Improving orthodontic bonding to silver amalgam

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In adult orthodontic patients, and occasionally in adolescents as well, amalgam restorations are present on the buccal surfaces of maxillary and mandibular molars. The ability to successfully bond orthodontic brackets and buccal tubes to more or less extensive amalgam restorations would therefore be of clinical value. The use of bonds rather than bands would contribute to improved gingival and periodontal health during fixed-appliance therapy.[1] This would be particularly important interdentally because periodontal breakdown tends to occur in these areas. Until recently, reliable bonding of orthodontic attachments to old amalgam fillings was considered inconceivable, and there are no published studies on orthodontic bonding to amalgam alloys.

However, as discussed in a recent overview by Zachrisson and Büyükyilmaz,[2] new technological advancements such as (1) intra-oral sandblasting to increase micromechanical retention; (2) the development of different types

Abstract

Flat rectangular tabs (n=84) prepared from lathe-cut amalgam (ANA 2000) were subjected to aluminum oxide sandblasting or roughening with a diamond bur. Mandibular incisor edgewise brackets were bonded to these tabs using: Concise (Bis-GMA resin); one of three metal-bonding adhesives, viz., Superbond C&B (4-META resin), Panavia Ex (10-MDP Bis-GMA resin) or Geristore (composite base); and Concise after application of the intermediate resins All-Bond 2 Primers A+B, or the Scotch-Bond Multi-Purpose (SBMP) system. All specimens were stored in water at 37° C for 24 hours before tensile bond strength testing. Alignment and uniform loading during testing were secured by engaging a hook in a circular ring soldered onto the bracket slot before bonding. Similar control brackets (n=12) were bonded with Concise to extracted caries-free mandibular incisors. Bond failure sites were classified by a modified ARI system.

Mean tensile bond strengths in the experimental group ranged from 3.4 to 6.4 MPa—significantly weaker than the control sample (13.2 MPa). Bond failure generally occurred at the amalgam/adhesive interface. Superbond C&B created the strongest bonds to amalgam; according to ANOVA and Duncan's Multiple-Range test, they were significantly stronger than the bonds with Panavia Ex and Concise, with Geristore in between. However, the bond strength of Concise to sandblasted amalgam was comparable to the Superbond C&B bonds when coupled with an intermediate application of All-Bond 2 Primers A+B. The SBMP, on the other hand, was less effective. Sandblasting was more effective in preparing the amalgam surface for bonding than roughening with a diamond bur, but the difference was not statistically significant. The clinical implications of these findings are discussed.

Key words

Adhesives • Amalgam • Bonding • Bond strength • Debonding

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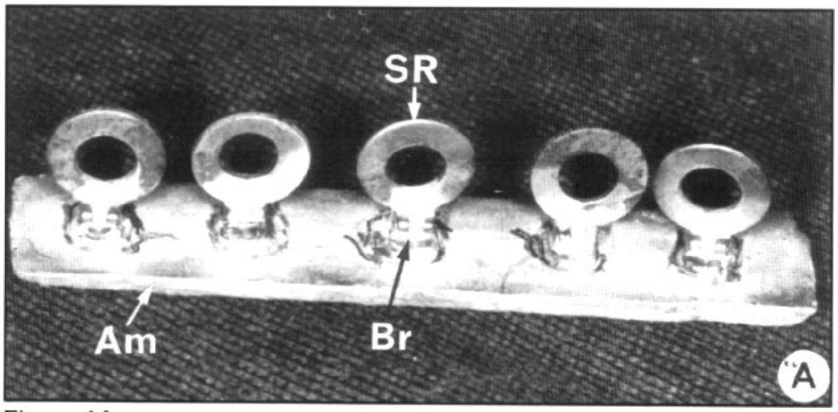

