM Corporation, Armonk, USA), SAS 9.4. (SAS Institute, Cary, USA) and a logit link were used. The analysis of the data with the regression model was performed by using a GEE model with binomially distributed target variable. Calculations were performed using the SAS procedure PROC GENMOD (SAS version 9.4).

Results

The present work suggests that there is a 43% recurrence of WSL during aligner therapy (Tab 4). WSL occurred in 29% of patients during MB treatment in this study. The WSL prevalence before aligner therapy was 17%, and 69% of subjects already had WSL before MB treatment (Tab 4). Almost every subject (98%) had WSL after MB therapy. Half of the subjects were still

free of WSL after aligner therapy. The incidence for aligner therapy was n=15 (43%) overall, with n=8 (53%) of male adolescents and n=7 (35%) of female adolescents. The WSL incidence of MB therapy was 29%, while 34% were male adolescents and 23% were female adolescents (Tab 4).

Table 4
Prevalence and incidence results after Aligner and MB therapy

		Aligner	**MB**
Prevalence	T0	17%	69%
	T1	52%	98%
	Difference	35% increase	29% increase
	Gender	x	m>f
	Upper/Lower jaw	Upper>Lower	x
	Incisors/Canines/Premolars	Premolars>Incisors	Premolars >Incisors Premolars >Canines
	Tooth surfaces	x	o,m,d>g
	Age	x	x
	Attachements	□>no attachement	x
Incidence	WSL	43%	29%
	Gender	x	m>f
	Upper/Lower jaw	Upper > Lower	x
	Incisors/Canines/Premolars	Premolars>Incisors Canines > Incisors	Premolars>Incisors Premolars>Canines
	Tooth surfaces	x	d>g, d>m
	Age	x	x
	Attachements	□>no Attachement	x

When both the maxilla and mandible are treated with aligner therapy, one is able to observe that the mandible has a greater predisposition to developing WSL than the maxilla. In both aligner and MB therapy, premolars are significantly more likely to be affected by WSL than incisors (Tab 4). The use of rectangular attachments showed a significantly greater likelihood of WSL development than when no attachment was used in aligner therapy. In evaluation of the prevalence and incidence of WSL on the distal, gingival, mesial and occlusal tooth surfaces, the age of the subjects was an influencing factor to the results and gender was not.

The prevalence and incidence of WSL after MB therapy was significantly larger in male subjects than in female. Furthermore, the distal tooth surface presents a significantly higher risk for the occurrence of WSL after MB therapy (Tab 5-8).

Table 5

Logistic regression (GEE model) - prevalence of tooth surfaces after aligner therapy. The variables rectangular, ellipsoidal, and rotation, refer to the attachment type during aligner therapy.

Logistic regression table							
Variable		**Regressions-coefficient**	**Standard-error**	**95% Confidenceinterval**		**Z**	**Pr > |Z|**
Intercept		-4.6458	1.0751	-6.7529	-2.5387	-4.32	<.0001
Gender	m	-0.2166	0.5000	-1.1966	0.7633	-0.43	**0.6648**
Gender	f	0.0000	0.0000	0.0000	0.0000	.	.
Jaw	Upper	**1.7768**	0.3889	1.0146	2.5390	4.57	**<.0001**
Jaw	Lower	0.0000	0.0000	0.0000	0.0000	.	.
Tooth	Canine	0.9187	0.4556	0.0257	1.8116	2.02	**0.0438**
Tooth	Premolar	**1.2020**	0.3842	0.4491	1.9550	3.13	**0.0018**
Tooth	Incisor	0.0000	0.0000	0.0000	0.0000	.	.
Area	d	-0.0153	0.0596	-0.1321	0.1015	-0.26	0.7973
Area	g	-0.2837	0.2121	-0.6994	0.1320	-1.34	0.1810
Area	m	-0.0781	0.0687	-0.2128	0.0566	-1.14	0.2560
Area	o	0.0000	0.0000	0.0000	0.0000	.	.
Age at start of treatment		-0.0031	0.0761	-0.1522	0.1461	-0.04	**0.9678**
Rectangular	1	**0.9829**	**0.2689**	**0.4558**	**1.5100**	**3.65**	**0.0003**
Rectangular	0	0.0000	0.0000	0.0000	0.0000	.	.
Ellipsoidal	1	-0.2148	0.7979	-1.7787	1.3491	-0.27	**0.7878**
Ellipsoidal	0	0.0000	0.0000	0.0000	0.0000	.	.
Rotation	1	-0.0052	0.4719	-0.9301	0.9196	-0.01	**0.9911**
Rotation	0	0.0000	0.0000	0.0000	0.0000	.	.

