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TABLE OF CONTENTS

[INTRODUCTION] [MATERIALS AND...] [RESULTS] [DISCUSSION] [CONCLUSIONS] [REFERENCES] [TABLES] [FIGURES]

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Effect of Resin-removal Methods on Enamel and Shear Bond Strength of Rebonded Brackets

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ABSTRACT

The objective of this study is to determine (1) the effect of different resin-removal methods on shear bond strength (SBS) of rebonded brackets, (2) condition of the enamel surface, (3) time spent to remove resin remnants, and (4) the location of the bond failure. A total of 80 premolars were included in the study. Fifty of them were divided into five groups and bonded using Light Bond™ sealant and Quick Cure™ adhesive. Ten of the samples were debonded, and the SBS of the first debonding was calculated. Forty brackets were debonded using pliers and examined by an optical microscope (16×) to determine the location of the bond failure interface, using a modified Adhesive Remnant Index (ARI). The remnant adhesives were cleaned with four methods: (1) low-speed tungsten-carbide bur (TCB), (2) high-speed TCB, (3) Sof-Lex finishing disks, and (4) microetcher. The brackets were rebonded, and a second set of SBS and ARI values were calculated and statistically evaluated. Thirty of the premolars were divided into five groups receiving the same resin-removal methods and examined by scanning electron microscope. Rebonded teeth had a greater SBS than the initial bonding, except in group 4. The rebonded SBS values were similar in groups 1–3, and only group 4 showed a statistical difference. Sof-lex discs were the most time-consuming procedures and left much adhesive remnant. The high-speed TCB was found to be the most hazardous to the enamel. The scarring of enamel after the debonding is inevitable but can be reduced.

KEY WORDS: Shear bond strength, Surface cleanup, Resin removal, Microetcher, Rebonding.

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INTRODUCTION Return to TOC

The concept of bonding resins to enamel has developed applications in all fields of dentistry, including orthodontics.[1] The primary orthodontic goal lies in returning the enamel surface to its original state after removal of orthodontic attachments.[2] Damage to enamel can be attributed to cleaning with abrasives before etching, acid etching, enamel fractures caused by forcibly removing brackets, or mechanical removal of remaining composite with rotary instruments.[3,4]

The search for an efficient and safe method of adhesive resin removal after debonding has resulted in the introduction of a wide array of instruments and procedures.[5] These include manual removal with the use of a scaler or a band-removing plier,[6] various shapes of tungsten-carbide burs (TCB) with low- or high-speed hand pieces,[2,7] Sof-Lex discs,[8] and special composite finishing systems with zirconia paste or slurry pumice as well as ultrasonic applications.[9] Also, novel approaches involving carbon dioxide–laser application have been promising,[10] whereas the Nd:YAG laser has demonstrated potent structural degradation of the composite, suggesting that it could be used as an adjunct to the removal of residual resin.[11] In addition, air-powder abrasive systems have been suggested for removing residual adhesive,[12] but the need for rubber dam and protective mask/eye-wear is an impractical aspect of this technique.[13]

Along with the introduction of novel methods, conventional instruments have been developed, such as specially designed burs, which are less aggressive to the enamel.[14] All the reported techniques produce different degrees of polish, and some introduced abrasion accompanied by a significant loss of enamel. These techniques may also have adverse effects on the pulpal tissues if not dissipated with an appropriate coolant.

A frequent and undesirable problem during treatment is bracket failure. Failure rates from 3.5% to 23% have been reported.[15] This is usually the result of either the patient accidentally applying inappropriate forces to the bracket or poor bonding technique. Thus, it is important to understand what to expect when a tooth is rebonded one or more times, because the literature provides contradictory findings regarding the shear bond strength (SBS) of rebonded attachments.[16]

The bond strength of attachments must be sufficient to withstand functional forces but at a level to allow bracket debonding without causing damage to the enamel, which may occur when bond strength exceeds 14 MPa.[17] Various studies have suggested bond strengths ranging from 6 to 10 MPa as adequate in clinics.[18,19]

No reliable protocol for estimating the in vivo strength provided by orthodontic bonding systems has been described.[20] The bond strengths observed in an in vitro study may be higher than those witnessed clinically. However, in vitro studies provide a guide in selection of the bracket/adhesive.[17] The universal testing machine is capable of measuring pure shear forces; however, there are shear, tensile, and torsional forces present during in vivo debonding. In addition, the rate of loading for the machine is constant, whereas it is not standardized or constant in in vivo debonding.