Figure 1A

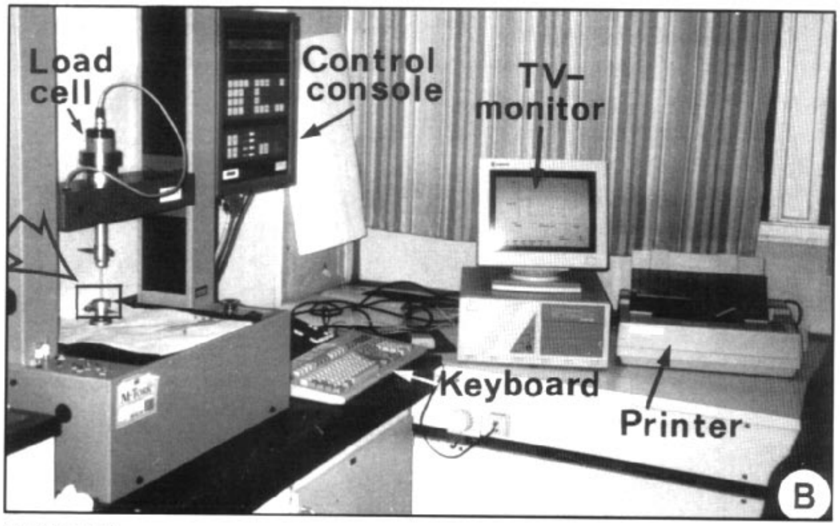

Figure 1B

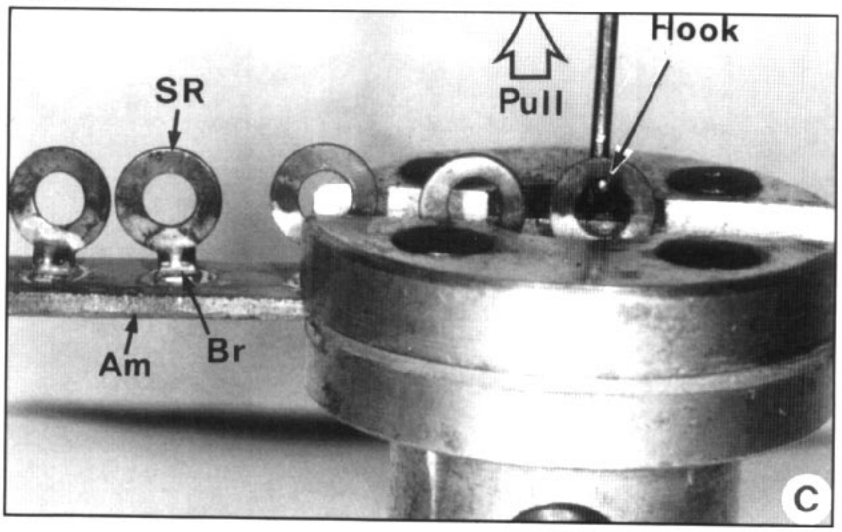

Figure 1C

Figure 1
Technique and equipment for tensile bond strength testing.
A: Amalgam tab (Am) with five bonded brackets (Br) each having a stainless steel ring (SR) soldered onto the bracket slot.
B: Overview of the Lloyd 1000R testing machinery.
C: Higher magnification of boxed area in B (open arrow) showing mounting system with amalgam tab inserted in slot of testing machine.

of metal-bonding adhesives; and (3) the introduction of intermediate resins which enhance bond strengths to various natural and artificial tooth surfaces, may help make orthodontic bonding to amalgam surfaces clinically successful. Therefore, the purpose of the present study was to compare the in vitro tensile bond strength of orthodontic brackets bonded to a silver amalgam subsequent to two different surface treatments (diamond bur vs. sandblasting), the use of two different intermediate resins (All-Bond 2 Primers A+B vs. Scotchbond Multi-Purpose), and the use of four different adhesives (Concise composite resin vs. three different metal-bonding adhesives: Superbond C&B, also marketed as C&B Metabond; Panavia Ex; and Geristore).

Material and methods

Flat, rectangular amalgam tabs of a standardized size of 45 x 10 x 1 mm (Figure 1A) were prepared by condensing silver amalgam alloy into recesses made in orthodontic plaster. The amalgam was allowed to harden for 24 hours. The amalgam tested was ANA 2000 (lot no. 045464, Nordiska Dental AB, Helsingborg, Sweden), a lathe-cut non-gamma 2 amalgam commonly used in Scandinavia. The tabs were polished with 600-grit silicone carbide paper (Struers A/S, Rodovre, Denmark), green rubber points (Dedeco green "midgets" no. 4572, Dedeco International Inc., Long Eddy, NY), and a polishing paste (Universal polishing paste, Ivoclar AG, Switzerland).

