Improving bonding of acrylic teeth to self-polymerizing denture base resins

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تشير الدلائل المتوفرة إلى ضعف قوة التماسك ما بين الأسنان الاكريلية وقاعدة الاكريل الذاتية التصلب بالرغم من أن هذه المواد لا تزال تستخدم بشكل واسع في عيادات ومختبرات طب الأسنان.

تختبر الدراسة الحالية أثر بعض الطرق المستخدمة في معالجة سطوح الأسنان التي تلتصق بقاعدة الاكريل ذاتي التصلب على قوة التماسك والالتصاق بينها . أجريت جميع الفحوصات المخبرية حسب مواصفات ADA رقم 15 واستخدام النظام الإحصائي ANOVA لتحليل المعلومات وكذلك فحص Scheffe Stest لقد تم معالجة سطوح الاسنان كما يلي:- أولاً : بواسطة التخريش الدقيق لسطح السن ، ثانياً: بواسطة تغطية سطح السن بمواد لاصقة هي (الكلوريد الثنائي الميثيل المخلوط مع سائل الاكريل المتعدد البلمرة)، ثالثا : جمع الطريقتين الأولى والثانية مع بعضهما وذلك لتقييم قوة الالتصاق والتماسك ما بين سطح السن وقاعدة الاكريل الذاتي التصلب . فقد أبدت طريقة المعالجة بواسطة التخريش الدقيق لسطح السن قوة التصاق عالية مع قاعدة الاكريل ، في حين لم تظهر طريقة معالجة سطح السن بتغطيته بمواد لاصقة أية فاعلية في تحسين قوة الالتصاق والتماسك ما بين سطح السن والقاعدة الاكريلية . وباستخدام الطريقتين الأولى والثانية معاً فقد تحسنت قوة الالتصاق ولكن ذلك لا يعود إلى المادة اللاصقة المستخدمة بل يعود بشكل عام إلى خشونة سطح السن الاكريلي.

This investigation evaluated the effect of different surface treatment of the tooth ridge lap surface on the strength of the tooth/denture base interfacial bonding. The surface treatment regimens investigated were: microblasting, coating with a solvent-based adhesive and a combined microblasting and adhesive coating of the ridge lap surface. All tests were conducted according to the ADA specification No. 15. The data were analyzed statistically using the one-way analysis of variance (ANOVA) and Scheffe *S* test. A value of $p < 0.01$ was considered significant. Roughening the tooth ridge lap surface by microblasting resulted in significantly stronger bonding to denture base than untreated ridge lap surface ($p = 0.001$). Adhesive-coating the ridge lap surface did not promote bonding significantly compared with the untreated tooth surface ($p = 0.500$). The combination treatment did improve bonding ($p = 0.007$) but was significantly less compared with roughening the ridge lap only. Of the three evaluated surface treatment regimens, microblasting the tooth ridge lap surface seemed to have a major and significant contribution to establishing a satisfactory interfacial bonding.

Introduction

Tooth bond strength of most self-curing acrylic denture base polymers are below the desirable limit (31.0 MPa) required as standard value by the ADA specification No. 15.[1] Previous investigators suggested various techniques to overcome the problem of poor bonding of denture teeth to autopolymerizing resins. Among these techniques were mechanical roughening of the tooth ridge lap surface,[2] exposing the tooth surface to solvents and combining the effect of solvent attack and modifying the polymerization of the acrylic denture base,[2-7] preparing vertical retention grooves in the ridge lap surface of the teeth,[8] grinding horizontal retention grooves in the tooth ridge lap,[9] modifying the ridge lap face with diatoric, monomer coating and/or removal of the glaze.[10]

These methods have been claimed to strengthen tooth-denture base adhesion and facilitate chemical bonding. Reported findings,[2-11] however, differed in emphasis, probably because of the differences in the experimental design[12] and the variations of the test environments.[11-14]

The present investigation attempted to evaluate the effect of some surface treatment methods of the tooth ridge lap surface on its bond strength to self-polymerizing denture base resin. The surface treatment techniques evaluated were: (a) surface roughening, (b) adhesive coating, and (c) combination treatment of roughening and adhesive coating.

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Materials and Methods

The autopolymerizing acrylic denture base resin used was Paladur, with batch Nos. of 32 for the powder and 012290 for the liquid*. This material was used in constructing all of the test specimens. The acrylic teeth used in this investigation were large size molars+. The teeth were manufactured and supplied loose not mounted in sets on cards in order to avoid wax contamination of the ridge lap surfaces.