The purpose of this in vitro study is to determine: (1) the effect of different resin-removal methods on SBS of rebonded brackets; (2) enamel surface alterations due to different resin-removal methods by scanning electron microscope (SEM); (3) time spent to remove resin remnants during different removal methods; and (4) mode of bond-failure interface by Adhesive Remnant Index (ARI) after the first and second debonding procedures.

MATERIALS AND METHODS Return to TOC

Eighty readily available caries-free and intact premolars were collected and stored in distilled water. The teeth were cleaned, polished with pumice and rubber prophylaxis cups for 10 seconds, and embedded in methylmethacrylate. Orthodontic metal brackets (Ormco Series 2000, Sybron Dental, Orange, Calif) were bonded to the teeth using Light Bond™ sealant and Quick Cure™ adhesives (Reliance Ortho Products Inc, Itasca, Ill), according to the manufacturer's directions (Table 1). The dimensions of the bracket were measured by a caliper compass and scanned. The scanned image was converted into a vectorial construction by an Autocad software program, and a three-dimensional solid model was achieved by the Pro-Engineer program. The average bracket surface area was determined as 9.63 mm.[2,21] All samples were stored in deionized water at 37°C for 24 hours and randomly assigned into five groups.

Fifty of the samples received the following treatments (Table 2):

- Group 1 (n = 10). The brackets were debonded by pliers (GAC International, Inc, Bohemia, NY). The remnant adhesive on the brackets was evaluated by ARI and removed by low-speed (Contra Angle: Bien Air INTRAmatic Calif 1132, Micromotor: Bien Air Aquilon 830 5.000–20.000 rpm, Switzerland) TCB 012 (Komet 0197 H21 R012, 8-bladed, Lemgo, Germany) with air cooling. The cleaned surfaces were polished with pumice and rubber prophylaxis cups, rebonded using the same adhesives, debonded by the universal test machine, and the SBS determined. The ARI scores were compared.

- Group 2 (n = 10). The brackets were treated as with group 1, except that the remaining resin was removed by high-speed TCB (012 Komet 314 H21R, 8-bladed) by air rotor (Bien Air Bora S36L up to 310.000 rpm, Switzerland) with air cooling.

- Group 3 (n = 10). The brackets were treated as with group 1, except that the remaining resin was removed by Sof-Lex finishing discs (coarse/fine/ultra fine) (black/blue/orange) (3M Dental, St Paul, Minn) with air cooling.

- Group 4 (n = 10). The brackets were treated as with group 1, except that the remaining resin was removed by a microetcher. The tooth surfaces were held approximately 5 mm from the tip of the microetcher and cleaned with 50 μm aluminum oxide particles under an enclosed ventilated hood.

- Group 5 (n = 10). Control group, where SBS at the first debonding was evaluated by the universal test machine (Lloyd, Fareham, Hampshire, UK).

A universal test machine was used for the shear bond test at a crosshead speed of 1 mm/min. Each tooth's facial surface was parallel to the direction of force during the shear strength testing. Force was applied to the bracket-tooth interface by a flattened steel rod. The load at the bracket failure was recorded by a PC connected to Lloyd test machine. The SBS values were calculated in megapascals by dividing the force by the area of the bracket base.