Surface treatment: The prepared amalgam specimens were rinsed ultrasonically in distilled water for 10 minutes and dried. Two kinds of surface treatment were used: (1) roughening with medium-grit diamond bur (Komet no. 068, Gebr. Brasseler GmbH & Co. Kb, Lemy, Germany) at 30,000 rpm, or (2) aluminum oxide sandblasting with 50-μ abrasive powder in a Microetcher erc (Danville Engineering, San Ramon, Calif) at approximately 7 kg/cm^2 of air pressure for 3 seconds from a distance of 10 mm. Selected specimens were prepared for scanning electron microscopy and examined in a Philips SEM 515, operated at 14.8 to 18.1 kV.

Bracket: The bracket type used was microarch mandibular incisor edgewise bracket (Microarch #72-612-00, GAC International Inc., Central Islip, NY) with a base area of 9.4 mm^2. Before the bonding procedure, a circular steel ring was soldered onto the bracket slot in order to control the type of stress and reduce the risk of introducing peripheral forces along the bond plane.[2,3] The brackets were bonded onto the tabs (Figure 1A) by the same operator (TB) according to routine procedures.[4]

Resins: As shown in Table I, a conventional orthodontic bonding adhesive (Concise, No 1994 A and B, 3M/Unitek, Monrovia, Calif) or one of three different popular types of metal-bonding adhesives[3,5]—namely a 4-META resin (Superbond C&B, Sun Medical Co. Ltd, Tokyo, Japan), a 10-MDP BisGMA resin (Panavia Ex, Cavex Holland BV, Haarlem, Holland) or a composite with fluoride-containing glass (Geristore, Den-Mat Corporation, Santa Maria, Calif)—was used according to the manufacturer's instructions or as described earlier.[4] Furthermore, two intermediate resins, All-Bond 2 Primers A and B (Bisco Dental Products, Itasca, Ill) and Scotchbond Multipurpose (SBMP, 3M Dental Products, St. Paul, Minn), which are claimed to enhance bond strengths to natural and artificial tooth surfaces were compared (Table I). With All-Bond 2, one drop each of Primers A and B were mixed and three coats were applied to the sandblasted amalgam surface. The primer layers were gently blown with oil-free, water-free air and allowed to dry for 10 seconds before the bonding procedure. Bonding resin was not used. With SBMP, the primer was applied to the sandblasted amalgam and gently dried before the adhesive was added, then gently thinned with air to smooth the layer and light-cured for 10 seconds. As shown in Table I, 12 brackets were bonded in each subgroup.

In all cases, the excess bonding adhesive outside the bracket base was left to allow totally undisturbed setting. Oxyguard air barrier gel (Cavex Holland BV, Haarlem, Holland) was applied to the specimens bonded with Panavia Ex. After polymerization, the Oxyguard was removed. To secure a uniform surface area during the bond strength testing, the excess adhesive was carefully removed with a small round TC bur (Komet no. H1 008, Gebr. Brasseler GmbH & Co Kb, Lemy, Germany). This procedure was executed in all 84 cases following the complete curing of the materials after 15 minutes at room temperature. The assemblies were then placed in water and stored at 37° C for 24 hours.

Bond strength testing: When removed from the water container, the amalgam tabs were securely mounted on a Lloyd 1000R testing machine (Lloyd Instruments Ltd, Fareham, Hants, England) as shown in Figure 1B-C. The tensile load was applied via a stainless steel hook (0.8 mm thick) engaging the circular ring of the bracket (Figure 1C). The cross-head speed was 1 mm/min. The force required to dislodge the bracket was recorded electronically on a graph and measured in Newtons. The force per unit area required for breakage was calculated and reported as the tensile bond strength in Megapascals (MPa).

Table I
Description of test design and number of samples

Adhesive	
Sandblasted, Superbond C&B	12
Sandblasted, Panavia Ex	12
Sandblasted, Geristore	12
Sandblasted, Concise	12
Intermediate Resins	
Diamond bur, All-Bond 2 Primers A+B, Concise	12
Sandblasted, All-Bond 2 Primers A+B, Concise	12
Sandblasted, Scotchbond MP, Concise	12

The bond failure site for each bracket was recorded and classified according to the modified Adhesive Remnant Index (ARI) of Årtun and Bergland.[6]

Twelve caries-free mandibular incisors, extracted for periodontal reasons, were used as a control sample. After storage in distilled water for 1 to 8 weeks, the control teeth were embedded in acrylic blocks and prepared for bracket placement.[2] Following conventional conditioning with 37% phosphoric acid for 60 seconds, brackets identical to those in the experimental groups were bonded to the enamel surface with Concise. After water storage at 37°C for 24 hours, tensile bond strength testing was carried out as above.