The bonding test tensile bars were constructed in a two-step procedure. In the first step, the provided large size maxillary acrylic teeth were machined into 9.0 mm cyliders using a milling machine. A dental gypsum mold was prepared by

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+Star Acrylite Industries, Inc., Amman, Jordan

investing stainless steel cylinders 50 mm long and 9.0 mm diameter. The prepared teeth were positioned in the mold so that the ridge lap surface of the tooth butted against one end of the mold. The autopolymerizing acrylic resin was prepared according to the manufacturer's instructions and allowed to reach a dough stage. It was then placed in the molds and trial packed. The flasks were placed in a curing clamp and the entire assembly was placed in a pressure pot under 30 lbs psi for 20 minutes.

After deflasking the stage 1 tooth-resin specimens (Fig. 1) were carefully trimmed of flash. They were divided into four groups of 12 specimens each. In group No. 1, the tooth ridge lap surface was untreated but left as processed to serve as a control group. The tooth ridge lap surface of the other specimens received three types of surface treatment. In group 2, the teeth had their ridge lap surfaces coated with a solvent-based adhesive (dimethylene chloride in a polymer/ monomer mixture). In group No. 3, the teeth ridge lap surfaces received a combination treatment of roughening (microblasting with 50 µm AL_2O_3 for 30 seconds) and coating with adhesive. In group No. 4, the ridge lap surfaces were roughened by microblasting only. A second set of stone molds was made in the same manner using 100 mm stainless steel cylinders of 9.0 mm diameter. The previously made (stage 1) tooth-resin specimens were placed in the molds with the tooth ridge lap surface in the centre of the mold. Autopolymerizing acrylic resin was prepared according to the manufacturer's directions and placed in the mold against the tooth ridge lap surface of the specimens. The acrylic resin was packed and cured in the same way as that described for stage 1. All of the bonding test tensile bars were carefully removed from the stone and trimmed of flash (Fig. 2). The specimens were milled to a uniform diameter of 8.0 mm. A section of each specimen extending 13.0 mm medially from a point 1.5 mm lateral to the tooth-bond interface was further milled into 6.0 mm ± 0.25 mm to isolate the tooth-bond interface (Fig. 3). All of the specimens were coded and stored in air until tested mechanically by a single operator who was unaware of the type of surface treatment given to different groups of specimens. A fifth set of 12 specimens was prepared entirely from the self-polymerizing acrylic resin of the same batch used for preparing the bond test tensile bars. The tensile bars of this set were prepared as cylinders by compression molding using the same dental stone molds employed in (stage 2) tooth-resin specimens. The prepared (100 mm X 9.0 mm) cylinders were milled into exact shape and dimensions as the previously prepared tensile bars (Fig. 3) except that they did not have a tooth in the middle segment. A sixth set of 12 specimens identical to the self-polymerizing acrylic tensile bars were constructed by the same manufacturer who supplied the teeth. The tensile bars of this group were manufactured using the same material batch that was used for making the teeth. The tensile test specimens of the last two groups, i.e., the self-polymerizing acrylic resin bars and the acrylic tooth material bars were included in this invetigation in order to compare the tensile strength of these materials and the tensile bond strength between them.

Fig. 1. Tooth ended half tensile bar prior to bonding to the secound half

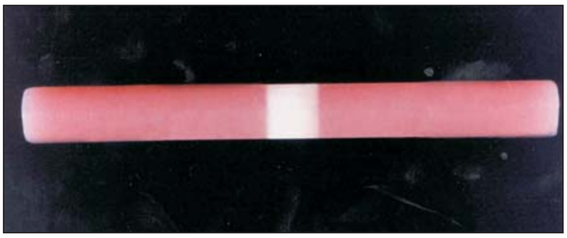

Fig. 2. A tensile test bar with a prepared tooth in its middle segment.

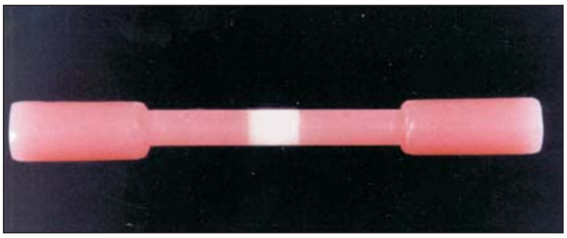

Fig. 3. The bonding test tensile bar milled to the required dumbbell shape.