The brackets were examined with 16× magnification by an optical microscope (Leica MS5, Wetzlar, Germany). Any adhesive that remained on the bracket was assessed according to a modified ARI and scored.[22] The ARI scale has a range of 5 to 0 (5 = 100% of adhesive left on bracket; 4 = 100–75% adhesive left on bracket; 3 = 75–50% adhesive left on the bracket; 2 = 50–25% adhesive left on the bracket; 1 = less than 25% of adhesive left on the bracket; 0 = no adhesive left on the bracket). All the debonded bracket bases were cleaned with a microetcher (Danville Engineering Inc, Danville, Calif) before rebonding.

The removal of the composite was considered complete when the tooth surface seemed smooth and free of composite to the naked eye under the light of an operatory lamp.[23] The time to remove all the composite completely from the enamel surface was recorded in seconds.

Thirty of the samples were randomly divided into five groups (n = 6). The first four groups received the same resin-removal methods as mentioned above. The fifth group received no treatment, and the intact enamel surfaces acted as a control. These enamel surfaces were investigated by SEM (JSM-6400, Fukuoka, Japan) for alterations in the enamel surface after different cleaning and polishing methods. The remnant particles were characterized by energy dispersive spectrum (EDS, NORAN System Six, Dreieich, Germany).

Statistical analysis

The differences between the SBS data were evaluated by a one-way analysis of variance (ANOVA) and post hoc Duncan test. Time spent to remove resin remnants of all groups were evaluated by Welch's ANOVA and post hoc Tamhane test. The statistical difference between first and second ARI scores of each group was evaluated by Wilcoxon signed ranks test. The significance was determined at a probability value of $P < .05$ for all the tests.

RESULTS Return to TOC

Table 3 demonstrates that the rebond SBS of groups 1, 2, and 3 were significantly greater than the initial bond strength (group 5). Also, the rebond SBS of groups 3 and 4 were significantly different. The rebond SBS values of group 4 were statistically similar with the control group.

There were significant differences between time spent for resin removal among four experimental groups ($P < .001$) (Table 4). Maximum time required to clean the surfaces was found in the Sof-Lex method. The minimum time spent was found in the high-speed TCB method.

Groups 2, 3, and 4 had statistically higher ARI scores after the second debonding (Table 5).

Figures 1 through 5 show the SEM analysis of the intact enamel and the enamel surfaces after resin cleanup and polishing.

DISCUSSION Return to TOC

Assessment of the effectiveness or safety of rotary instruments is limited to inspecting the surface under SEM to reveal the topography and morphology of the enamel surface. In this study, SEM was used to give a better understanding of what happens to enamel with the different methods of resin removal tested. Nonetheless, SEM lacks a quantitative scale, cannot be used for the comparative assessment, and provides only subjective information.[4]

The earliest studies relating the effects of debonding on the enamel surface were conducted by Newman and Facq.[24] Brown and Way[25] suggested that there was less enamel loss in the clinic than in vitro because the destructive removal is more extensive in vitro.

In this study, the TCB was very efficient in residual resin cleanup. SEM photographs clearly demonstrate that the enamel scarring was inevitable with both low- and high-speed TCB (Figures 1 and 2). Using a TCB with high speed seems to be a very efficient way to clean the surface and the least time consuming (Table 4), but it was the most hazardous procedure to the enamel (Figure 2).

When TCB are used at high speed, they can cause damage to enamel because they are harder than the enamel.[6] Van Waes et al[23] and Zachrisson and Årtun[26] concluded that a TCB at low speed produced the finest scratch pattern with the least enamel loss of 7.4 μm. Retief and Denys[27] recommended the use of TCB at high speed with adequate air cooling, whereas Rouleau et al[6] and Campbell[2] suggested water spray instead of air cooling. In this study, air cooling was preferred to water cooling to assist in the observation of the resin remnants.