Table 6
Logistic Regression (GEE model) – Incidence of tooth surfaces during aligner therapy. The variables rectangular, ellipsoidal, and rotation, refer to the attachment type during aligner therapy.

Logistic regression table							
Variable		**Regression s-coefficient**	**Standard-error**	**95% Confidence interval**		**Z**	**Pr > |Z|**
Intercept		-4.5515	1.2223	-6.9472	-2.1557	-3.72	0.0002
Gender	m	-0.2565	0.5530	-1.3403	0.8273	-0.46	**0.6428**
Gender	w	0.0000	0.0000	0.0000	0.0000	.	.
Jaw	OK	1.6525	0.4035	0.8617	2.4433	4.10	**<.0001**
Jaw	UK	0.0000	0.0000	0.0000	0.0000	.	.
Position	Canine	0.9025	0.4595	0.0020	1.8030	1.96	**0.0495**
Position	Premolar	1.1185	0.3839	0.3660	1.8709	2.91	**0.0036**
Position	Incisor	0.0000	0.0000	0.0000	0.0000	.	.
Surface	d	-0.0168	0.0494	-0.1136	0.0801	-0.34	0.7344
Surface	g	-0.3284	0.2006	-0.7215	0.0647	-1.64	0.1016
Surface	m	-0.1118	0.0632	-0.2356	0.0120	-1.77	0.0767
Surface	o	0.0000	0.0000	0.0000	0.0000	.	.
Age at start of treatment		-0.0098	0.0879	-0.1821	0.1625	-0.11	**0.9114**
Rectangular	1	1.0275	0.2811	0.4765	1.5784	3.66	**0.0003**
Rectangular	0	0.0000	0.0000	0.0000	0.0000	.	.
Ellipsoidal	1	-0.0285	0.7947	-1.5860	1.5290	-0.04	0.9714
Ellipsoidal	0	0.0000	0.0000	0.0000	0.0000	.	.
Rotation	1	0.1407	0.4816	-0.8033	1.0846	0.29	0.7702
Rotation	0	0.0000	0.0000	0.0000	0.0000	.	.

Table 7
Logistic regression - prevalence of tooth surfaces after MB therapy

	Hypothesis test			95% WALD-confidence interval for Exp(B)	
Parameters	**df**	**Sig.**	**Exp(B)**	**Lowest value**	**Highest value**
(Constant Term)	1	,945	,938	,153	5,764
male	.	.	1	.	.
female	1	,049	,645	,417	,999
Tooth 11	.	.	1	.	.
Tooth 12	1	,000	1,846	1,388	2,456
Tooth 13	1	,000	1,950	1,377	2,762
Tooth 14	1	,000	2,379	1,657	3,414
Tooth 15	1	,013	1,506	1,090	2,080
Tooth 21	1	,291	1,126	,903	1,403
Tooth 22	1	,001	1,688	1,294	2,281
Tooth 23	1	,000	2,474	1,771	3,455
Tooth 24	1	,000	2,524	1,763	3,613
Tooth 25	1	,000	2,005	1,383	2,907
Tooth 31	1	,000	,213	,141	,321
Tooth 32	1	,000	,387	,265	,567
Tooth 33	1	,928	,983	,679	1,424
Tooth 34	1	,000	2,161	1,464	3,189
Tooth 35	1	,004	1,797	1,201	2,689
Tooth 41	1	,000	,226	,146	,350
Tooth 42	1	,000	,417	,285	,610
Tooth 43	1	,771	1,061	,712	1,581
Tooth 44	1	,000	2,120	1,465	3,068
Tooth 45	1	,000	2,042	1,370	3,046
Surface o	1	,007	1,235	1,058	1,441
Surface d	1	,000	1,372	1,218	1,547
Surface m	1	,000	1,331	1,182	1,498
Surface g	.	.	1	.	.

