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Effectiveness of a Selective Etching Technique in Reducing White Spots Formation around Lingual Brackets: A Prospective Cohort Clinical Study

Domenico Dalessandri ¹, Marino Bindi ², Francesca Massetti ¹, Gaetano Isola ^{3,*}, Marco Migliorati ⁴, Luca Visconti ¹, Corrado Paganelli ¹ and Stefano Bonetti ¹

- ¹ Department of Medical and Surgical Specialties, Radiological Sciences, and Public Health, School of Dentistry, University of Brescia, Piazzale Spedali Civili 1, 25123 Brescia, Italy; domenico.dalessandri@unibs.it (D.D.); palazzolosulloglio@dentistimassetti.it (F.M.); l.visco@libero.it (L.V.); corrado.paganelli@unibs.it (C.P.); s.bonetti63@gmail.com (S.B.)
- ² Dental Clinic, A.O.U. Maggiore della Carità di Novara, Viale Piazza d'Armi 1, 28100 Novara, Italy; marino.bindi@maggioreosp.novara.it
- ³ Department of General Surgery and Medical and Surgical Specialties, School of Dentistry, University of Catania, Via Plebiscito 628, 95124 Catania, Italy
- ⁴ Department of Orthodontics, School of Dentistry, University of Genova, Largo Rossana Benzi 10, 16132 Genova, Italy; marco.migliorati@unige.it
- * Correspondence: gaetano.isola@unict.it; Tel.: +39-095-7435359

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Abstract: The risk of developing white spot lesions (WSLs) after orthodontic treatment with lingual brackets is generally considered lower than with labial ones, even if plaque accumulation is frequently higher due to the increased difficulty level in oral hygiene maintenance. In this prospective clinical study, selective enamel etching technique effectiveness in reducing plaque accumulation and WSLs was tested. Thirty patients were bonded with a split-mouth approach: two randomly selected opposite quadrants were used as the test sides, using customized plastic etching guides, and the other two as control sides, applying traditional direct etching methods. The plaque presence around the braces was recorded after 1, 3, 6, and 12 months according to a lingual plaque accumulation index (LPAI), as was the presence of WSLs. PAI measured values were significantly higher in the control sides during the observation period. Test and control sides differed significantly for new WSL onset only after 12 months of treatment. Therefore, the present research demonstrated that this guided enamel etching technique allowed for significant reduction in plaque accumulation around the lingual brackets and reduced onset of white spots after one year of treatment.

Keywords: plaque accumulation; lingual bracket bonding; lingual orthodontics; oral hygiene; white spot lesions; enamel etching

1. Introduction

Lingual orthodontics is the most esthetic and an almost invisible orthodontic technique available to correct several types of malocclusions [1]. Even if compared with clear aligner therapy (CAT), which employs a sequence of transparent plastic trays to progressively straighten teeth, lingual braces are hard to see at talking distance because they are bonded to the internal teeth surface [2]. It can be argued that the use of inter-arch elastics attached to lingual braces, or to composite buttons placed on the external teeth surface, has a negative impact on smile esthetics. The same consideration can be made regarding the use of supplementary appliances, such as the Herbst mandibular advancement device [3]. The same occurs with CAT when using similar inter-arch elastics attached to buttons bonded to teeth, or to special notches cut on the plastic tray margins

[4]. This also occurs when applying several attachments to the vestibular teeth surface, such as tooth-colored composite resin shapes of variable dimensions, to increase aligner retention and tooth movement control [5].

Unfortunately, fixed orthodontic appliances are difficult to clean, especially if bonded lingually because of the limited space available between each tooth and the reduced accessibility to daily oral hygiene procedures, compared to brackets applied to labial teeth surfaces [6,7]. Alternatively, increased salivary flow and continuous mechanical cleaning consequent to tongue function were supposed to have a positive effect on reducing the risk of white spots lesions (WSLs) and caries onset during the treatment, compared to vestibular brackets [8,9]. Furthermore, lingual brackets with fully customized large bases covering nearly the entire lingual or palatal teeth surfaces were deemed to provide a better seal protecting dental enamel from acid attacks derived from plaque accumulation underneath the archwire and around the bracket [10,11]. From this point of view, removable appliances such as clear aligners (CAs) seem to be more favorable—especially in patients having a high susceptibility to develop carious lesions—because they can be easily removed, allowing optimal access to all teeth surfaces during daily oral hygiene practices [12].

