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Evaluation of enamel roughness after the removal of brackets bonded with different materials: *In vivo* study

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The aims of this *in vivo* study were to evaluate the effect of bonding with resin-modified glass ionomer cement (RMGIC) and to assess enamel surface roughness before and after the removal of brackets bonded with composite or RMGIC from the maxillary central incisors. Fifteen orthodontic patients were selected for the study. For each patient, the teeth were rinsed and dried, and brackets were bonded with composite (Transbond XT) and RMGIC (Vitremer Core Buildup/Restorative). At the conclusion of orthodontic treatment, their brackets were removed. Dental replicas were made of epoxy resin in initial conditions (before bonded) and after polishing with an aluminum oxide disc system. Adhesive remnant index (ARI) and surface roughness was measured on the dental replicas and data were evaluated statistically by Mann-Whitney and paired t-test, respectively. No bracket debonding occurred during patients' treatment periods. It was verified that the ARI values of the two maxillary central incisors were similar (p = 0.665). For both bonding materials, the ARI value of 3 was predominant. After polishing, surface roughness was similar in the composite and RMGIC groups (0.245 µm and 0.248 µm, respectively; p = 0.07). In both groups, enamel surface roughness values were significantly lower after polishing compared with the initial condition (p < 0.001). RMGIC promoted efficiency in cementing brackets without fail during treatment; the choice of composite or RMGIC materials was not a factor that influenced the roughness of the enamel surface, however, polishing led to smoother surfaces than those found at the beginning of the treatment.

Key Words: Micro-shear bond strength, Bleaching, Self-etch adhesives

Introduction

Intact enamel is a component of a beautiful smile and orthodontic treatment is not supposed to jeopardize its original quality (1). Filled restorative materials have been used as orthodontic adhesives (2). Enamel demineralization during orthodontic treatment is a severe complication. Preventive measures developed to solve these problems include the use of dental bonding materials that release fluoride locally near brackets (3). An attempt to improve the availability of fluorides to reduce the occurrence of carious lesions is to add fluoride to dental materials used close to orthodontics bracket. Fluoride can be added to the cement itself, to the adhesive, and to the sealants or varnishes used to protect the bonding interface (4). Fluoride is essential to control the caries lesions and its use is indicated in different phases of dental treatment (5).

White spot lesions are opaque milky-white zones of spongy external enamel (6). White spot lesions compromise aesthetics and increase susceptibility to further decay (7). These problems have led to research into further possibilities in direct bonding. One approach is to replace composite resin with a fluoride-releasing material, such as glass ionomer cement (GIC) (7). However, the physical properties of conventional GIC compromise the shear bond strength between orthodontic brackets and tooth surfaces (8). It is prone to elastic deformation in areas of high stress due to its lower modulus of elasticity compared to resin agents (9). Thus, the glass ionomer must be modified with a resin matrix to improve the shear bond strength while maintaining the material's fluoride-releasing property (10).

Several laboratory studies have examined the properties after debonding with resin-modified glass ionomer cement (RMGIC) (7, 10). A few *in vivo* studies have been conducted (3), but not found none has involved the maxillary central incisors. Thus, the aims of this *in vivo* study were to evaluate the effect of bonding with RMGIC, and to examine enamel surface roughness before and after the removal of brackets from maxillary central incisors bonded with composite or RMGIC. The null hypotheses were that 1) initial enamel surface roughness would not differ from that after cement removal, and 2) enamel surface roughness after polishing would not differ according to the bonding material used.

Material and Methods

The absolute risk of enamel surface roughness was reported to be 0.13 µm in an earlier study (11). Using an α of 0.05, 90% power and a two-sided test, the minimum sample size in this equivalence trial was 8 patients in order to detect a 0.05 µm difference in the risk of enamel surface roughness between groups (www.sealedenvelope.com). 8 patients per group would be required, but 15 patients per group were included, so that any possible volunteer dropouts would not affect the result. The research ethics committee of the University of North Parana, Brazil, approved this study. Study participants were 15 patients (8 male, 7 female) ranging in age from 12 to 24 years (mean, 18.08 years; standard deviation, 2.38). No patient had caries, restorations, a history of trauma, bruxism, or cracks on the maxillary central incisors.