Remnant removal with Sof-Lex aluminum oxide finishing discs showed a progressive decrease in surface irregularities but was the most time-consuming method (Table 4) and left too much remnant on the enamel surface (Figure 3). The result was consistent with other authors.[27,28] Campbell found that discs and rubber wheels are effective, but these may be cumbersome for clinicians.[2]

Microetching results in an irreversible loss of enamel by removal of both organic and inorganic components of the enamel matrix.[29] SEM photographs showed different surface patterns at different magnifications. The enamel seemed smooth at 300×, but at 1500× magnification revealed deep pits (Figure 4), which may be the possible cause of the lower rebond strength found in this group (Table 3). This finding is consistent with reports of smooth surfaces after microetching at 500× magnification.[30]

Throughout the first debonding, the brackets of the experimental groups were debonded by pliers to mimic in vivo debonding conditions and to ensure that the surfaces and their SEM evaluations would represent clinically debonded surfaces. However, in the control group, the SBS for the initial debonding was measured using the universal test machine to compare the data obtained from the experimental groups for the second debonding.

One of the aims of the study was to evaluate the effect of resin-removal methods on the rebond strength. Investigators have compared initial and rebond strengths and reached different conclusions. Some authors reported that initial bond strengths were significantly greater than the rebond strengths,[31–33] whereas others found that there were no significant differences between them.[16,34,35] Egan et al[36] reported that initial bond strengths were equivalent to those of rebonding only once but were higher than three times rebonding. Several authors reported greater rebond strength that is consistent with this research.[17,37]

The increased rebond strength found in this study may be due to an increase in enamel roughness after resin removal and an increase in the mechanical retention of the debonded brackets cleaned by the microetcher.[38,39] The rebond strength of the microetcher group presented lower values, and the difference was statistically significant when compared with the Sof-Lex group presenting the highest rebond SBS values (Table 3).

The ARI scores showed that, excluding the first group, the second ARI scores were significantly greater (Table 5). This indicates that the bond between the bracket and adhesive was much stronger than the adhesive-enamel surface, leaving less adhesive on the tooth surface. The increase in ARI scores may also be attributed to the cleaning of the bracket base by microetching.

The overall findings of this study reveal that scarring of enamel after debonding procedures is inevitable but can be reduced by choosing the right protocol. TCB used at low speed may be the method of choice with acceptable enamel surface, reasonable application time, and rebond strength.

CONCLUSIONS Return to TOC

- The shear rebond strengths after resin cleaning with low-speed TCB, high-speed TCB, and Sof-Lex discs are higher than the initial bond strengths. Rebonding after resin removal by microetching presents shear bond strengths similar to the first bonding.
- Although resin removal with high-speed TCB was the quickest procedure, it represented the most hazardous enamel scars.
- Sof-Lex disc showed a decrease in surface irregularities, but it was the highest time-consuming method, and there were too many remnants on the enamel surface.

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TABLES Return to TOC

TABLE 1. Materials and Application Procedures

Materials	Components	Chemical Composition	Steps of Application	Lot Number Exp Date
Etching agent Reliance Ortho products	Gel	Orthophosphoric acid	Apply gel and leave for 30 sec without rubbing	308130
			Rinse thoroughly for 20 sec and air dry	11/06
Light Bond™ Reliance Ortho products	Liquid	Fluoride release, small particle, glass filled	Apply bond and light cure for 10 sec	402270 04/07
Quick Cure™ Reliance Ortho products	Paste	Highly filled	Apply the paste on the bracket, light cure for 5 sec from various directions	310230 04/07

TABLE 2. The Outline of the Treatment Procedures of all Groups[a]

	Application Steps	Group 1	Group 2	Group 3	Group 4	Group 5
First debonding	Debonding by pliers	●	●	●	●	
	Debonding by Universal Test Machine					●
Remnant adhesive evaluation	ARI Scoring	●	●	●	●	
Surface cleanup methods	Carbide bur at low speed (micromotor)	●				
	Carbide bur at high speed (aerotor)		●			
	Sof-Lex discs			●		
	Microetcher				●	
Surface evaluation	SEM	●	●	●	●	
Surface preparation	Pumice and rubber prophylactics cups	●	●	●	●	
Rebonding	Rebonding	●	●	●	●	
Second debonding	Universal Test Machine	●	●	●	●	
Remnant adhesive evaluation	ARI Scoring	●	●	●	●	

[a] ARI indicates Adhesive Remnant Index; SEM, Scanning electron microscope.