Two other factors potentially increasing the risk of WSLs and dental caries onset are an overextended enamel surface etching before bracket bonding and the presence of adhesive or resin excesses around the brace's bases [13]. For this reason, a method for selective enamel etching before labial brackets application was developed, and it was found to be effective in reducing both WSLs onset and plaque accumulation around the orthodontic appliance during the first months of treatment [14]. A similar method could be easily applied to the lingual braces bonding procedure, which normally involves the use of indirect bonding trays to precisely position fully customized brackets in an optimal position.

Therefore, the aim of this study was to evaluate whether the use of a selective and individually customized etching technique before indirect lingual braces bonding could be helpful in reducing plaque accumulation around brackets, the formation of WSLs of the surrounding enamel, and the onset of dental caries during the orthodontic treatment.

2. Materials and Methods

Thirty patients between ages 12.2 and 17.9 years, 13 males and 17 females, scheduled for a fixed fully customized lingual orthodontic treatment, were enrolled in this prospective split mouth study. Sample size was determined according to previously published data regarding the variable plaque accumulation, to obtain a power of 0.8 and an alpha level of at least 0.05 [15]. Inclusion criteria were the presence of malocclusion, willingness to undergo a fully customized fixed lingual orthodontic treatment, and a non-extractive and non-surgically assisted treatment plan. Exclusion criteria were the absence of one or more permanent teeth (except third molars), presence of restorative materials on teeth lingual/palatal surface, enamel alterations (development defects, WSLs, brown spots), dietary restrictions or intolerances, and presence of systemic or local (caries, periodontal pockets) pathologies. The study was conducted according to the criteria set by the declaration of Helsinki and was approved by our institutional review board (approval code HMN3912, 4 September 2017). Each participant, together with both parents, signed an informed consent before participating.

Etching guides were prepared in the following way:

- A light-body (low viscosity) poly-vinyl siloxane (PVS) dental impression material (Acquasil™ Ultra LV, Dentsply Intl, York, PA, USA) was placed inside each indirect bonding transfer tray, paying attention to avoid the formation of any type of gap or air bubble, until filling it completely (Figure 1).

- After waiting the appropriate setting time, the PVS was removed, checked for impression precision, and an .STL file was generated using an intraoral scanner (CS3600, Carestream Dental, Atlanta, GA, USA).
- This .STL file was then printed in resin with a 3D printer (Formlabs Form 2), and it underwent vacuum thermoforming to thermoform a blue-colored polyethylene terephthalate (PET) thermoplastic sheet into an etching guide.
- The etching guide was completed making holes on the lingual/palatal teeth surface, exactly corresponding in shape, dimension, and position to the bracket base.



Figure 1. Etching guide preparation: (a) light-body poly-vinyl siloxane dental impression material placed inside the indirect bonding transfer tray; (b) impression of the inner surface of the indirect bonding tray.

The indirect bonding of lingual brackets was achieved starting from the upper arch, using a split-mouth technique, etching randomly to one half-arch, with the etching guide (test side) and the other half-arch without it (control side). To avoid any bias resulting from right- or left-handedness in patients, the two tests and control sides in the lower arch were crossed, ensuring that on both the right and left sides there was one half dental arch treated with the guided etching technique and the other without. Randomization was performed by preparing a simple randomization list by flipping a coin: the side of the coin (i.e., heads, test; tails, controls) determined the assignment of the upper right quadrant of each patient. The coin tossing was stopped when one group reached the number of 15, and the remaining were then assigned to the other list [16].

Before lingual bracket bonding, the etching guides were first fitted on the dental arches to check the correct and complete possibility of insertion. Then, all lingual and palatal dental surfaces were cleaned with a rotating brush and a fluoride-free silicate-based polishing paste (Zircate, Dentsply, York, PA, USA) and gently air-dried. The isolation kit, Nola Dry Field System (Great Lakes Orthodontics, Tonawanda, NY, USA), formed by a double cheek retractor and a tongue basket linked by thin saliva ejector silicone tubes to the aspiration system of the chair, was applied. On the test sides, the two etching guides were inserted, and the enamel of each tooth was sandblasted for one second with 50 μm aluminum oxide particles. The teeth were then carefully washed to remove any residual sand, they were air-dried, and orthophosphoric acid at 37% was applied for 30 s into the holes (Figure 2). Then the acid was aspirated, and the etching guides were removed and separately washed and dried. The two control half-arches were sandblasted and acid-etched with the same products, washed, and dried.