Table 8
Logistic regression - incidence of tooth surfaces during MB therapy

	Hypothesis test			95% WALD-confidence interval for Exp(B)	
Parameters	**df**	**Sig.**	**Exp(B)**	**Lowest value**	**Highest value**
(Constant Term)	1	,430	,938	,153	5,764
male	.	.	1	.	.
female	1	,055	,697	,483	1,007
Tooth 11	.	.	1	.	.
Tooth 12	1	,003	1,730	1,210	2,475
Tooth 13	1	,001	2,172	1,402	3,365
Tooth 14	1	,027	1,688	1,060	2,688
Tooth 15	1	,497	1,165	,749	1,814
Tooth 21	1	,100	1,287	,953	1,739
Tooth 22	1	,001	1,860	1,295	2,672
Tooth 23	1	,000	2,474	1,771	3,455
Tooth 24	1	,000	2,799	1,797	4,361
Tooth 25	1	,012	1,851	1,147	2,986
Tooth 31	1	,008	,482	,281	,826
Tooth 32	1	,336	,783	,476	1,289
Tooth 33	1	,060	1,561	,981	2,483
Tooth 34	1	,000	2,796	1,697	4,608
Tooth 35	1	,002	2,428	1,387	4,251
Tooth 41	1	,009	,469	,266	,829
Tooth 42	1	,670	,906	,575	1,426
Tooth 43	1	,001	2,313	1,437	3,721
Tooth 44	1	,000	2,568	1,589	4,152
Tooth 45	1	,000	2,725	1,552	4,787
Surface o	1	,395	,930	,786	1,100
Surface d	1	,022	1,157	1,021	1,310
Surface m	1	,670	1,030	,900	1,179
Surface g	.	.	1	.	.

Discussion

To ensure objective comparability of the MB and Aligner subject groups, standardized measurements and data collection in both comparison groups were done identically. The presence of WSL was measured at two time points (Tab 5-8). The comparatively small size of the aligner sample should be mentioned as a limitation. Thus, the 840 teeth in the aligner sample

comprise only just under one third of the teeth from the MB sample. The subject sample size of the group undergoing aligner therapy was similar to that of subject sample sizes in literature (Tab 3). In future research projects with aligner therapy, multicenter studies should be preferred in order to include more subjects.

The evaluation was performed with three images per tooth, these being, a right-lateral, left-lateral and front view photo. Identical exclusion criteria were used for both studies. Subjective evaluation criteria was not an influencing factor on the measured values in the aligner and MB study since the examination was performed by the same examiner during orthodontic treatment. The ratio between female and male subjects was largely balanced in both subject groups. The anterior teeth, canine teeth, and the premolars were included in the photo evaluation. The labial tooth surfaces proved to be the most accessible for photo diagnostics and visual examination when screening for WSL, and in turn made them the easiest to evaluate. Furthermore, only subjects with labial conventional MB appliances were included in this study. In addition to the evaluation of the labial surfaces, the vestibular tooth surfaces were also included in the study with aligner subjects. This was due to the investigation on the effect of attachment-fitted tooth surfaces on WSL.

Retrospective evaluation of digital photographs represents the methodological investigation in this study. Photographs required for photo diagnostics are usually taken before, during, and at the end of orthodontic therapy. This means that photo diagnostics provide easily accessible information that can be viewed at any time, and allow for re-evaluation of the pictured tooth surfaces. Since the evaluation is performed by an examiner and not by a computer program, the diagnostic procedure with photographs is not an objective examination. QLF is an alternative highly sensitive diagnostic approach, but is routinely impractical due to its long application time.