All specimens of all the groups were tested in tension on the MTS 810 testing machine++ . The machine was fiited with a 10 KN load cell (model 251-111). The load cell was calibrated by the usuall weight-hanging method. The testing machine was driven at the cross-head speed of 0.25 mm/min as recommended by the ADA specification No.15[1]

++MTS systems, MN, USA

until catastrophic failure of the specimen occurred. Specimens that did not fail along the tooth ridge lap-denture base interface, i.e, breaking through the denture base resin or along the tooth occlusal surface-denture base interface were not counted.[1] Whenever this happened, the failed specimens were replaced by new ones of the same design and dimensions. The value of bond strength reported for each group was the average of 12 specimens rounded off to the nearest 0.1 MPa.

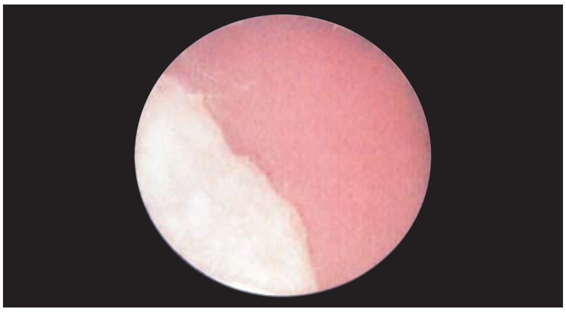

Fig. 4. Bond fracture surface showing a mixed adhesive / cohesive failure (magnification X 90).

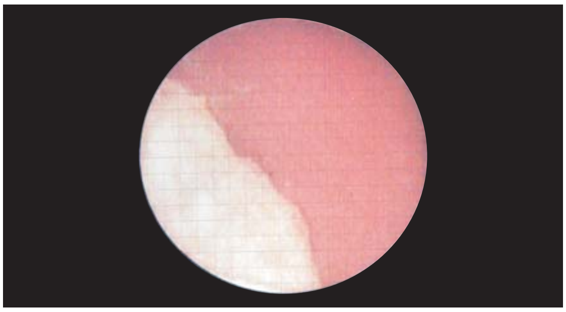

Fig. 5. Bond fracture surface showing an approximately 32% adhesive failure measured by using a measuring grid (magnification X 90).

After rupture, the fractured tooth-denture base interface was examined microscopically with a reflected light microscope. The locus of failure for each specimen was determined and accordingly, the specimens were classified into those failing interfacially, i.e., exhibiting adhesive failure through the interface and those specimens showing a mixed adhesive/cohesive failure (Fig. 4). In the latter case, the surface area of the adhesive failure portion of the specimens cross section was measured using a measuring grid fitted into the microscope lense (Fig. 5) and the result was expressed as a percentage surface area of adhesive failre of the specimen. When mixed failure was demonstrated by a number of specimens the calculated percentages of adhesive failure of all specimens were totalled and the grand total was divided by the number of specimens to give the locus of bond failure for the group.

Statistical Analysis

Means (n = 12) and standard deviation values of the tensile bond strength for the different groups representing different surface treatment of the tooth ridge lap were calculated (Table 1). One-way analysis of variance (ANOVA) test was employed to compare the means of various surface treatment groups. In addition, the Scheffe *S* statistical test was also employed to compute the limits of the confidence interval (I) for each difference between means. A value of $p < 0.01$ was cosidered significant.

Table 1. Tensile bond strength to self-curing denture base resin of acrylic teeth having their ridge laps treated prior to bonding.

Type of tooth ridge lap treatment	**Tensile bond strength (MPa) mean ± (s.d.) (n = 12)**	**Locus of failure**
Untreated ridge lap (group 1) control	27.1 ± (8.5)[a]	78% adhesive
Adhesive coated ridge lap (group 2)	27.6 ± (3.7)[a]	73% adhesive
roughened and adhesive coated ridge lap (group 3)	33.2 ± (5.4)[b]	66% adhesive
Microblasted ridge lap (group 4)	35.4 ± (4.9)[c]	60% dhesive
Self-polymerizing acrylic tensile bar	57.7 ± (8.4)	-
Acrylic tooth material tensile bar	45.3 ± (6.9)	-

b vs a p = 0.007
c vs a or vs b p = 0.001

Results

Mean tensile bond strength values and standard deviations of the means (n = 12) for all the investigated groups are presented in Table 1. The locus of bond failure for each group is presented as percentage surface area of the adhesive failure.

