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Does orthodontic debonding lead to tooth sensitivity? Comparison of teeth with and without visible enamel microcracks

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Introduction: Our aim was to assess the possible changes in sensitivity of teeth with and without visible enamel microcracks (EMCs) up to 1 week after the removal of metal brackets. **Methods:** After debonding, 15 patients possessing teeth with visible EMCs and 15 subjects whose teeth were free of EMCs were enrolled in the study. For each experimental group, a control group was formed. The assessments of tooth sensitivity elicited by compressed air and cold testing were performed 5 times: just before debonding, immediately after debonding, and at 1, 3, and 7 days after debonding. Tooth sensitivity was recorded on a 100-mm visual analog scale. **Results:** For the patients without visible EMCs, discomfort peaked immediately after debonding and started to decrease on day 1; at 1 week after debonding, the visual analog scale scores were lower than just before debonding and immediately after debonding. For the subjects possessing teeth with visible EMCs, the pattern of sensitivity dynamic was inherently the same. However, the patients with visible EMCs showed higher visual analog scale values at each time interval. **Conclusions:** Debonding leads to a short-term increase in tooth sensitivity. EMCs, a form of enamel damage, do not predispose to greater sensitivity perception in relation to bracket removal. (Am J Orthod Dentofacial Orthop 2017;151:284-91)

One factor that discourages patients from seeking orthodontic treatment is the anxiety and fear of related pain and discomfort from the orthodontic appliance.[1,2] Studies about patients experiencing pain or discomfort during orthodontic therapy have shown values up to 95%.[2,3] The levels and durations of discomfort during elastic separation, placement of different bracket systems, activation of archwires, and use of intermaxillary elastics are presented in detail in previously published investigations.[4-9] However, the pain experienced during debonding is currently poorly quantified. A few studies have assessed the level of discomfort during debonding with different instruments or biting on a soft acrylic wafer at the time of bracket removal.[3,10] Possible changes in the pain dynamic with time after debonding have been not observed. Therefore, there is little knowledge regarding the duration and the intensity of discomfort experienced during the time period after bracket removal.

The perception of pain during orthodontic force application has generally been attributed to mechanical damage and inflammatory reactions in the periodontium.[11,12] However, there is evidence suggesting that elements in the dental pulp may contribute as well.[12] A trend has been noted where reports of greater orthodontic tooth pain were associated with increased pulpal sensitivity evoked by electrical tooth stimulation.[12]

Caries, restorations, enamel irregularities, and tooth structure defects might cause variations in tooth sensitivity assessment.[13] Enamel microcracks (EMCs), a form of enamel damage after debonding, are a concern for patients receiving orthodontic care.[14-16] It has been shown that EMCs may jeopardize the integrity of the enamel and cause stains and plaque accumulation on the fractured surfaces.[17-19] The susceptibility to carious lesions increases and affects the appearance of

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the teeth.[18] Pronounced EMCs (visible with the naked eye under normal room illumination) are often noticed by the patients at the beginning of the orthodontic treatment or after the removal of fixed appliances.[20,21] Current knowledge indicates that measured quantitative pronounced EMC characteristics (width of EMCs is expressed in microns and length in millimeters) are greater in comparison with weak EMCs (not apparent under normal room illumination but visible by scanning electron microscopy), but this does not predispose to increased EMCs after debonding.[20-22] However, if a visible EMC is located on more than a third of the buccal tooth surface, its inclination does not exceed 30° to 45°, and ceramic brackets are used, the combination of these EMC characteristics might lead to a greater risk of more tooth surface damage after debonding up to 20.4%.[23] Still, it is unknown whether the teeth with visible EMCs might be more susceptible to discomfort and pain during the orthodontic treatment.

Therefore, the aims of this study were to (1) evaluate the sensitivity of teeth with pronounced EMCs and to compare it with teeth without visible EMCs just before debonding and up to 1 week after the removal of fixed appliances; (2) determine the time for a clinically significant reduction in teeth sensitivity; (3) determine whether there is a correlation between the tooth sensitivity values just before debonding and the likelihood of their increasing during the removal of brackets; and (4) find out whether insensitive teeth with and without visible EMCs just before debonding might progress to sensitive ones immediately after debonding.