Successively, a thin layer of self-adhesive dual-cure resin cement (RelyX™ Unicem 2 Automix, 3M, ESPE, Seefeld, Germany) was applied to the lingual braces base, and the indirect bonding tray was inserted into the patient mouth. When it was completely fitted on all the teeth, a LED curing lamp (VALO™ cordless, Ultradent, UT, USA) was used for

20 s on each tooth: 10 s on the incisal and 10 s on the gingival edge of every single bracket. Afterward, the first external stiff tray was removed, and the light curing sequence was repeated. Finally, the internal soft tray, proceeding from distal to mesial, and from vestibular to lingual, was removed, and the light curing sequence was repeated for the last time (Figure 3). Possible composite excess was removed with a sharp-pointed dental scaler and abrasive strips (Sof-Lex™, 3M, Seefeld, Germany), followed by the application of the rotating brush with the polishing paste.



Figure 2. Etching guide in place with orthophosphoric acid at 37%.



Figure 3. Brackets in place; before composite excess removal.

Finally, the patients were trained in hygienic home procedures following a protocol specifically developed for lingual orthodontic appliances [17–23].

Afterward, the orthodontic treatments started (t_0), and the plaque presence around the braces was recorded after 1, 3, 6, and 12 months (from t_1 to t_4). Plaque presence was rated according to a lingual plaque accumulation index (LPAI), using a numerical scale from 0 to 4 to evaluate the amount of plaque accumulated on the occlusal, mesial, apical,

and distal margins of the bracket base (Table 1). At the same time points, the possible presence of WSLs and caries was recorded [24–27].

Table 1. Scores assigned to LPAI.

Score	Clinical Presentation
0	No plaque
1	Plaque accumulation on one bracket base margin
2	Plaque accumulation on two bracket base margins
3	Plaque accumulation on three bracket base margins
4	Plaque accumulation on four bracket base margins

During the orthodontic treatment, the patients underwent sessions of professional oral hygiene every 4 months. At the end of the treatment (t_5), which lasted, on average, 2 years and 20 months \pm 4 months, braces were removed. The final intraoral pictures were taken a month after to allow any hyperplastic gingiva present—which could potentially hide the presence of WSLs and caries—to regain its normal appearance. Bracket bonding failures during treatment were recorded on a dedicated form, indicating when and where they occurred.

Statistical Analysis

The rater repeatability in measuring LPAI and the presence of WSLs or caries were evaluated at each time point using the intraclass correlation coefficient (ICC) applied to double measurements recorded twice at an interval of 1 h from 10 randomly selected patients. ICC was interpreted as follows: values < 0.21 indicated poor agreement; 0.21–0.30, slight agreement; 0.31–0.40, fair agreement; 0.41–0.60, moderate agreement; 0.61–0.70, substantial agreement; 0.71–0.80, strong agreement; 0.81–0.99, almost perfect agreement; and 1, perfect agreement. After a descriptive statistical analysis of all collected data, the Shapiro–Wilk normality test and Levene test for equality of variances were performed. For the ordinal variable LPAI, mean intragroup differences among t_1 , t_2 , t_3 , and t_4 were analyzed with the Friedman test; intergroup differences at t_1 , t_2 , t_3 , and t_4 , were analyzed with the Wilcoxon–Mann–Whitney test. Mean intergroup differences across t_1 , t_2 , t_3 , t_4 , and t_5 for the dichotomous (absence = 0, presence = 1) nominal variables, WSLs, and caries were analyzed with the Pearson chi-square test; the Cochran Q test, followed by the post-hoc pairwise McNemar test with Bonferroni correction, was applied to identify significant intragroup changes across the time points. SPSS software version 22 (IBM, Armonk, NY, USA) was used for all calculations.

3. Results

Forty-one consecutive patients were assessed for eligibility: eight were excluded due to not meeting the inclusion/exclusion criteria. The remaining thirty-three were asked to participate in the present study to achieve thirty participants (i.e., three did not agree to participate). Any dropout was registered.