TABLE 3. Comparison of Mean Shear Bond Strength Values (MPa) Between the Control and the Experimental Groups With One-way Analysis of Variance and Post Hoc Duncan Test[a]

Groups	n	Mean	Std. Deviation	Minimum	Maximum
1: Low-speed TCB	10	31.2 [a,b]	6.31	22.79	40.51
2: High-speed TCB	10	30.4 [a,b]	6.97	14.31	38.11
3: Sof-Lex	10	34.9 [a]	7.85	26.13	48.34
4: Micro-etcher	10	27.3 [b,c]	2.44	23.18	30.85
5: Control	10	22.7 [c]	4.67	15.92	31.01

F = 5.839, p=0.001

[a, b, c]: groups identified with the same letter are not statistically significant (p>0.05)

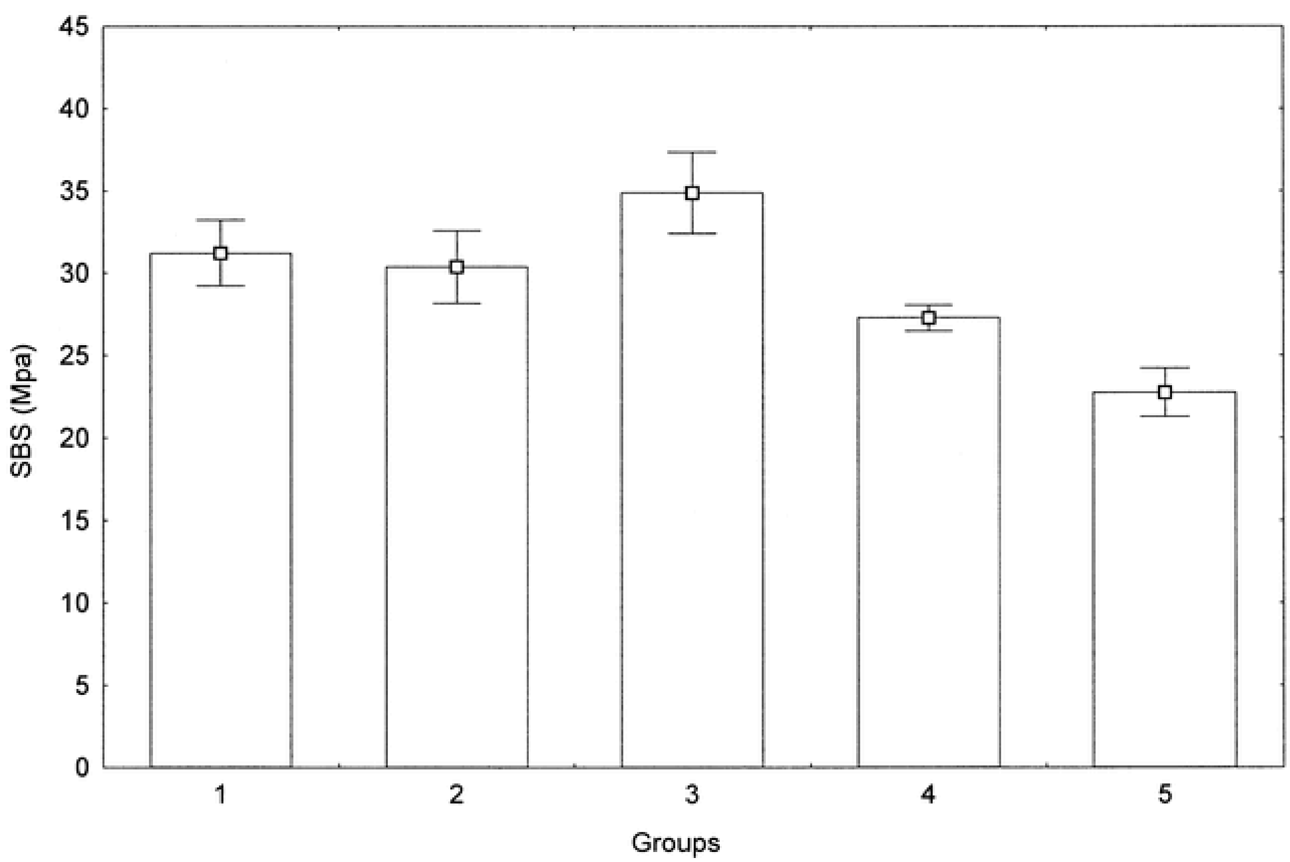


TABLE 4. Comparison of Time (seconds) Required to Remove Composite Resin From Debonded Tooth Surfaces With Welch's Analysis of Variance and Post Hoc Tamhane Test[a]

Groups	N	Mean	Std Deviation	Minimum	Maximum
1: Low-speed TCB	10	9.35 [a]	1.06	7.74	10.70
2: High-speed TCB	10	6.36 [b]	0.99	5.09	7.91
3: Sof-Lex	10	28.40 [c]	3.01	21.95	32.16
4: Microetcher	10	9.92 [a]	1.88	7.5	13.70

$F = 152.553$, $p<0.001$

[a, b, c]: groups identified with the same letter are not statistically significant.