Plaque, discoloration and calculus cause fluorescence loss and are thus all complicating factors that can impair examination. Furthermore, the localization of the lesions, the incident light and the salivation and dehydration of the tooth surfaces are key factors that influence the evaluation. Each study represents higher results in diagnosing incisive WSL with the QLF method than the last. The study by Ifland and Heinrich-Weltzien used the QLF method to measure occlusal enamel lesions. This method displayed a high sensitivity to the detection of carious lesions, with values ranging from 84 to 91%.

The intensity of the white spot lesions that occurred in this study, were assessed using the Enamel Decalcification Index (EDI) according to Banks & Richmond (1994). The EDI evaluated the severity of WSL and organized them in grades of 0 to 3 (Fig. 1), while an assessment of the extent of WSL was performed separately. Thus, though WSL could be similar in grade, the extent could always vary. The extent index analyzes the extent of a lesion in 20% steps using a specially designed digital scaled graticule with concentric circles as an evaluation aid (Fig. 2). The EDI is not used often in empirical studies, which makes it difficult to compare results [10]. However, the 1982 index by Gorelick et al. [2] was not used in this study because the assessment of vestibular tooth surfaces does not divide the vestibular tooth surfaces into four areas, and areas with bonded brackets or attachments are not taken into consideration. No differentiation is made regarding the area in which WSL occurs on the vestibular tooth surface, and the intensity of the WSL is assessed without considering the extent. The index of Gorelick et al. underwent modification by Artun and Brobakken in 1986 [17]. In 1994, modification was made by Banks and Richmond [19] and further development to EDI with the more precise evaluation by dividing the vestibular area around the bracket into four areas. Fehr's (1961) index [17] assesses the surface texture of the tooth surfaces, as well as their opacity in order to evaluate the severity of lesions. Though this index was not used in this study to assess and divide WSL.

A total of 17% of subjects had at least one WSL prior to aligner therapy in this study. The prevalence of WSL before aligner therapy was much lower than for MB therapy. Before MB therapy, 69% of subjects were diagnosed with at least one WSL. This unexpectedly large discrepancy between the two groups makes it difficult to compare the incidence of new WSL, since more than half of the subjects in the MB group were already affected by a WSL before treatment begin. The probability that a subject with prior WSL will develop more WSL during treatment is much higher than that of a subject who begins treatment with no WSL [21]. The large range of prevalence at time T0 for aligner therapy can be credited to aligner therapy being an aesthetic treatment method, and is not only used for functionally recommended treatments. It can be concluded that the subjects of aligner therapy pay more attention to the aesthetics and dental care of their teeth than the MB therapy subjects.

The increase in prevalence between T0 and T1 during MB therapy was 29%. After aligner therapy, a total of 52% of subjects had detectable WSL, which is a 35% increase. This increase is slightly greater than the prevalence increase between T0 and T1 during MB therapy. Pre-existing WSL prior to orthodontic therapy may indicate poorer oral hygiene in the subject, which in turn increases the likelihood that the subject will develop further WSL during orthodontic therapy. This is evident in the study, which concluded that subjects with poor oral hygiene had significantly more WSL at the start of treatment than subjects with good oral hygiene [7]. This shows that dental hygiene before the start of orthodontic treatment, is also an influencing factor for the development of WSL. In view of this, Azeem et al [21] ensured that patients with existing WSL prior to the start of treatment were excluded from their study.

The study by Buschang et al. (2019) [23] also draws a comparison between aligner and MB therapy. Photographs are also used for evaluation, which in the study by Buschang et al. are evaluated by two investigators. There are 244 subjects in the aligner group and 206 subjects in the MB group. The mean age in the aligner subject group is 30.4±14 years and 29.2±11.5 years in the MB group. The incidence in the aligner proband group is 1.2% of patients and 3 new WSL occurred during the study period. The incidence is 26% of patients in the MB proband group, and 174 new WSL occurred. Thus, the study confirms the study by Buschang et al. and shows that subjects have a lower risk of developing WSL when treated with aligner therapy. Likewise, Buschang et al. also saw a higher incidence of WSL in the maxilla compared to the mandible. The prevalence of WSL in MB therapy has literature values ranging from 2–96% [5, 6], which can be explained by the varying amount of teeth examined in each study. Other variables were controlled, for the study included treatment duration, age at treatment initiation, and whether additional fluoride applications and standardized oral hygiene instructions were provided. The comparability of the studies is further hampered by different sized subject groups and the lack of control groups. In addition, most studies differ in terms of diagnosis and methodological evaluation.