The bond strength values attained by the control (group 1) of 27.1 MPa is about 12.6% less than the standard value of 31.0 MPa required by the ADA specification No. 15[1] for bond strength of acrylic teeth to denture base polymers. The adhesive coated ridge lap specimens (group 2) exhibited bond strength values that were only about 2.0% higher than the control group. This slight increase in bond strength was statistically insignificant (p = 0.500) and the attained bond strength of 27.6 MPa by this group was still below the optimum bond strength of 31.0 MPa.[1] Tensile bond strength results shown by the specimens that received combined treatment of roughening and adhesive coating (group 3) of 33.2 MPa were significantly stronger than the control group (p = 0.007). Group 3 specimens were also significantly stronger than their counterparts in group 2 that received adhesive coating treatment of the tooth ridge lap surface (p = 0.008). The mean bond strength value exhibited by group 3 specimens was about 6.6% higher than the standard value of 31.0 MPa required by the ADA specification No. 15.[1] The mean bond strength value of 35.4 MPa demonstrated by group 4 specimens that received roughening of the tooth ridge lap surface was the highest bond strength value compared with all of the other groups. It was significantly stronger than the controls (p = 0.001) and higher in strength than the adhesive coated group (p = 0.001) and also significantly stronger than group 3 specimens that were treated by a combination of roughening and adhesive coating (p = 0.009). The mean bond strength value exhibited by the roughened group 4 specimens was about 12.4% higher than the acceptable bond strength limit of 31.0 MPa suggested by the ADA specification No. 15.

Discussion

The present investigation showed that surface treatment of the ridge lap of denture tooth can result in significant differences in bond strength of the tooth to self-polymerizing denture base resin.

Comparing the present results to other investigators poses difficulties, because of differences in method used. Cunningham[11] stated that "the lack of uniformity in experimental techniques and the diverse range of products assessed makes recommendations for laboratory practice difficult to formulate."

Although a universal testing method needs to be formulated to replace the various techniques now employed, yet some comparisons show interesting similarities as well as disagreements.

The results of this study indicated that tooth bond strength to self-polymerizing resin was not significantly higher when the ridge lap was painted with adhesive compared to bond strength of the controls. Spratley[9] and Civjan *et al.*[2] also found that pretreatment of the teeth with methylmethacrylate, as a solvent, did not increase bond strength. Morrow *et al.*[15] reported that painting ridge laps of acrylic teeth with monomer/polymer solution resulted in about 50% reduction in bond strength. The value of bond strength for the adhesive coated specimens reported by these investigators (29.6 MPa) was comparable with the bond strength value of 27.6 MPa shown in this study by identical specimens. These values (in both studies) were less than the acceptable bond strength value of 31.0 MPa as suggested by the ADA specification No. 15.[1] Huggett *et al.*[17] and Ritchie *et al.*[5] reported a marked reduction in bond strength caused by adhesive treatment of ridge lap surface of acrylic teeth. The results arrived at in this study for the effect of adhesive on bond strength did not confirm earlier findings of Rupp *et al.*[6] and Cunningham[12,13] who reported that cementing of the tooth surface with resin cement significantly improved denture-tooth bond strength.

This study showed that roughening the tooth ridge lap surface caused significant increase in bond strength to self-curing resin. The recorded bond strength for the roughened tooth-denture base specimens was higher than the optimim bond strength required by the ADA specification No. 15.[1] This may be ascribed to the fact that surface roughening has increased the surface area available for bonding where some mechanical interlocking might have occurred across the interface.[3] It also seemed likely that the increased magnitude of bond strength could have been derived from an enhanced surface reactivity as a result of the removal of a saturated surface layer by grinding and the exposure of the subsurface layer of a higher free surface energy available for bonding.[3] Ritchie *et al.*[5] reported a 26% increase in tensile bond strength as a result of roughening the tooth ridge lap prior to bonding to a self polymerizing denture base resin. This is comparable to the results of the present investigation that showed a 30.6% increase in the tensile strength of the tooth-denture base bond achieved by microblasted tooth ridge laps. Civjan *et al.*[2] reported improvement in tensile bond strength by approximately 135% attained by roughened tooth ridge laps. Cardash *et al.*[8] found that cutting vertical grooves in the ridge lap increased bond resistance to shear stresses by 44%. Barpal *et al.*[10] reported a 62% increase in bond resistance to shear loading when the ridge lap had a diatoric. Fletcher *et al.*[3] found that ground ridge laps increased bond strength by 47% when tested in tension and that bond strength increased by more than 100% when shear loads were applied to the tooth-denture base interface. Vallittu[16] reported that retention grooves cut on the ridge lap increased bond resistance to three-point loading by 67%.