Table I. Example of a questionnaire

Patient name:	Date:
Birth date:	Gender:
Date of bonding procedure:	Date of debonding procedure:
Duration of treatment:	Type of brackets:

1. Do you complain about tooth sensitivity? 0 - Yes, 1 - No
2. Do you currently receive or have you previously received professional desensitizing treatment? 0 - Yes, 1 - No
3. Have you used over-the-counter desensitizing products within the previous six weeks (eg, special varnish or mouth rinse)? 0 - Yes, 1 - No
4. Have you used anti-inflammatory, analgesic, and psychotropic drugs for a long term? 0 - Yes, 1 - No
5. Are you pregnant or breast-feeding? 0 - Yes, 1 - No
6. Do you have eating disorders (eg, bulimia nervosa)? 0 - Yes, 1 - No
7. Do you suffer from digestive system or endocrine system diseases (eg, chronic acid regurgitation, diabetes)? 0 - Yes, 1 - No
8. Do you often (several times a week) drink natural fruit juice or carbonated refreshments, and eat fruits (especially citrus fruits)? 0 - Yes, 1 - No
9. Have you had dental treatment within the previous three months? 0 - Yes, 1 - No
10. Have you had periodontal surgery within the previous three months? 0 - Yes, 1 - No
11. Have you previously whitened your teeth? 0 - Yes, 1 - No

MATERIAL AND METHODS

A detailed medical history, including questions about tooth sensitivity before and during orthodontic treatment with fixed appliances, was taken of each patient in a questionnaire (Table I).[24] The selection criteria for the subjects and the teeth are listed in Table II.[24] All eligible patients were given verbal and written information about the study and the opportunity to ask further questions.

The sample size was estimated using the sample size calculator,[25] by which a sample size of 60 was required to detect differences in sensitivity intensity values with a 5% confidence interval (CI) and 90% confidence level (population size, 76). Thus, 60 patients were included in the study; 30 received orthodontic treatment, and the rest served as the controls (untreated orthodontically).

The investigation was performed according to the protocol in Figure 1. Metal brackets were removed with the conventional utility Weingart pliers (Dentaurum, Ispringen, Germany) by hand (the mesial and distal edges of the bracket wings were squeezed gently until the bracket became free), and all visible residual adhesive was carefully removed using a slow-speed hand piece and a carbide finishing bur.[20,26] The orthodontic archwire was removed before the debonding procedure. The teeth were kept out of occlusion (biting on a cotton roll) during the debonding. In the weeks before the removal of the brackets, the patients were in a passive phase of orthodontic treatment (no activation procedures, such as changes of archwires, ligatures, or elastics, were performed; and the same dietary instructions, such as avoidance of solid, extremely hot or cold foods, were given). After debonding, orthodontically treated patients were divided into 2 groups of 15: group 1, patients possessing teeth with visible EMCs (mean age, 18.5 ± 3.62 years; average time of treatment, 21.2 months); and group 2, patients whose teeth were free of visible EMCs (mean age, 17.1 ± 3.72 years; average time of treatment, 20.8 months). The identification of EMCs with a naked eye under normal room illumination was the main criterion for assigning patients to 1 of the 2 groups. The distribution of EMCs among premolars included in the study is shown in Table III.

Table II. Subjects and teeth selection criteria

Selection criteria for subjects
Informed consent from patients and parents
Patients aged 14-24 years
Patients bonded with metal brackets (Discovery; Dentaurum, Ispringen, Germany) on 1 or both dental arches using 34.5% phosphoric acid gel (Vococid; Voco, Cuxhaven, Germany) and light-cure adhesive (Transbond XT; 3M Unitek, Monrovia, Calif). During orthodontic treatment, rebonding procedure not performed, and the duration did not exceed 36 months.
No current or previous professional desensitizing treatment and use of over-the-counter desensitizing products within the previous 6 weeks
No long-term use of anti-inflammatory, analgesic, and psychotropic drugs
No pregnancy or breast-feeding
No recorded eating disorders or excessive dietary or environmental exposure to acid
No history of systemic conditions that may cause dentin hypersensitivity (eg, chronic acid regurgitation)
Selection criteria for teeth
Primary teeth selection criteria
Maxillary and mandibular premolars have intact buccal enamel with no white spots, signs of hypoplasia or erosion, or wedge-shaped defects
No pretreatment with chemical agents (ie, hydrogen peroxide)
No previous orthodontic, endodontic, or restorative treatment
No signs of gingival recession
Secondary teeth selection criterion
Enamel microcracks visible on the buccal enamel surface