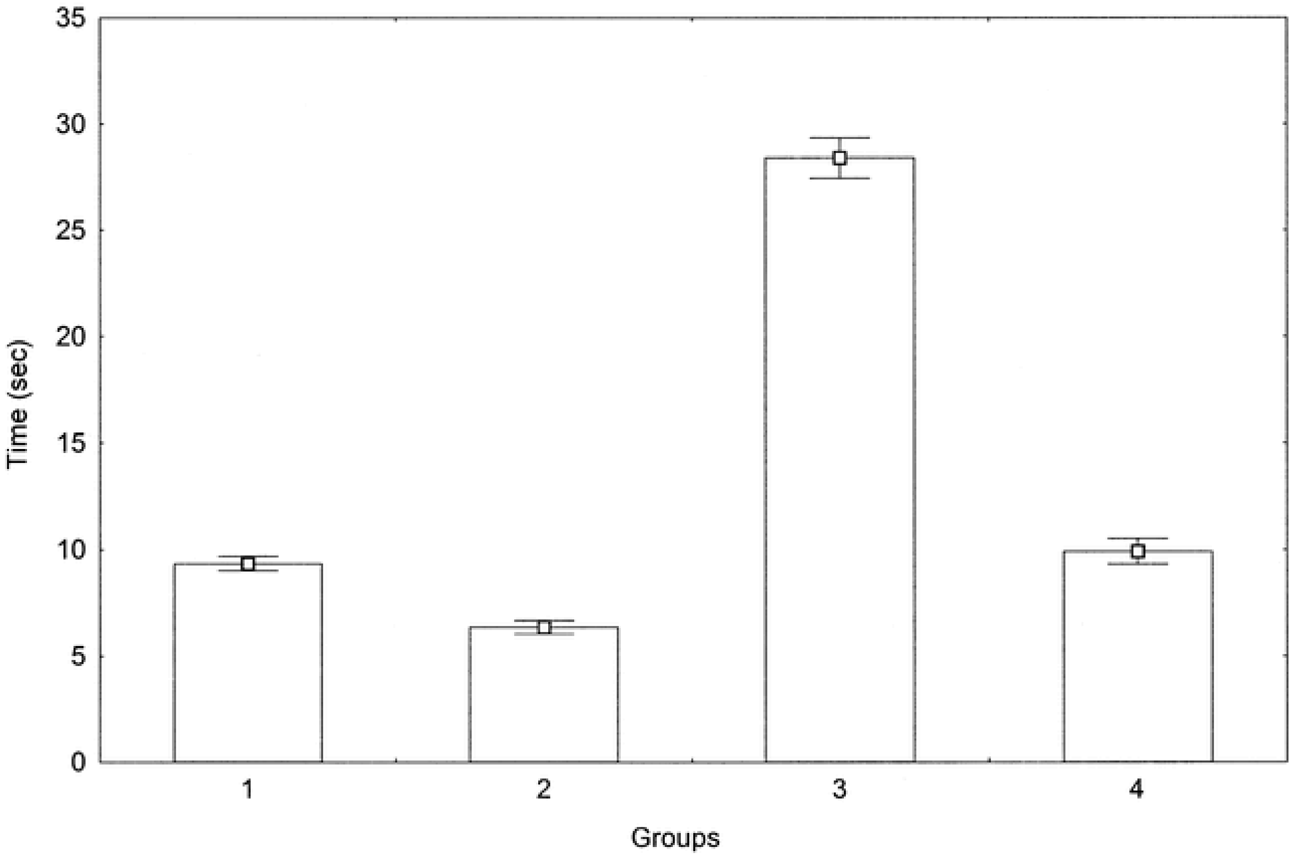