Statistical analysis: The significance of the differences between the means presented in Table II was estimated by analysis of variance (ANOVA) and by Duncan's Multiple-Range test at a 5% level of significance.[7]

Results

Surface treatment: The diamond bur-abraded amalgam surfaces (Figure 2) appeared rough on visual inspection; under higher magnification in the SEM, the periodic ridges and grooves had few undercuts (Figures 3B-C, 4B). The sandblasted amalgam surfaces (Figure 2) had a frosted appearance. In the scanning

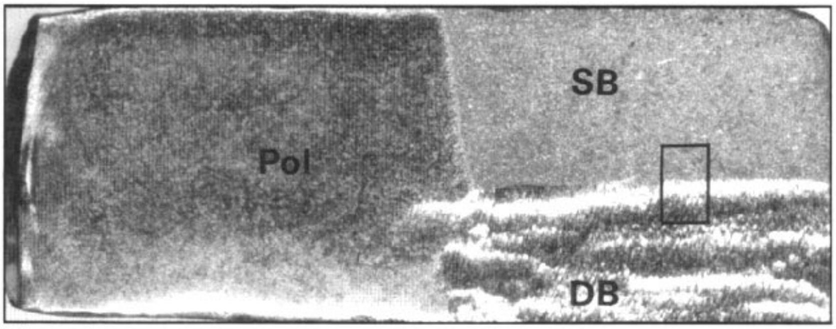

Figure 2

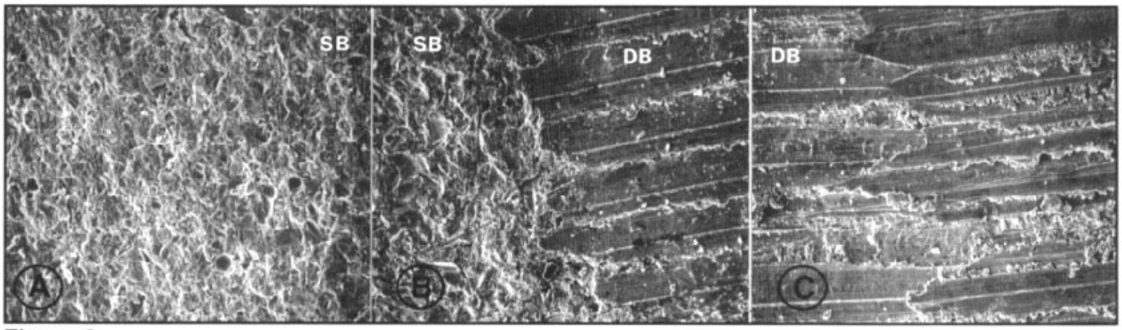

Figure 3

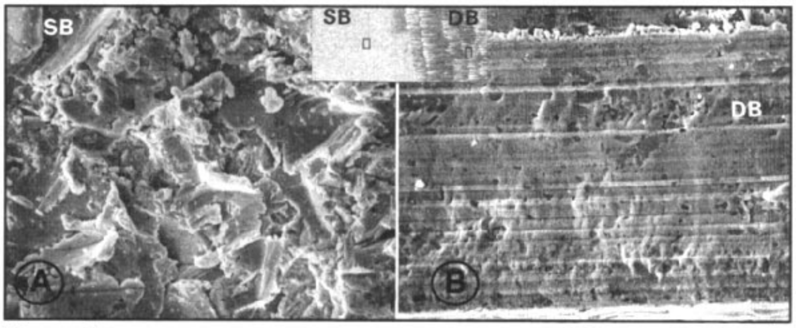

Figure 4

Figure 2
Polished (Pol) amalgam tab with right half sandblasted (SB) or roughened with diamond bur (DB).

Figure 3
Scanning electron microscopic appearance of boxed area in Figure 2 showing difference in micromechanical retention area between sandblasted (SB) and diamond bur (DB) roughened amalgam surface. Orig. magnification x 300.

Figure 4
Higher magnification of boxed area in Figure 2. A and B show difference in appearance between boxed areas in the insert of sandblasted (SB) and diamond bur (DB) roughened amalgam surface, respectively. Orig. magnification x 2000.

microscope, an irregular surface with multiple undercuts was observed (Figure 3A-B, 4A).