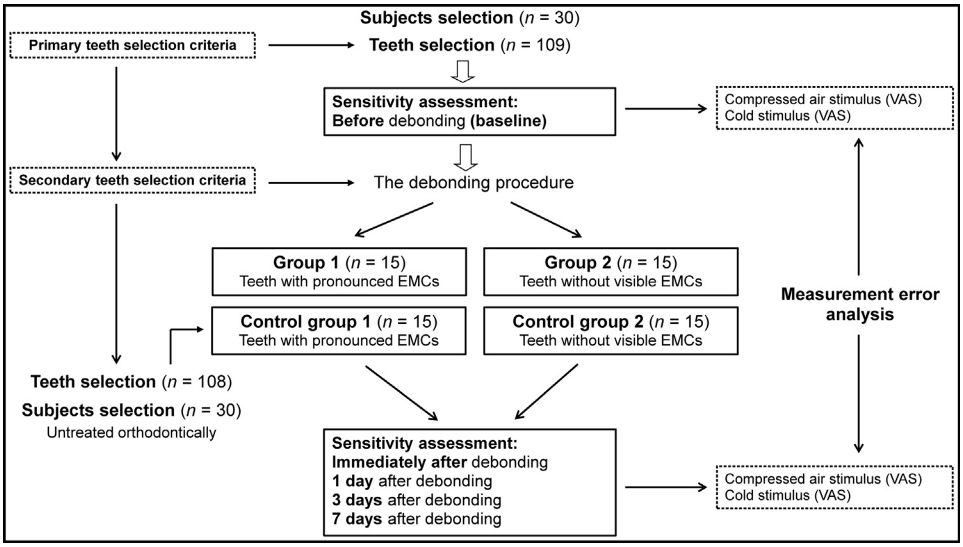

Fig 1. The study protocol.

Thirty orthodontically untreated patients were divided into 2 groups of 15: control group 1, patients having teeth with EMCs (mean age, 18.9 ± 3.15 years); and control group 2, subjects without EMCs (mean age, 18.0 ± 3.76 years). The protocol of the study was approved by the ethical review board of the Institute of Odontology at Vilnius University in Vilnius, Lithuania.

Tooth sensitivity was assessed by timed applications of compressed air (applied first) and cold stimulus (freshly melted ice water).[24] Thermal stimuli (compressed air and cold) application procedures are shown in Table IV and Figure 2. The intensity of the evoked discomfort or sensitivity by compressed air and cold stimulus was measured using a 100-mm long visual analog scale (VAS).[27] The sensitivity assessment was performed at 5 time points: just before debonding (baseline), immediately after debonding, and at 1, 3, and 7 days after debonding. The VAS scores of each patient (all evaluated teeth) from every group

Table III. Distribution of visible enamel microcracks in premolars in the study

Distribution of visible enamel microcracks (%)	*Experimental group 1 (n = 15)*	*Control group 1 (n = 15)*
<25	-	-
25-50	12 (80%)	9 (60%)
>50	3 (20%)	6 (40%)

(experimental and control) were averaged to determine the mean sensitivity intensity score at each time point. Orthodontically treated patients were blinded to the presence of visible EMCs and so were the subjects in the control groups. After enrollment in the investigation, the patients were given identical oral hygiene instructions. No desensitizing agents were permitted, including dentifrices and analgesics, during the study period.

Statistical analysis

Statistical analysis was carried out using the SPSS statistical package (version 17.0; SPSS, Chicago, Ill). A paired-samples *t* test was performed to evaluate differences between tooth sensitivity values at the different time points of the same group. An independent-samples *t* test was applied to compare mean sensitivity intensity values between the 2 unrelated groups on the same continuous, dependent variable. Spearman correlation coefficients of the baseline tooth sensitivity values and their changes during debonding were calculated. For graphic representation, error bars were used in which the 95% confidence interval was demonstrated. In case of overlapping confidence intervals, there was no statistical difference between the 2 comparison groups. In other cases with no overlapping confidence intervals, the statistical significance of the differences was evident with 95% probability. Significance for all statistical tests was predetermined to be $P \leq 0.05$.

RESULTS

Visibility of the EMCs was assessed repeatedly by the same investigator (I.D.) 1, 3, and 7 days after debonding before the tooth sensitivity assessment procedures. For standardization, the same time of the day, tooth position (patient's head position), and its isolation conditions were used. After repeated EMC visibility evaluations, no significant discrepancies between the results were observed.