Prophylactic procedures were performed with pumice and a rubber cup set into a handpiece (Dabi-Atlante, Ribeirao Preto, SP, Brazil) operated at low speed for 10 seconds. The teeth were washed, dried, and impressed by dual-phase addition (putty/wash) with a one-step technique (Ultra-light, Aquasil Ultra XLV and Putty, Aquasil Easy Mix Putty; DENTSPLY Caulk, Milford, DE, USA). The mold of right and left central incisors was cast with epoxy resin (20-8130-032; Buehler, Lake Bluff, Illinois, USA).

The same professional bonded brackets in all patients after the teeth were rinsed and dried. Two types of bonding material were used: composite (Transbond XT; 3M Unitek, Monrovia, CA, USA) and RMGIC (Vitremer Core Buildup/Restorative; 3M ESPE, St. Paul, MN, USA; Table 1). Thirty metal brackets (Morelli, Sorocaba, SP, Brazil) were bonded to the maxillary right and left central incisors, respectively. In each patient, the right and left incisors were allocated randomly to the one of two bonding groups, by simple randomization in a Table of random numbers in the Excel program (Microsoft Corporation - Redmond, Washington, USA).

Table 1. Bonding materials used in the study.

Bonding Materials / Material (Manufacturer)	Composition*
Composite / Transbond XT (3M Unitek)	Silane-treated quartz, bisphenol A diglycidyl ether dimethacrylate, bisphenol A bis (2-hydroxyethil ether) dimethacrylate, dichlorodimethylsilane reaction product with silica
RMGIC / Vitremer Core Buildup/Restorative (3M ESPE)	Powder: fluoroaluminosilicate glass, redox system; Liquid: aqueous solution of a modified polyalkenoic acid, 2-hydroxyethyl methacrylate

RMGIC, resin-modified glass ionomer cement. *Information provided by the manufacturers.

For composite bonding, the middle third of the buccal face of each tooth was etched with 35% phosphoric acid gel (Scotchbond Etching Gel; 3M ESPE) for 20 s, rinsed with air/water spray for 20 s, and air dried for 20 s. One layer of Transbond XT Primer (3M Unitek) was applied to the etched tooth and light activated for 10 s using a light-emitting diode (Ultraled; Dabi-Atlante) set to 790 mW/cm^2. Standard stainless-steel maxillary incisor brackets were then positioned and bonded firmly to the tooth with Transbond XT, the excess material was removed with a microbrush (KG Sorensen, Cotia, SP, Brazil), and the resin was light activated. The edge of each bracket was exposed to the light-emitting diode (Ultraled) for 10 s, with a total exposure time of 40 s.

For RMGIC bonding, one layer of Vitremer Core Buildup/Restorative Primer (3M ESPE) was applied to the etched tooth and bracket base for 30 s, air dried for 15 s, and light activated for 10 s using a light-emitting diode (Ultraled). Standard stainless-steel maxillary incisor brackets were then positioned and bonded firmly to the tooth with Vitremer Core Buildup/Restorative, the excess material was removed with a microbrush (KG Sorensen), and the RMGIC was light activated. The edge of each bracket was exposed to the light-emitting diode for 10 s, with a total exposure time of 40 s. Vitremer Core Buildup/Restorative Finishing Gloss (3M ESPE) was applied to the edge of each bracket, which was exposed to the light-emitting diode (Ultraled) for 5 s (total exposure time, 20 s).

The patients' orthodontic treatment duration ranged from 15 to 28 months (mean, 21.5 months; standard deviation, 2.5), and they used mouthwash with 10 ml 0.2% sodium fluoride solution (Drogaderma Farmácia de Manipulação, Presidente Prudente, SP, Brazil) for 1 min once a week. After treatment, the brackets were removed with pliers (ETM 346; Ormco, Orange, CA, USA). Then, prophylactic and impression procedures were performed as described above.

The adhesive remnant index (ARI) was determined by examining the dental replicas (of debonded teeth with remaining resin) under an optical microscope (Eclipse E100; Nikon, Tokyo, Japan) at 40× magnification. The ARI was used to classify the failure mode as follows: 0, no bonding resin left on the tooth; 1, less than half of the bonding resin left on the tooth; 2, more than half of the bonding resin left on the tooth; and 3, all bonding resin left on the tooth, with a distinct impression of the bracket mesh (12).