Bond strength measurements: Table II shows the mean tensile bond strengths and standard deviations for each testing combination. Tensile bond strengths in the experimental groups with the highest ratings ranged between 5.3 and 6.4 MPa. This was significantly weaker than the bonds created by Concise to etched enamel ($P<0.05$). The strongest bonds were achieved with Superbond C&B to sandblasted amalgam. The Superbond C&B bonds were significantly stronger than those obtained with Panavia Ex and Concise, whereas the difference to Geristore (6.4 vs. 5.5 MPa) was not statistically significant ($P> 0.05$).

The bond strength with Concise to sandblasted amalgam was significantly improved ($P<0.05$) with the intermediate application of All-Bond 2 Primers A+B. These bonds were not significantly different from those obtained with Superbond C&B and Geristore after sandblasting (Table II). On the other hand, the intermediate resin SBMP had no such reinforcing effect. When the amalgam alloy was sandblasted, it had a higher mean bond strength to Concise than when roughened with a diamond bur; however, the difference (6.3 vs. 5.3 MPa with All-Bond 2) was not statistically significant in this series ($P>0.05$).

Bond failure site: As a general rule, bond failure occurred at the amalgam/adhesive interface, with no adhesive left on the metal (Table III). However, in a few instances with Superbond C&B and Geristore, breaks occurred in the adhesive (Table III). There were no bond failures in the adhesive/bracket interface.

Discussion

The bond strengths recorded between the different resin combinations and the sandblasted amalgam specimens in this study were generally in agreement with those found in comparable studies by other investigators.[8-12] In all our cases, the experimental bonds were significantly weaker than the bond between Concise and etched enamel. In other studies,[8-14] Superbond C&B, Panavia Ex, and Geristore were found to have lower bond strengths to amalgam than to bovine or human enamel. In a recent study, however, Caughman et al. claimed that sandblasting with 60-µ aluminum oxide of spherical amalgam alloy provided tensile bond strengths to Panavia that were equivalent to that of Panavia to etched bovine enamel.[9]

As discussed elsewhere,[3] it is difficult to determine the mean in vitro tensile bond strength which is required for successful clinical bonding of orthodontic attachments to enamel. According to Reynolds,[15] values from 5 to 8 MPa would appear reasonable. The bond strengths to amalgam obtained with the best combinations in this study (Table II) might therefore be clinically adequate, but additional clinical testing is, of course, needed before definite conclusions can be drawn.

The present results must also be considered in light of the fact that three basic types of silver amalgam are used in restorative dentistry: lathe-cut (like the ANA 2000 of this study), admixed (mixture of lathe-cut and spherical amalgam, like Dispersalloy (LD Caulk, Dentsply, Milford, Del) and all-spherical amalgam (like Tytin, Kerr Manufacturing Co, Romulus, Mich). It is difficult, not to say impossible, for an orthodontist to differentiate between these types of amalgams in old restorations. It may be of interest to know, however, that higher bond strengths are usually experienced when bonding composite resin to a spherical amalgam alloy (such as Tytin) compared to the admixed or lathe-cut.[8-11]

The effects of thermocycling and long-term water storage on the resin-amalgam bond were not examined in this study. Some previous studies indicate that thermocycling may have no harmful influence on the tensile bond strength of Superbond C&B and Panavia Ex to sandblasted nonprecious crown and bridge alloys.[16,17] Most previous studies on bond strengths of composite resins to amalgams have used water storage at 37°C for 24 hours.[8-14] In future studies, thermocycling might provide interesting information on differences in coefficient of thermal expansion and temperature-dependent degradation of the bonds.

Somewhat surprisingly, the difference in bond strength to the diamond bur-roughened amalgam surfaces and the 50-µ aluminum oxide-sandblasted surfaces were not statistically significant when the intermediate resin All-Bond 2 Primers A+B was used (Table II). This is in contrast to our findings when bonding to

Table II
Tensile bond strengths of orthodontic brackets bonded to amalgam tabs after different surface treatments with various combinations of intermediate resins and bonding adhesives

Experimental sequence	Mean tensile strength MPa	SD
Sandblasted, Superbond C&B	6.4	1.5
Sandblasted, All-Bond 2 Primers A+B, Concise	6.3	1.8
Sandblasted, Geristore	5.5	1.8
Diamond bur, All-Bond 2 Primers A+B, Concise	5.3	1.7
Sandblasted, Concise	5.0	1.3
Sandblasted, Panavia Ex	4.5	1.5
Sandblasted, Scotchbond MP, Concise	3.4	0.6
Reference: Concise to etched enamel	13.2	4.4

Vertical lines connect mean values which do not differ significantly according to Duncan's Multiple-Range test.