A clear trend which emerged from these

studies,[2,3,5,8,10,16] with varied experimental designs is the fact that a mechanically roughened tooth ridge lap did enhance tooth-denture base bond strength. The results of the present investigation were consistent with the findings of those studies. In contrast to these findings, Cunningham *et al.*[13] stated that "tooth surface modification by grinding or grooving made no significant difference when compared with unmodified surfaces." Spratley,[9] in an earlier study, reported a 40% reduction in bond strength caused by roughening tooth ridge lap. He suggested that "a rough surface may trap wax residue resulting in a decreased bond strength. The results of this study neither confirmed Cunningham *et al.*[13] findings nor support Spratley's[9] results.

Our findings demonstrate that a combination treatment of the ridge lap surface by microblasting and adhesive coating significantly enhanced tensile bond strength. However, the major contribution to the enhancement of bond strength was due to microblasing the rige lap surface rather than to the adhesive coating treatment.

Conclusions

This investigation tested the tensile bond strength of a self-polymerizing acrylic resin to acrylic denture teeth that had their ridge lap surfaces, roughened, adhesive-coated, and both roughened and coated with adhesive.

The conclusions were as follows:

1. The strongest bonding occurred between the self-polymerizing resin and roughened tooth ridge laps.
2. The combined treatment of roughening and adhesive coating the ridge lap achieved an intermediate bond strength.
3. Coating the tooth ridge lap with solvent-based adhesive did not show significant improvement in bond strength.
4. In the light of these findings, it is recommended that ridge lap surfaces of acrylic denture teeth may be roughened by microblasting prior to processing.

References

1. American Dental Association. Revision of the ANSI/ADA specification No. 15 for synthetic resin teeth. Chicago: Am Dent Assoc 1998: 1-11.
2. Civjan S Huget EF, de Simon LB. Modifications of the fluid resin technique. J Am Dent Assoc 1972; 85: 109-112.
3. Fletcher AM Al-Mulla MA Amin WM Dodd AW, Ritchie GM. A method of improving the bonding between artificial teeth and PMMA. J Dent 1985; 13: 102-108.
4. Ritchie GM Fletcher AM Amin WM, Dodd AW. Tooth bond characteristics of some acrylic denture base polymers. Proc Eur Prosthodont Assoc 1983; 6: 32-34.
5. Ritchie GM Fletcher AM Amin WM, Dodd AW. The effect of water and saliva on the bond strength of PMMA to differing interface contours of acrylic teeth. Proc Eur Prosthodont Assoc 1986; 9: 73-75.
6. Rupp NW Bowen RL, Paffenbarger GC. Bonding cold-curing denture base acrylic resin to acrylic resin teeth. J Am Dent Assoc 1971; 83: 601-606.
7. Ritchie GM Fletcher AM Amin WM Al-Mulla M, Dodd AW. Further mechanical tests on the bond between poly (methyl methacrylate) teeth and some acrylic denture base polymers. Proc Eur Prosthodont Assoc 1984; 7: 107-110.
8. Cardash HS Applebaum B Baharav H, Liberman R. Effect of retention grooves on tooth-denture base bond. J Prosthet Dent 1990; 55: 526-528.
9. Spratley MH. An investigation of the adhesion of acrylic resin teeth to dentures. J Prosthet Dent 1987; 58: 389-392.
10. Barpal D Curtis DA Finzen F Perry J, Gansky SA. Failure load of acrylic resin denture teeth bonded to high impact acrylic resins. J Prosthet Dent 1998; 80: 666-671.
11. Cunningham JL. Bond strength of denture teeth to acrylic bases. J Dent 1993; 21: 274-280.
12. Cunningham JL. Shear bond strength to heat-cured and light-cured denture base resin. J Oral Rehabil 2000; 27: 312-316.
13. Cunningham JL, Benington IC. An investigation of the variables which may affect the bond between plastic teeth and denture base resin. J Dent 1999; 27: 129-135.
14. Cardash HS, Liberman R, Helft M. Effect of retention grooves in acrylic resin teeth on tooth-denture base bond. J Prosthet Dent 1986; 55: 526-528.
15. Morrow RM, Matvias FM, Windeler AS, Fuchs RJ. Bonding of plastic teeth to two heat-curing denture base resins. J Prosthet Dent 1978; 39: 565-568.
16. Vallittu PK. Bonding of resin teeth to the polymethyl methacrylate denture base material. Acta Odontol Scand 1995; 53: 99-104.
17. Huggett R, John G, Jagger RG, Bates JF. Strength of the acrylic denture base tooth bond. Br Dent J 1982; 153: 187-190.

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