ICC values indicated almost perfect repeatability of evaluator measurements, ranging from 0.94 to 0.99. LPAI and WSLs values at, respectively, the four and five time points are summarized in Tables 2 and 3. At t_5 one caries was found in a control side when a fracture of both lingual cusps (Figure 4) in a tooth 3.6 was recorded during bracket debonding procedure. In the twenty-nine remaining patients there was no decay onset detected. LPAI values in control sides were constantly higher compared to test group at all time-points, with an increase from t_1 to t_2 , and a stabilization (plateau) from t_2 to t_5 ; intragroup analysis revealed a worsening of oral hygiene status between t_1 and t_2 in the control group, followed by a stabilization period from t_2 to t_4 , whilst any difference along the time points was found in the test side. Incidences of WSLs were significantly higher, compared to t_0 (0% of patients with preexisting lingual/palatal WSLs), at t_1 (3.33%), t_2

(20%), t_3 (26.67%), t_4 (33.33%), and t_5 (40%)—with significant differences between different time points after the first 6 months of treatment—within the control sides. However, on the test sides there were no significant differences across the time points t_0 and t_1 (0%), but only compared to t_2 (13.33%), t_3 (13.33%), t_4 (16.67%) and t_5 (20%), with any significant differences between different time points after the first 6 months of treatment. Variations in LPAI and WS presence are represented graphically in Figure 5; Figure 6, respectively. Any bracket bonding failures occurred during treatment, not in test, nor in control sides.

Table 2. Mean (SD) LPAI scores at t_1 , t_2 , t_3 , t_4 . SD = standard deviation; LPAI = lingual plaque accumulation index. C = control sides; T = test sides. t_1 = after 3 months; t_2 = after 6 months; t_3 = after 9 months; t_4 = after 12 months. ** $p < 0.01$; **** $p < 0.0001$.

Timepoint	C	T	<i>p</i> Value C vs. T
t_1	2.51 (0.14)	1.17 (0.13)	0.00 ****
t_2	2.92 (0.13)	1.30 (0.06)	0.00 ****
t_3	2.93 (0.13)	1.30 (0.05)	0.00 ****
t_4	2.93 (0.12)	1.31 (0.07)	0.00 ****
C	<i>p</i> value t_1 vs. t_2 0.00 ****	<i>p</i> value t_2 vs. t_3 0.16	<i>p</i> value t_3 vs. t_4 0.08
T	<i>p</i> value t_1 vs. t_2 0.01 **	<i>p</i> value t_2 vs. t_3 0.56	<i>p</i> value t_3 vs. t_4 0.16

Table 3. Number of patients with WSLs at t_1 , t_2 , t_3 , t_4 , t_5 . WSLs = white spot lesions. C = control sides; T = test sides. t_1 = after 3 months; t_2 = after 6 months; t_3 = after 9 months; t_4 = after 12 months; t_5 = end of treatment. * $p < 0.05$; ** $p < 0.01$; *** $p < 0.001$; **** $p < 0.0001$.

Timepoint	C	T	<i>p</i> Value C vs. T
t_1	1	0	0.31
t_2	6	4	0.49
t_3	8	4	0.20
t_4	10	5	0.14
t_5	12	6	0.02 *
C	<i>p</i> value t_1 vs. t_2 0.06	<i>p</i> value t_1 vs. t_3 0.02 *	<i>p</i> value t_1 vs. t_5 0.00 ***
T	<i>p</i> value t_1 vs. t_2 0.00 ****	<i>p</i> value t_2 vs. t_3 1	<i>p</i> value t_2 vs. t_5 0.50



Figure 4. Fracture of both lingual cusps during debonding.

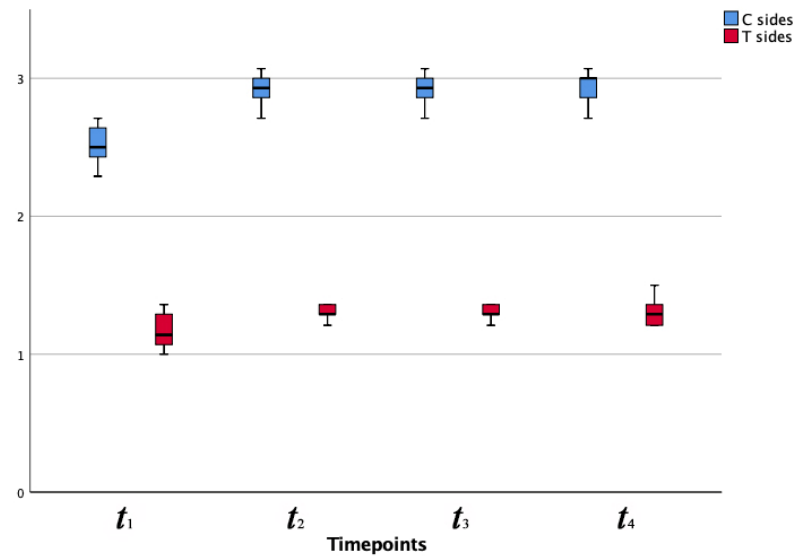


Figure 5. LPAI trend during the study.

