

Bond strength of acrylic teeth to heat cure acrylic resin and thermoplastic denture base materials

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ABSTRACT

Background: tooth debonding was one of the major reasons for denture repair. With the use of recently introduced thermoplastic denture base materials the problem of tooth debonding increased due to the nature of the bond between these materials and the acrylic teeth. This study was aimed to assess the bond of the acrylic teeth to conventional heat cure acrylic resin and to thermoplastic resin denture base material and methods to enhance it.

Materials and methods: acrylic resin teeth were bonded to heat cure acrylic resin with and without wetting the ridge laps of the teeth with monomer and acrylic teeth with prefabricated retentive holes, unmodified and modified, in their ridge laps were processed with Valplast thermoplastic resin denture base material. The samples were subjected to tensile forces till failure.

Results: In general the chemical bond strength of acrylic teeth and heat cure acrylic resin was greater than the mechanical bond strength of the teeth with the Valplast thermoplastic denture base material. Wetting the acrylic resin teeth with monomer enhanced the bond strength with heat cure acrylic resin by 88%. Modifying the prefabricated retentive means of the acrylic resin teeth enhanced the bond strength with the Valplast thermoplastic resin denture base material by 58%

Conclusion: wetting the ridge laps of the teeth can increase the bond strength of acrylic teeth and the conventional heat cure resin. A partial solution for the debonding of teeth from Valplast thermoplastic resin dentures is by modifying the prefabricated retentive means for the acrylic teeth to increase the bond strength.

Key words: Acrylic, teeth, bond, thermoplastic, Valplast

الخلاصة:

نبذة عن الدراسة: ان انفصال الاسنان عن مادة الطقم تعتبر من المشاكل الرئيسية لإعادة تصليح الطقم . ومع استعمال المواد الحديثة لصناعة الاسنان وخاصة المواد البلاستيكية المعالجة حرارياً بدأت تتزايد مشكلة انفصال الاسنان عن مادة الطقم بسبب طبيعة ترابط الاسنان المصنوعة من مادة الأكريليك بمادة الطقم المصنوع من مادة البلاستيك المعالج حرارياً. هذه الدراسة تهدف الى معرفة وتقدير نسبة الترابط بين الاسنان المصنوعة من مادة الأكريليك وبين مادة الطقم الأكريليك الحراري من جهة وبين مادة الطقم البلاستيك المعالجة حرارياً من جهة اخرى وايجاد الطرق لزيادة وتحسين الترابط بينهم.

المواد المستعملة وطريقة العمل: اسنان مصنوعة من مادة الاكريليك ترتبط بمادة الطقم الأكريليك الحراري بوجود او بدون ترطيب لقاعدة السن بالمادة السائلة للأكريليك الحراري. والاسنان المصنوعة من مادة الأكريليك تحتوي على شقوق مصنوعة مسبقاً من قبل الشركة مطورة وغير مطورة في قاعدة الاسنان لتماسك الاسنان مع الطقم المصنوع من مادة البلاستيك المعالج حرارياً .

النماذج المستعملة معرضة الى قوة الشد لحين الانفصال.

النتائج:

بصورة عامة قوى التماسك الكيميائي للأسنان المصنوعة من مادة الأكريليك ومادة الطقم المصنوعة من الاكريليك الحراري هي اقوى من التماسك الميكانيكي الحاصل بين الأسنان المصنوعة من مادة الأكريليك ومادة الطقم المصنوعة من البلاستيك المعالج حراريا.

ترطيب قاعدة الاسنان المصنوعة من مادة الأكريليك بالمادة السائلة للأكريليك الحراري يعزز قوة ترابط الأسنان مع مادة الطقم الأكريليك بنسبة 88%.

تحويل وتعديل الشقوق المصنوعة من قبل الشركة في قاعدة الاسنان يعزز قوة الترابط بين الأسنان المصنوعة من مادة الأكريليك وبين مادة الطقم المصنوعة من البلاستيك المعالج حراريا بنسبة 58%.