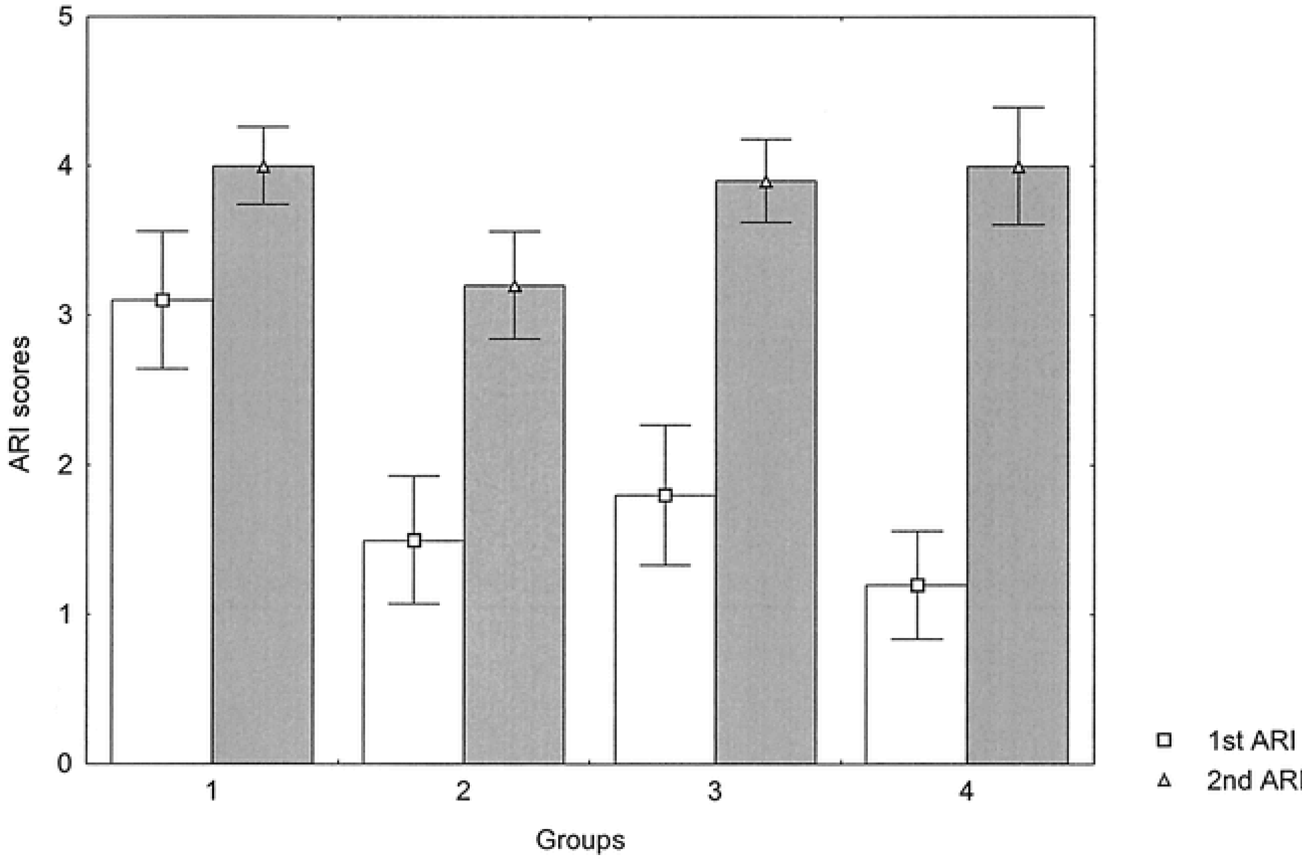