The teeth were polished with aluminum oxide discs (Sof-Lex; 3M ESPE; n = 15) at low speed with intermittent cooling, in decreasing order of abrasiveness for 20 s each, until a visibly smooth and polished surface was obtained. After the removal of remaining resin, new replicas of the polished teeth were obtained using the procedures described above.

Surface roughness was measured on the dental replicas obtained initially and those obtained after polishing. Measurements were performed with a surface roughness tester (SJ 400; Mitutoyo, Kawasaki-Shi, Kanagawa, Japan) with a length of 1.25 mm and cutoff of 0.25 mm at a speed of 0.05 mm/s. Three measurements were made in different directions with an angle of 120° among them, and a mean value was calculated for each dental replica.

Statistical Analysis

Statistical analysis was performed with Minitab 16 for Windows 8 (Minitab, State College, PA, USA). The distributions of the surface roughness measurements were investigated with the D'Agostino–Pearson normality test; then, parametric tests were used. Data for roughness values were evaluated by paired t-test at the 5% significance level ($\alpha = 0.05$) for the different bonding materials. ARI data were evaluated by Mann-Whitney at the 5% significance level ($\alpha = 0.05$) for the different groups.

Results

No bracket debonding occurred during patients' treatment periods. The frequency distributions of ARI values are shown in Table 2. It was verified that the ARI values of the two maxillary central incisors were similar ($p = 0.665$). For both bonding materials, the ARI value of 3 was predominant. The enamel surface roughness test results are shown in Table 3. After polishing, surface roughness was similar in the composite and RMGIC groups (0.245 µm and 0.248 µm, respectively; $p = 0.07$). In both groups, enamel surface roughness values were significantly lower after polishing compared with the initial condition ($p < 0.001$).

Table 2. Frequency distributions of adhesive remnant index (ARI) scores.

Bonding Materials	ARI Scores (%)			
	0	1	2	3
Composite	0	0	13.3	86.7
RMGIC	0	20	20	60

RMGIC, resin-modified glass ionomer cement. The ARI was used to classify the failure mode as follows: 0, no bonding resin left on the tooth; 1, less than half of the bonding resin left on the tooth; 2, more than half of the bonding resin left on the tooth; and 3, all bonding resin left on the tooth, with distinct impression of the bracket mesh.

Table 3. Mean enamel surface roughness (Ra, μm) under initial conditions and after polishing.

Enamel	Composite (n = 15)	RMGIC (n = 15)		
	Mean ± SD	Mean ± SD	95% CI (Lower limit / Upper limit)	P value
Initial conditions	0.370 ± 0.020	0.372 ± 0.170	(-0.013 / 0.013)	.99
After polishing	0.245 ± 0.005	0.248 ± 0.007	(-0.007 / 0.001)	.07
95% CI (Lower limit / Upper limit)	(0.115 /0,135)	(0.109 / 0,134)		
P value	<.001	<.001		

RMGIC: resin-modified glass ionomer cement. SD: Standard Deviation. CI: Confidence Interval.

Discussion

Fluoride treatment has been recommended for preventing dental caries (13). In orthodontics practice, white spot lesions are frequently observed around orthodontic appliances (14-16). For this reason, fluoride-releasing dental bonding materials are frequently used to provide a source of fluoride near brackets (3,14). GIC has adhesive (17), biocompatible (14), and fluoride-releasing (15) properties, but low bond strength to dental substrate (14,18). The incorporation of hydroxyethyl-methacrylate (HEMA) or bisphenolglycidyl-methacrylate into GIC yields RMGIC, which has enhanced compressive strength, hardness, modulus of elasticity, and resistance to solubility and bacterial adhesion (19). The RMGIC used in the present study contains a HEMA monomer, which may have contributed to the lack of bracket debonding during orthodontic treatment. Thus, RMGIC has clinical relevance because it can be used for bracket bonding while reducing the occurrence of white lesions around brackets through fluoride release.