الاستنتاج:

ترطيب قاعدة الاسنان المصنوعة من مادة الأكريليك يزيد من قوة الترابط بين الأسنان و مادة الطقم الأكريليك الحراري . تحويل وتعديل الشقوق المصنوعة من قبل الشركة في قاعدة الاسنان المصنوعة من مادة الكريلك تقلل نسبيا من مشكلة انفصال الأسنان عن مادة الطقم المصنوعة من البلاستيك المعالج حراريا.

INTRODUCTION

Various denture repairs of conventional prosthodontics was to a considerable extent associated with detachment of the teeth from the denture base, which could reach approximately 20% of denture repairs within the first 1-2 years.⁽¹⁻³⁾ Recent increase of use of implants with increased forces applied to prosthetic components could probably lead to greater numbers of denture failure associated with teeth debonding or fracture.^(4,5)

Tooth debonding was one of the problems many authors sought to solve or at least attempted to lessen. Their attempts were to increase the bond between the tooth and the denture base by mechanical and chemical techniques which included grooves, holes, break of the glaze of the tooth surface, and wetting with monomer or other chemical agent. Also, different polymerization methods and types of acrylic resins and denture teeth were used to enhance the adhesion between denture teeth and acrylic resins.^(2,6-14)

Failure of bond between denture teeth and denture base was mainly adhesive or cohesive failure. Adhesive failure occurred when there was no trace of denture base material on the ridge laps of the teeth after fracture, as stated in The Glossary of Prosthodontic Terms⁽¹⁵⁾ the ridge lap of the tooth is the surface that has been shaped to accommodate the residual ridge. On the other hand, failure of the bond was considered cohesion failure when there were remnants of the denture base material on the ridge laps of the teeth after fracture.⁽¹⁶⁾

Thermoplastic materials were introduced as early as the 1950's as Polyamides (nylon plastics). With time these materials developed into several types; thermoplastic acetal, thermoplastic polycarbonate, thermoplastic acrylic, and thermoplastic nylon (resin).^(17,18)

Thermoplastic resins gained popularity recently with the surfacing of new materials with better properties like Valplast from VALPLAST INTERNATIONAL CORP, FRS "flexible resin system" from DENSPLY. They were advantageous over the conventional acrylic resins (polymethyl methacrylate PMMA) because they're flexible, nearly unbreakable, light weight, monomer free, no porosity, chemically resistant, and excellent esthetically because were clasps constructed from the same material making the clasps undistinguishable from the gums.⁽¹⁷⁻¹⁹⁾ Their drawback was that these materials adhered to the teeth mechanically and this increased the problem of teeth detachment which was already present with acrylic resin denture base materials.^(19,20)

This study was intended to investigate the bond strength of teeth to conventional heat activated acrylic resins and to thermoplastic nylons. The study also examined the bond strength of teeth to heat activated acrylic resin and the effect of wetting the ridge laps of the teeth with monomer. Furthermore, the study was aimed to explore the bond strength of acrylic teeth with prefabricated retentive means on the ridge laps attached to thermoplastic nylons and the effect of modifying these retentive means on the bond strength.

MATERIALS & METHOD

The teeth used in this research were 3-layer cross-linked synthetic resin teeth (MEHECO PHARMACEUTICALS AND CHEMICALS IMP. & EXP. CORP., China). They had a prefabricated groove and hole on the ridge laps of the teeth for retentive means with dimensions of 0.5 mm depth and 2 mm width of the hole, as shown in figure 1.

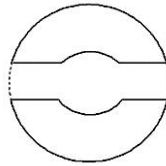


Fig 1. View of the ridge laps of the teeth.

The samples were grouped into four groups with each group consisting of eight samples. The first group (AT) included acrylic teeth (without retentive grooves and holes) used with heat cure acrylic resin. The second group (AMT) was of acrylic teeth (without retentive grooves and holes) wetted for 5-10 seconds with monomer of denture base polymer and processed with heat cure acrylic resin. The third group (VT) included acrylic teeth (with prefabricated retentive groove and hole of 0.5 mm depth and width of 2 mm for the hole, see figure 2) used with Valplast soft denture base material. The last group (VMT) was of acrylic teeth (with modification of the prefabricated retentive groove and hole) used with Valplast soft denture base material. This modification was shaped with the use of a round burr to deepen the retentive groove and hole to 1 mm and to increase the convergence of the retentive means without increasing the diameter of 2 mm, figure 3.