Each patient was assessed by 1 operator (I.D.) during the entire study. The pain levels from the VAS scale were measured using a digital caliper by the same examiner. Measurement error was analyzed using the method suggested by Dahlberg.[2] Measurements (sensitivity intensity values from the VAS scale) of 5 patients were repeated 2 weeks later, and the estimated error between measurements was calculated. Measurement error was found to be 0.12 mm, and the effect of this error on the reliability of the sensitivity intensity measurements was deemed nonsignificant.

The mean sensitivity intensity values compared with the stimulus applied and time for the patients having teeth with visible EMCs are shown in Table V. The sensitivity was greatest immediately after debonding followed by a decrease on day 1 with higher mean sensitivity intensity values for the cold stimulation group. Tooth sensitivity elicited by cold testing demonstrated gradual changes (corresponding to straight lines in Fig 3); at day 7, the recorded discomfort values were lower than just before debonding ($P \leq 0.05$) and immediately after debonding ($P \leq 0.05$). Differences in the control group were nonsignificant. The reductions in sensitivity intensity scores were 33% or greater at day 3 (41.98%, air stimulation; 37.78%, cold stimulation) and at day 7 (85.71%, air stimulation; 37.04%, cold stimulation). After debonding, 1 tooth (2.38%) became sensitive to air stimulation, and 2 teeth (4.76%) became sensitive to cold stimulation.

The time changes in sensitivity for air and cold stimulation for the patients without EMCs are presented in Table VI. The sensitivity intensity was highest immediately after debonding and started to decrease continuously at day 1 with both thermal stimuli. For air stimulation, significant differences were recorded immediately after debonding and at day 7; for cold stimulation, there were significant differences just before debonding and immediately after debonding, just before debonding and at day 1, immediately after debonding and at day 3, immediately after debonding and at day 7, and at days 1 and 7. There was no significant difference in the control group. Reductions in sensitivity intensity scores of 33% or more at day 3 (55.87%, air stimulation) and at day 7 (77.33%, air stimulation; 55.26%, cold stimulation) were seen. After removal of the brackets, 11 teeth (16.42%) became sensitive during air stimulation, and 6 teeth (8.96%) became sensitive using cold stimulation.

Patients with visible EMCs showed higher mean sensitivity intensity values at each time interval using air stimulation ($P > 0.05$, Fig 3) and cold stimulation ($P \leq 0.05$, Fig 3).

No correlations between the tooth sensitivity values just before debonding and their increasing values immediately after debonding were observed for the patients with visible EMCs (Spearman rho, 0.336; $P > 0.05$) and without them (Spearman rho, 0.504; $P > 0.05$).

Table IV. Thermal stimuli applications

	Compressed air	*Cold*
Temperature (°C)	19-24	0
Application procedure	Compressed air from a dental syringe at a right angle to the buccal cervical surface of the tooth and a distance of about 1-3 mm	With a pipette or syringe, application of freshly melted water on the cervical third of the buccal tooth surface
Application duration (s)	1	≤3
Application procedure characteristics	The buccal cervical surfaces of the premolars were selected as sites for the sensitivity evaluation	
	Application procedure was performed for every tooth individually starting from the maxillary right second premolar and finishing with the mandibular right second premolar (maximum of 8 teeth per patient)	
	Before testing, the patients were asked to raise their right hand at the moment sensation was first felt, at which time the application of the stimulus was discontinued	
	Ten minutes of recovery was provided between stimulus applications for each tooth	

Fig 2. Applying the stimulus.

DISCUSSION

The results of this study demonstrated that the patients having teeth with and without visible EMCs showed increased tooth sensitivity just before debonding and up to 1 week after the removal of metal brackets. The highest discomfort values were recorded immediately after debonding and started to decrease on day 1 for both experimental groups. At day 7, the calculated VAS scores were significantly lower than just before debonding (patients with visible EMCs) and immediately after debonding (subjects with and without visible EMCs). Attention should be paid to the statistically significant difference between the experimental group and its control group immediately after debonding, with higher sensitivity intensity values in the experimental group. Such findings suggest that orthodontic debonding might play a role in tooth sensitivity caused by cellular and molecular changes in the dental pulp during orthodontic force application.[11,12]

A reduction in sensitivity intensity score of 33% or more was noticed at day 3 (41.98%, air stimulation; 37.78%, cold stimulation) and at day 7 (85.71%, air stimulation; 37.04%, cold stimulation) for the patients with visible EMCs; for those without visible EMCs, there were reductions at day 3 (55.87%, air stimulation) and at day 7 (77.33%, air stimulation; 55.26%, cold stimulation). It has been demonstrated that a 33% decrease in pain is an acceptable standard for determining that a change in pain is meaningful from the patient's perspective.[27]