After MB treatment, Lovrov et al [10] found a WSL prevalence of 26% by examining photographs. Similar results were obtained by Geiger et al [13] with 34% and Lucchese [14] with 40-43% WSL prevalence. Lucchese et al. examined subjects after 12 months and used newer composite materials to secure the brackets. The advanced technology and the use of different bonding materials may have resulted in a lower prevalence [14]. Tufekci et al [9] reviewed subjects as early as six months into treatment and found a prevalence of 38%, and a prevalence of 46% at 12 months. Boersma et al. 2005 [15] found prevalence's of 97% after completion of MB treatment, where the subjects had one or more lesions. The reason for the higher prevalence may be due to the quantitative light-induced fluorescence method for detecting WSL. This is a more sensitive method than visual assessment. Furthermore, the study period of 24 months is longer than in the study of Lucchese et al. The results of Ogaard et al [16] showed similarly high results of 96%. These results are consistent with those of Mizrahi et al. [11] with 84%. Akin et al [24] showed a prevalence in their subject group of 65%. However, the study does not include information on whether regular follow-up appointments took place, the socioeconomic background and ethnicity of the subjects, or whether prophylactic fluoride therapy was concomitant. If explanations for the different prevalence values are sought, then the different study design and differences in the analytical procedure should be taken into account.

The selection of teeth that were chosen for examination were different in each study examined. Some studies investigated only the anterior teeth or only the anterior teeth in the maxilla [6]. This study showed a higher prevalence and incidence for WSL in the maxilla with aligner therapy. Thus, studying the maxilla and mandible separately certainly has an impact on the results, compared to evaluating both jaws together. Of the subjects in this study, 43% of the adolescents acquired new WSL under aligner therapy, whereas only 29% of the adolescents in the MB therapy comparison group had new WSL. Since all subjects from both groups were from the patient population of the Department of Orthodontics of the University Medical Center Mainz, the percentages seem comparable at first glance and would seem to be able to assure a better outcome of aligner therapy in terms of WSL incidence. However, with regard to the relatively low number of subjects in the aligner group, it seems reasonable to compare the percentages with the incidence rates reported in the literature. Compared with the study by Azeem et al. [21], who found the occurrence of at least one WSL in only 28% of subjects after aligner therapy, the WSL incidence of 43% measured in this study is much higher. In this study, 99% of the tooth surfaces examined showed no WSL before the start of aligner therapy, while 91% of the tooth surfaces were still free of WSL after the completion of aligner therapy.

A comparison of the two studies yields the following figures for the recurrence of WSL in each case, shown as a percentage of the subjects and as a percentage of the tooth surfaces. The incidence in terms of tooth surfaces by Azeem et al [21] is 3%, and 8% in this study. This shows a relatively small difference in tooth surface incidence. The patients who had WSL for the first time after MB therapy represented 74% of their collective in Banks et al [19]. Similar high results were obtained by Enaia et al. [6] with 61%, they examined only four anterior teeth, and Hadler-Olsen et al. [5] found an incidence 60%. Richter et al [20] showed an incidence of 73%. They also examined teeth 16 to 46, and Gorelick et al. [2] diagnosed WSL in 50% of cases, using the same index and comparing orthodontically treated patients with untreated controls. Akin et al [24] recorded an incidence of 55%. They studied 150 patients at two different time points. The incidence and prevalence results are comparable to those of Enaia [6] and Gorelick [2]. The variance in WSL incidence under MB therapy could be attributed to the different methods used and lack of standardization of the studies. The studies do not uniformly address whether oral hygiene instructions and fluoride applications were suggested to the subjects. Similarly, the number of teeth examined, the age of the patients at the start of treatment, the duration of treatment, oral hygiene at the start of treatment, and whether the subjects used fluoridated drinking water all influence the available results. Richter et al [20] showed that the geographic and socioeconomic status of the subjects and whether the study was conducted in a private practice or in a dental clinic, could also contribute to the variance in incidence. The prevalence and incidence in the study on gender distribution in MB therapy showed significantly higher percentages in male adolescents. Before MB therapy, there was a higher rate of disease in the female subjects. One explanation for this observation was that the permanent teeth eruption occurs earlier in girls than in boys, meaning that permanent teeth have a longer residence time in the mouth of girls than in boys. This results in a longer exposure period in the oral cavity where demineralization can occur.