Fig 2. Cross section of the ridge lap of the teeth with prefabricated retentive groove and hole.



Fig 3. Cross section of the ridge lap of the teeth with modification of the prefabricated retentive groove and hole

Wax models were used with a diameter of 5mm, length of 28mm, and an increase of diameter of 8mm at the 3mm end of the model opposite to the tooth-model interface surface, figure 4.

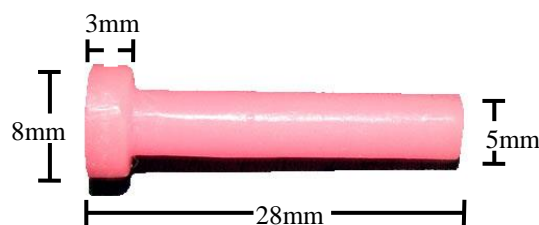


Fig 4. Wax model and its dimensions

The teeth were adhered to the wax models and poured in the flask with extra hard stone type IV (MICROMOD, Italy). The wax was eliminated from the flask and the teeth were cleaned from the wax by boiling water and detergent and this was adapted in this research because a high percentage (over 60 %) of staff in different prosthodontic departments dewaxed denture teeth with boiling water without the

use of a wax solvent as revealed by a survey conducted by Cunningham & Benington⁽²¹⁾. Each group was processed with the denture base material according to the sample grouping with the following materials:

1. Heat cure acrylic (non cross linked) (ENTACRYL, ENTA B.V. Bergen op zoom the Netherlands ISO 9000, Holland).
2. Valplast soft denture base material (VALPLAST INTERNATIONAL CORP., New York, USA.)

The above materials were mixed and manipulated according to the manufacturer's instructions. The finished samples were placed in distilled water in an incubator for 48 hours at a temperature of 37°C before testing.

The samples were subjected to a tensile force with an Instron testing machine of a cross head speed of 5mm/min using a load cell with a maximum load capacity of 1000N. Specially made chucks were used to hold the samples in the Instron testing machine at each end. The chucks were connected to the testing machine by universal joints to minimize any non-tensile forces during loading. The force at failure was recorded in Newton. The value of tensile bond strength was calculated for each test specimen as the force at de-bonding divided by a cross-section area of interface according to the following formula:

$$\text{Bond strength (N/mm}^2\text{)} = \frac{\text{F (N)}}{\text{A (mm}^2\text{)}}$$

(ASTM specification D-638 M, 1986) where F= force of failure (Newton) and A= surface area of the cross section (square millimeter)

The broken samples were visually inspected at the fracture sight to assess the cause of the failure whether adhesive or cohesive failure.

Statistical analysis was conducted with descriptive statistics, independent sample t-test, one-way analysis of variance (ANOVA), and multiple comparison tests utilizing the least significant difference test (LSD) and at a significance level of p<.05.

RESULTS

The means for acrylic teeth bonded to acrylic resin were (27.25 N/mm²) and Valplast thermoplastic resin were (18.0625 N/mm²) in general, as shown in figure 5. Acrylic teeth bonded to acrylic resin highly significantly better then did to Valplast thermoplastic resin, when compared statistically as shown in table 1.