One week after debonding, the VAS values were 0.49 mm (air stimulation) and 14.48 mm (cold stimulation) for the patients with visible EMCs, and 0.56 mm (air stimulation) and 2.00 mm (cold stimulation) for the patients without visible EMCs. Although we found no investigation addressing this subject (visible vs invisible EMCs and tooth sensitivity assessment through thermal stimuli), we identified that sensitivity intensity values were similar to those in other studies (evaluating spontaneous pain or pain from chewing or biting during other orthodontic procedures from the questionnaires completed by the patients).[2,7,9,28] According to the VAS scale ratings in the literature, the average sensitivity 1 week after debonding could be considered no pain (VAS values fell to 0-4 mm) for the patients without visible EMCs and mild pain (VAS values fell to 5-44 mm) for the patients with visible EMCs.[27]

Further examination of the results showed that the patients with visible EMCs had higher sensitivity intensity values than did the subjects without visible EMCs just before debonding and up to 1 week after the removal of brackets. However, the changes in VAS scores did not differ much between the groups; this might have been expected. A similar tendency for greater discomfort values for the patients with visible EMCs was noticed in the control group: the sensitivity values and the changes in intensity with time were much smaller compared with

Table V. Sensitivity intensity mean values (mm) compared with the stimulus applied and time for patients having teeth with visible enamel microcracks

	Statistics	*JBD*	*IAD*	*1 day*	*3 days*	*7 days*
Air stimulation						
Experimental group 1 (n = 15)	Mean	3.43	7.60	2.74	1.99	0.49
	SD	0.42	2.09	1.88	0.36	0.35
Control group 1 (n = 15)	Mean	-	-	-	-	-
	SD	-	-	-	-	-
Cold stimulation						
Experimental group 1 (n = 15)	Mean	23.00	29.13	25.62	14.31	14.48
	SD	10.37	15.51	18.24	11.01	0.91
Control group 1 (n = 15)	Mean	12.04	12.04	14.29	10.08	10.08
	SD	6.25	6.25	8.86	6.09	6.09

For air stimulation, there was no significant difference in the experimental group ($P > 0.05$). No teeth in the control group were sensitive during air stimulation; thus, no statistics could be computed in the group and between the experimental and control groups. For cold stimulation, there was a significant difference in the experimental group JBD and at day 7, IAD and at day 7, and between the experimental and control groups IAD ($P \leq 0.05$); there was no significant difference in the control group ($P > 0.05$).
JBD, Just before debonding (baseline); *IAD*, immediately after debonding (for the control group, the IAD value is the same as at baseline).