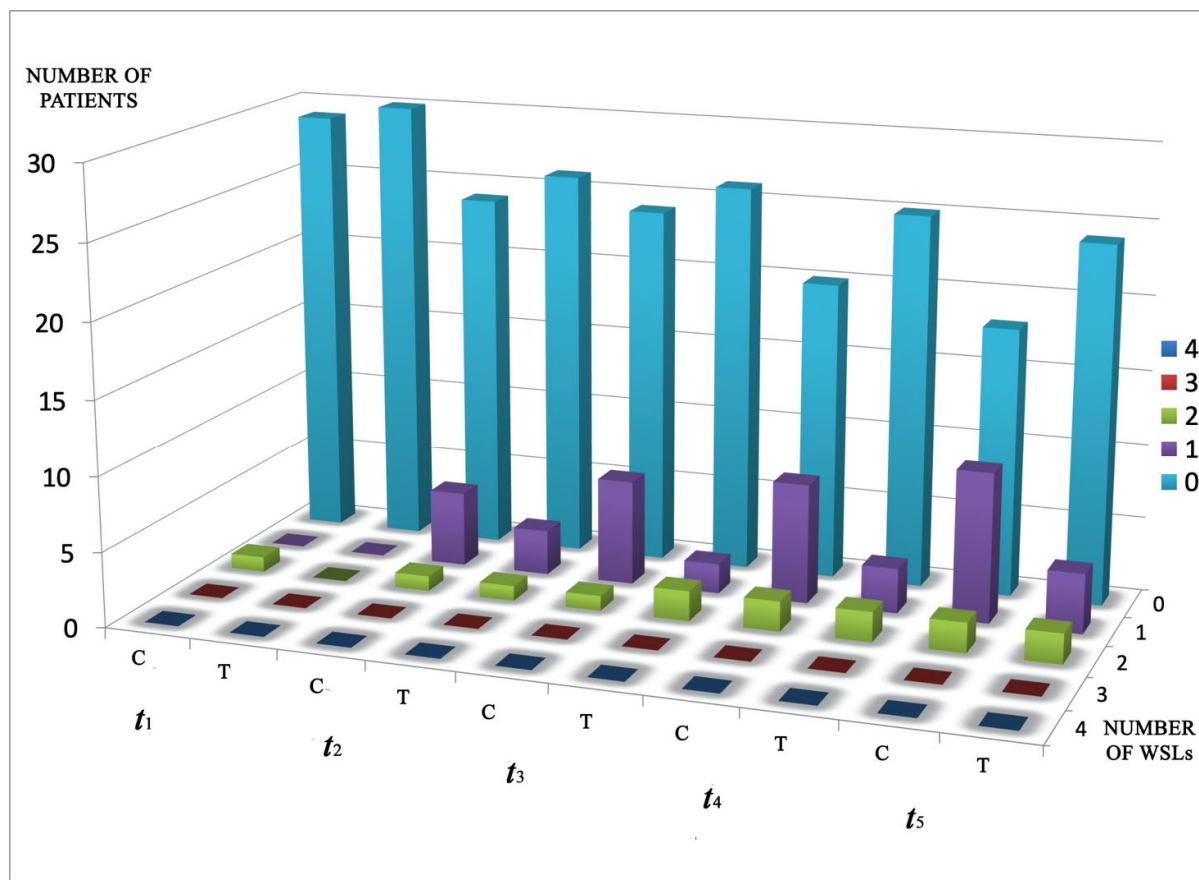


Figure 6. WSLs trend during the study.

4. Discussion

This study investigated the effectiveness of a selective sandblasting and etching technique in reducing plaque accumulation and white spots formation around braces in a group of adolescent patients wearing fixed, fully customized lingual multibracket appliances. To answer this question, we prospectively collected data on plaque presence around braces margins, WSLs, and caries onset every three months during the first year of treatment, and on WSLs and caries onset at the end of treatment. We also collected data regarding accidental braces debonding to detect any negative effect on bond strength. Patients with restricted dietary regimens were excluded because these have been found to influence the incidences of WSLs. We also excluded patients with previous enamel alterations or restorations on teeth lingual/palatal surface, as these alter the bonding pattern and constitute additional variables to be tested separately [28,29].