Compared to the results with aligner therapy, there was no significant difference in the gender distribution of WSL in both prevalence and incidence. Similarly, Oogard. et al showed no significant difference in gender distribution under MB therapy. This study showed significantly higher prevalence and incidence of WSL for maxillary teeth under aligner therapy (Tab. 4). Evaluation and comparison of the tooth surfaces affected by WSL in this study showed a greater burden of WSL in the premolars and canines compared to the anterior teeth in the University Medicine patient population (Tab.7). Boersma et al [15] found a lower prevalence of caries on the incisors and canines compared to the molars and premolars, supporting the findings of this study. This study showed that age at treatment initiation had no effect on prevalence and incidence in this study. Akin et al [12] showed a significant association between the age of patients at the start of treatment for MB therapy and the increased incidence of WSL. Richter et al [20] confirmed that 11- to 14-year-old patients under orthodontic therapy had a higher risk of WSL occurrence. Levine et al. [25] also associated prepubertal age (9-12 years) with a higher risk of WSL. This point may play a role in the decision around when to start treatment.

There are currently no known comparative studies that have examined the influence of different attachment types on the development of WSL. This study demonstrated that tooth surfaces with rectangular attachments were more likely to be affected by WSL compared to tooth surfaces without attachments. The shape and size of the attachment played a minor role. A possible explanation for this observation is the creation of plaque retention sites due to the applied attachments. This is consistently communicated in the literature [21].

Conclusions

MB therapy resulted in a higher risk of WSL than aligner therapy in the tooth surfaces studied. Premolars and canines expressed a higher WSL prevalence than incisors. The use of attachments during aligner therapy resulted in the development of significantly more WSL. Therefore, it is important to instruct patients in proper oral hygiene around attachments as well as bracket bases.

Abbreviations

(WSL) White Spot Lesions

(MB) Multibracket

(EDI) Enamel-Decalcification-Index

(DMS V) Fifth German Oral Health Study

Declarations

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Authors' contributions:

CE was the principal investigator and participated in the design of the study. CE and DO selected the patient's data for the study and contributed to writing the manuscript. HW designed and organized the whole study and was a major contributor to writing the manuscript. IS, as statistician, analyzed and interpreted the data. JW was the data manager and prepared the database and contributed to writing the manuscript. JT contributed to writing the manuscript and translated the manuscript in English. All authors read and approved the final manuscript.

Ethics approval and consent to participate:

All investigations and procedures were conducted according to the principles expressed in the Declaration of Helsinki. The study protocol was approved by the ethics committee of the Medical Chamber of Rhineland-Palatinate (No.9565). Informed consent was obtained from all subjects and their legal guardians.

Consent for publication

Not applicable.

Availability of data and materials:

The data used for analysis has been referenced in the text or tables of the paper.

Competing interests:

The authors declare that they have no competing interests.