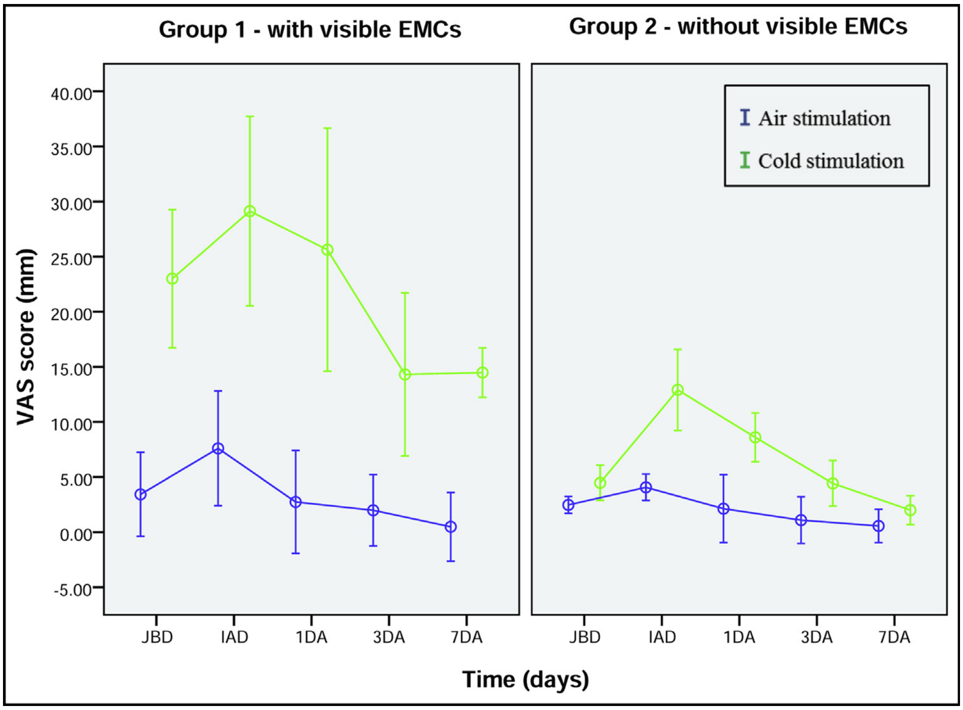

Fig 3. Sensitivity intensity mean values with 95% CI for air stimulation and cold stimulation compared with time for patients having teeth with and without visible EMCs. The *lines* are guides for the eye only. *JBD*, Just before debonding; *IAD*, immediately after debonding; *DA*, day.

the experimental groups. Since the debonding procedure was not performed for the control group patients, this contributes to the assumption that not only the removal of brackets, but also the visible EMCs play a significant role in sensitivity perception. The forces generated during orthodontic debonding might strengthen this discomfort; therefore, sensitivity values remained higher for the experimental group.

Since it was not the aim of this investigation to evaluate time of formation, dynamics, or changes of the quantitative EMC characteristics, the patients were not examined for EMCs before the bonding procedure. On the basis of the findings of the previous studies that new EMCs form in approximately 25% to 40% of teeth after the removal of metal brackets, it can be assumed that at least half of the patients having teeth with visible

Table VI. Sensitivity intensity mean values (mm) compared with the stimulus applied and time for the patients having teeth without visible enamel microcracks

	Statistics	*JBD*	*IAD*	*1 day*	*3 days*	*7 days*
Air stimulation						
Experimental group 2 (n = 15)	Mean	2.47	4.07	2.13	1.09	0.56
	SD	0.08	1.98	2.94	0.85	0.17
Control group 2 (n = 15)	Mean	-	-	-	-	-
	SD	-	-	-	-	-
Cold stimulation						
Experimental group 2 (n = 15)	Mean	4.47	12.91	8.61	4.43	2.00
	SD	2.89	8.08	4.32	4.02	1.25
Control group 2 (n = 15)	Mean	3.55	3.55	3.72	3.86	3.86
	SD	2.31	2.31	1.68	2.48	2.48

For air stimulation, there was a significant difference in the experimental group IAD and at day 7 ($P \leq 0.05$); no teeth in the control group were sensitive during air stimulation; thus, no statistics could be computed in the group and between the experimental and control groups. For cold stimulation, there were significant differences in the experimental group JBD and IAD, JBD and at day 1, IAD and at day 3, IAD and at day 7, at days 1 and 7, and between the experimental and control groups IAD ($P \leq 0.05$); there was no significant difference in the control group ($P > 0.05$).
JBD, Just before debonding (baseline); *IAD*, immediately after debonding (for the control group, the IAD value is the same as at baseline).

EMCs after debonding already had them before the orthodontic therapy.[14,29] For the patients in the control groups, the same evaluation of tooth sensitivity was performed as for the patients in the experimental groups. But discomfort was assessed 4 times because the brackets were not bonded and debonded for the subjects in the control groups; thus, sensitivity mean values at 2 time points (just before debonding and immediately after debonding) were the same.

For a randomized controlled trial, the patients in the study sample should be randomly selected for the experimental and control groups. Since the aims of this investigation were to evaluate patients with and without visible EMCs with respect to debonding and to compare these results with patients who were not treated orthodontically, random allocation of the subjects to these groups was not technically possible. However, random selection was ensured of the 15 patients in group 1 from the subjects who satisfied all the inclusion criteria and possessed pronounced EMCs and the 15 patients in group 2, those without visible EMCs.

Thus, in this study, we combined the EMC characteristics examined in vitro with their impact on tooth sensitivity in vivo in relation to orthodontic debonding.

CONCLUSIONS

Debonding led to a short-term increase in tooth sensitivity. Higher absolute discomfort values were noticed for the patients with visible EMCs; however, the pattern of sensitivity was the same for all subjects. Thus, in principle, EMCs, a form of enamel damage, do not cause greater tooth sensitivity in relation to orthodontic debonding. Nevertheless, a careful explanation of the time course of tooth sensitivity after bracket removal is recommended, and patients should be fully informed during the initial consent.

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