The natural microroughness of enamel is attributable to its microstructure. Enamel etching and resin infiltration into the superficial enamel layer during the bonding of orthodontic brackets may make it impossible to resume the initial conditions of the enamel (before orthodontic treatment). Bracket debonding and adhesive removal may be associated with iatrogenic effects, including enamel cracking or fracture, removal of the fluoride-rich external enamel layer, remnant adhesive, and surface roughening. Adhesive remnants and surface roughening may be associated with discoloration and plaque accumulation. Moreover, the surface roughness of enamel and dental materials may influence bacterial retention. According to a previous study (20), remnant resin removal with aluminum oxide discs (Sof-Lex) produces wear beyond the maximum average depth, causing more damage to the enamel. In contrast to this finding, the polishing of enamel surfaces with Sof-Lex discs produced the best results in other studies (11,21). In one study (11), greater roughness was observed when resin was removed with finishing abrasive tips; the authors of another study (22) recommended the use of the same tips for resin removal to minimize the grooves produced by drills and discs. Notwithstanding the uncertainty about the type of material to use for finishing, the consensus is the importance of enamel polishing after bracket debonding and resin removal to increase smoothness (11,21, 22). Polishing also provides a special shine and prevents biofilm retention. In the present study, the teeth were polished with aluminum oxide discs (Sof-Lex) and enamel surfaces were significantly less rough after the removal of both bonding materials compared with the initial condition. Thus, the polishing technique used effectively smoothed the enamel surfaces, providing a shine and preventing the retention of biofilm. These properties are essential for any tooth, but the effects are more visible on the central incisors. Moreover, polishing improves light reflection (23).

Higher ARIs are associated with the need for increased chair-side time to mechanically remove remnant adhesive after bracket removal. Furthermore, enamel damage is a risk during mechanical adhesive removal and polishing (24). The ARI score of 3 predominated in both groups in this study, without statistical difference between the different materials. The site of bonding failure provides information about the quality of the bond between the adhesive and tooth, and between the adhesive and bracket base (25). However, no bracket adhesion failure occurred during orthodontic treatment in the present study. Thus, the data indicate that both materials used are effective for this type of treatment. However, RMGIC has the main advantage of releasing fluorine, which reduce white spot formation and biofilm retention. The limitation of the present study was that it did not assess the reduction of white spot formation or biofilm retention, for this reason, future studies should involve the evaluation of white spot development and biofilm retention to clinically confirm our findings. In sum, the null hypothesis 1 was not accepted, as the initial surface roughness of enamel differed from that after polishing. However, the null hypothesis 2 was accepted, as the efficacy of bracket bonding and the surface roughness of enamel after bonding did not differ according to the bonding material used. Therefore, based on this *in vivo* study of bracket bonding and debonding on the maxillary central incisors, the following conclusions can be drawn: RMGIC promoted efficiency in cementing brackets without fail during treatment; the choice of composite or RMGIC materials was not a factor that influenced the roughness of the enamel surface, however, polishing led to smoother surfaces than those found at the beginning of the treatment.

Resumo

Os objetivos deste estudo *in vivo* foram avaliar o efeito da colagem com cimento de ionômero de vidro modificado por resina (CIVMR) e a rugosidade da superfície do esmalte antes e após a remoção dos braquetes colados com compósito ou CIVMR em incisivos centrais superiores. Quinze pacientes ortodônticos foram selecionados para o estudo. Para cada paciente, os dentes foram lavados e secos, e os braquetes colados com compósito (Transbond XT) e CIVMR (Vitremer Core Buildup / Restorative). Ao término do tratamento ortodôntico, os braquetes foram removidos. As réplicas dentais foram confeccionadas em resina epóxica nas condições iniciais (antes da colagem) e após o polimento com sistema de discos de óxido de alumínio. O índice de remanescente adesivo (IRA) e a rugosidade da superfície foram mensurados nas réplicas dentais e os dados foram avaliados estatisticamente por Mann-Whitney e teste t pareado, respectivamente. Não ocorreu descolagem de braquetes durante os períodos de tratamento dos pacientes. Verificou-se que os valores do IRA dos dois incisivos centrais superiores foram semelhantes ($p = 0{,}665$). Para ambos os materiais de colagem, o valor de IRA predominante foi 3. Após o polimento, a rugosidade da superfície do esmalte foi semelhante nos grupos compósito (0,245 µm) e CIVMR (0,248 µm) ($p = 0{,}07$). Em ambos os grupos, os valores de rugosidade da superfície do esmalte foram significativamente menores após o polimento em comparação com a condição inicial ($p < 0{,}001$). CIVMR promoveu eficiência na colagem de braquetes sem falhas durante o tratamento; a escolha dos materiais compósito ou CIVMR não foi um fator que influenciou na rugosidade da superfície do esmalte, porém, o polimento levou a superfícies mais lisas do que as encontradas no início do tratamento.

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