Table III
Bond fracture sites according to a modified ARI scoring system[6] of 84 orthodontic brackets bonded to amalgam tabs after different surface treatments with various combinations of intermediate resins and bonding adhesives.

Experimental sequence	ARI score 0	1	2	3
Sandblasted, Superbond C&B	9	2	1	-
Sandblasted, All-Bond 2 Primers A+B, Concise	12	-	-	-
Sandblasted, Geristore	8	2	2	-
Diamond bur, All-Bond 2 Primers A+B, Concise	12	-	-	-
Sandblasted, Concise	12	-	-	-
Sandblasted, Panavia Ex	12	-	-	-
Sandblasted, Scotchbond MP, Concise	12	-	-	-

0 = no adhesive left on amalgam surface
1 = less than half left
2 = more than half left
3 = all the adhesive left on amalgam surface with distinct impression of bracket mesh

gold alloy.[2] Caughman et al.[9] recently found indications of higher mean bond strengths with 60-μ aluminum oxide sandblasting than when 50-μ abrasive powder from another company was used, although the differences were not statistically significant. Studies are under way in our laboratory to compare the effect of sandblasting using the Microetcher with 50-μ and 90-μ abrasive powders on different amalgam types (lathe-cut, admixed and all-spherical).

The strongest bonds to sandblasted amalgam in this study were achieved with Superbond C&B, a 4-META/MMA-TBB resin,[2,3] which is in accordance with recent findings by others.[11] The liner version of Superbond C&B is manufactured in Japan and termed Superbond-D liner, which in the U.S. is marketed as Amalgambond (or Amalgambond Plus when the HPA powder is added to the kit). Indeed, Amalgambond and other metal-bonding resins like All-Bond 2 and Panavia Ex and 21 are increasingly being used in restorative dentistry for bonding amalgam and composite to dentin, to enamel, and to previously placed amalgam restorations.[10,18-20] This probably prevents microleakage and microgaps, reduces hypersensitivity, provides stronger amalgam-to-amalgam bonds, and reduces the need for mechanical retention. Being a cement with good long-term durability and not a liner, Superbond C&B is probably better suited than Amalgambond for bonding orthodontic attachments to amalgam restorations. A clinical drawback of Superbond C&B is its curing time of 10 minutes or more. The more practical orthodontic versions, Orthomite Superbond and MCP Bond, are not yet available in Europe or the United States.

In orthodontic practice, the bond strength to pure amalgam is probably not decidedly critical in most instances. There is usually a considerable amount of sound enamel surrounding a buccal amalgam filling. For most routine situations, therefore, a conventional bonding adhesive like Concise appears to provide reliable bonds to sandblasted amalgam and neighboring acid-etched enamel. This is in agreement with our clinical experience.[2] In those circumstances when the restoration is more extensive, the intermediate application of All-Bond 2 Primers A+B should help reinforce the Concise bond to the sandblasted amalgam. This bond strength will be equivalent to that of Superbond C&B and Geristore (Table II), either of which may also be useful.

Conclusions

In conclusion, the results of the present in vitro study indicated that:

1. The mean tensile bond strengths to sandblasted amalgam in this study ranged from 3.4 to 6.4 MPa, which was significantly lower than the bond strength of Concise to etched enamel. With few exceptions, the bond failures occurred at the amalgam/adhesive interface, regardless of resin combination used.
2. The strongest bonds to sandblasted amalgam were obtained with Superbond C&B. This bond strength was significantly higher than that of Panavia Ex and Concise, with Geristore in an intermediate position.
3. The bond strength of Concise to amalgam was significantly improved with the intermediate application of All-Bond 2 Primers A + B. This combination produced bonds to sandblasted amalgam which were comparable to those of Superbond C&B.
4. The All-Bond 2 primers significantly improved the Concise bonds to amalgam compared to the Scotchbond Multi-Purpose system.
5. Sandblasting the amalgam surface prior to bonding produced higher mean bond strengths with Concise than roughening with a diamond bur, but the difference was not statistically significant.

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