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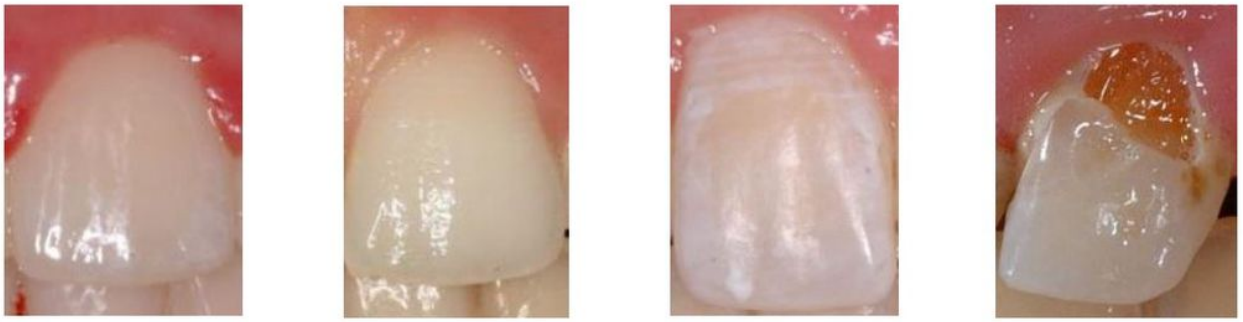
Figures



Grade 0	Grade 1	Grade 2	Grade 3
• no demineralization	• clinically visible demineralisation <50% of the assessed area	• moderate to serious demineralisation >50% of the assessed area	• demineralisation affecting the entire surface or caries in the sense of surface cavities

Figure 1

Incidence distribution based on intensity (EDI).

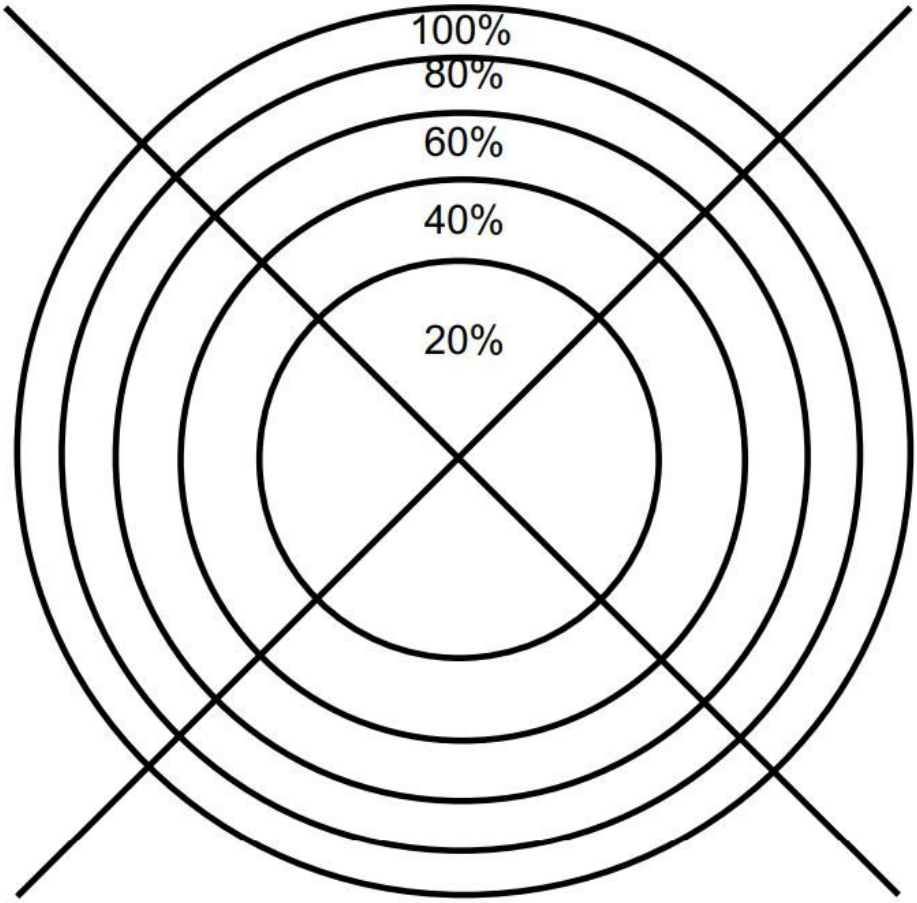


Figure 2

Newly developed digital scaled graticule with concentric circles, to evaluate the distribution of the incidence according to extent (%).