We opted for a split mouth study design to limit the influence of specific characteristics on the final results for each patient, such as daily sugar intake, oral hygiene maintenance ability, and enamel strength. Furthermore, crossing upper and lower test and control sides, we were able to adjust results also according to patient manual dexterity (right- or left-handed) [30].

The increase in plaque accumulation found in control sides during the first 6 months of treatment, followed by a stabilization period during the following 6 months, could be explained by a protracted negative influence of a rough enamel surface, altered by an overextended enamel sandblasting and etching, on bacterial adhesion and plaque retention. This could also explain why dental plaque accumulation was lower in test sides compared to control sides, without any increase during the entire first year of treatment in test sides, where all the enamel surface sandblasted and etched was covered by the bracket

base and sealed with a resin cement. Furthermore, the utilization of a self-adhesive resin cement allowed for avoiding the application of a bonding agent known to contain chemical components with an estrogenic effect that, if some adhesive remnants remain below the gingival margin, promote increased inflammation, gingival swelling, and, consequently, an increase in plaque accumulation [31,32].

The increase in WSLs formation in control sides compared to the test sides could be considered a direct consequence of the aforementioned difference in plaque accumulation around braces. In fact, the main etiopathological factor of acquired WSLs is plaque accumulation, acid production, and the consequent dissolution of apatite crystals and the loss of calcium, phosphate, and other ions, which eventually leads to the demineralization of the underlying enamel. This subsurface porosity gives the lesion a milky appearance that can be found on the smooth surfaces of teeth. From an esthetic point of view, these lesions are less important compared to vestibular WSLs, as they are hidden from the view of a possible observer. More importance is related to the role of WSLs as a precursor of dental caries: in this case it is important to identify active lesions, usually with a rough surface, and to arrest their progression toward a sound caries using a minimally invasive restorative approach to interrupt this pathological enamel degeneration [33,34].

A limit of the selective etching technique proposed in this study may be its complexity and the consequent increase in time and costs. In fact, it is necessary to take an impression of the indirect bonding tray, to scan and print it, and finally to thermoform and crop a plastic etching guide. Furthermore, all these steps increase the risk of inaccuracies in guide realization. All these limits could be encompassed if companies producing lingual brackets are able to offer to the orthodontists, perhaps as an option, these guides in the same way as they do with indirect bonding trays. This would allow increased guide precision and reduce the final costs for orthodontists, considering the ease of this production at the manufacturer level [35].

Alternative methods for the reduction in WSLs incidence are, among others, the coating of brackets or wires with antibacterial agents [36], monthly use of a 22,600 ppm fluoride varnish or a 5% sodium fluoride film, and daily use of casein phosphopeptide-stabilized amorphous calcium phosphate creams or bioactive glass toothpastes [37]. Resin infiltration is considered useful in terms of both reducing the WSL area and to increasing its esthetic appearance [38]. Innovative systems such as telemonitoring and web-based smartphone apps, reducing plaque accumulation and ameliorating overall oral hygiene, help to reduce a factor favorable for WSL onset [39,40].

A limit of this study could be considered the young age of participants, hypothetically limiting the applicability of the results of this study to older people, who still today are most frequently looking for an esthetic and almost invisible orthodontic appliance. In fact, since previous research has reported increased caries activity in adolescents compared with adults, it could be possible that reduced susceptibility of adult patients to WSLs and caries formation neutralize the positive effect of preserving enamel surface integrity from overextended sandblasting and etching [41].

Future research directions could consider the use of “smart” bonding materials to increase enamel strength, such as the effect of the periodic application of a thin layer of a fluoride-releasing bonding agent around braces bases margins in preventing plaque accumulation and enamel alterations, weighing the pros (antibacterial and enamel remineralizing effect of fluoride) and cons (increased enamel roughness; adjunctive procedure) [42,43]. Another direction could be the exclusion of the sandblasting procedure [44]. Sandblasting is a procedure frequently performed in lingual orthodontics due to the wide diffusion of official clinical protocols suggested by the main companies producing fully customized lingual appliances [45]. Recently, a systematic review regarding the effect of enamel sandblasting on enhancing bond strength of orthodontic brackets was not able to support a positive effect of this procedure [46]. Exclusion of the sandblasting step could reduce enamel roughening and, consequently, bacterial adhesion [47].

5. Conclusions

The selective sandblasting and etching technique presented in this study was effective in reducing plaque accumulation and white spots formation around braces in a group of adolescent patients wearing fixed, fully customized lingual multibracket appliances, without any negative effect on bond strength.

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