TABLE 5. Statistical Comparison of the First and Second ARI Scores of Four Experimental Groups With Wilcoxon Signed Ranks Test[a]

Groups	N	ARI Score: 1st Score ± Std. Deviation	ARI Score: 2nd Score ± Std. Deviation	Z	P
1: Low-speed TCB	10	3.1 ± 1.45	4.0 ± 0.82	1.59	0.111
2: High-speed TCB	10	1.5 ± 1.35	3.2 ± 1.14	2.55	0.011
3: Sof-Lex	10	1.8 ± 1.48	3.9 ± 0.88	2.54	0.011
4: Microetcher	10	1.2 ± 1.14	4.0 ± 1.25	2.60	0.009



FIGURES Return to TOC

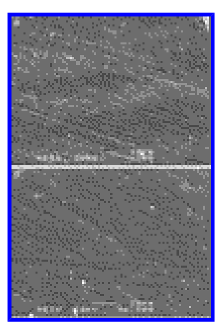


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FIGURE 1. (a, b) Representative SEM photographs of enamel surfaces of group 1 at 500× and 1500× magnifications. SEM indicates scanning electron microscope

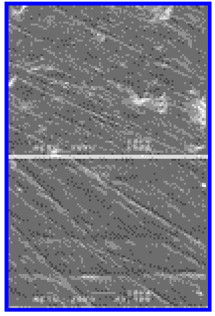

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FIGURE 2. (a, b) Representative SEM photographs of enamel surfaces of group 2 at 500× and 1500× magnifications. SEM indicates scanning electron microscope

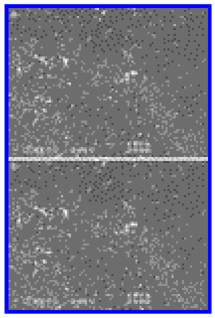

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FIGURE 3. (a, b) Representative SEM photographs of the enamel surfaces of group 3 at 500× and 1500× magnifications. The radiopacities are characterized by EDS as Silicone, magnesium, and aluminum. SEM indicates scanning electron microscope; EDS, energy dispersive spectrum

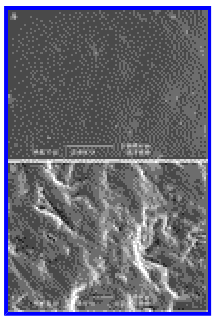

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FIGURE 4. (a, b) Representative SEM photographs of the enamel surfaces of group 4 at 300× and 1500× magnifications. SEM indicates scanning electron microscope

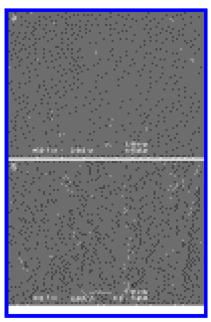

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FIGURE 5. (a, b) Representative SEM photographs of the intact enamel at 500× and 1500× magnifications. SEM indicates scanning electron microscope

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