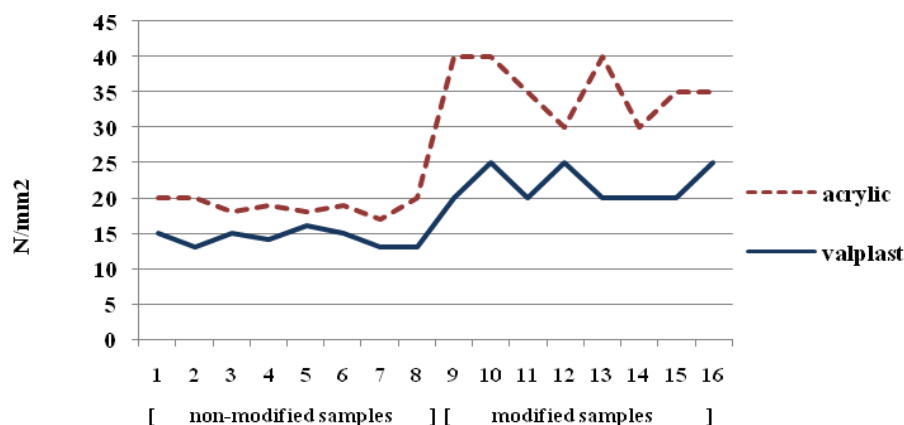


Fig 5. Bond strength of acrylic resin & teeth and Valplast & teeth in general

Table 1. Independent sample t-test for bond strengths of teeth to acrylic and Valplast

	Mean diff.	Std. Error	df	t	Sig.
Acrylic – Valplast (Equal variances not assumed)	9.1875(**)	2.53471	21.569	2.46	.002

** Highly significant (p< .01)

The means of the bond strength for the four test groups are shown in figure 6. Wetting the ridge lap of the acrylic teeth with monomer before processing with heat cure acrylic resin (group AMT) gave rise to the greatest bond strength of all test groups (35.625 N/mm²). The lowest value (14.25 N/mm²) was for the acrylic teeth with the prefabricated retentive means (without modification) processed with Valplast thermoplastic resin (group VT). The mean of the bond strength for the acrylic teeth and heat cure acrylic (groups AT) was considerably close in value (18.875 N/mm²) to that of the acrylic teeth with prefabricated retentive means and Valplast thermoplastic resin (21.875 N/mm²) (group VMT).

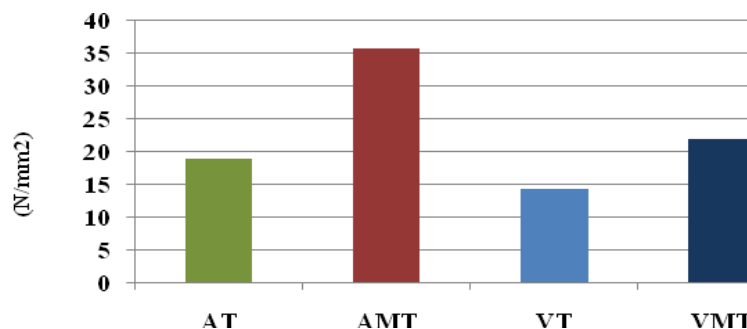


Fig 6. Bond strength for the four test groups

Statistically, as seen in tables 2 & 3, the comparison between all test groups were highly significantly (p< .01) different from each other except for the comparison between groups AT and VMT in which their means were significantly different (p< .05).

Table 2. One-way ANOVA for bond strength between test groups.

	Sum of Squares	df	Mean Square	F	Sig.
Between Groups	2030.094	3	676.698	101.256	.000(**)
Within Groups	187.125	28	6.683		
Total	2217.219	31			

** Highly significant (p< .01)

Table 3. Least significant difference (LSD) between test groups

Test Groups	Mean Diff.	Std. Error	Sig.
AT-AMT	-16.75000(**)	1.29258	.000
AT-VT	4.62500(**)	1.29258	.001
AT-VMT	-3.00000(*)	1.29258	.028
AMT-VT	21.37500(**)	1.29258	.000
AMT-VMT	13.75000(**)	1.29258	.000
VT-VMT	-7.62500(**)	1.29258	.000

* Significant (p<. 05), ** Highly significant (p< .01)

The visual inspection of the sample pieces showed the following results:

- Point of failure for group AT was the junction between the teeth and acrylic without remnants of acrylic on the ridge laps (adhesive failure).
- Point of failure for group AMT was at the junction between the teeth and acrylic leaving remnants of acrylic on the ridge laps of the teeth (cohesive failure).
- Point of failure for group VT was at the junction between the teeth and Valplast thermoplastic resin without remnants of Valplast thermoplastic resin on the ridge laps or in the retentive means (adhesive failure).
- Point of failure for group VMT was at the junction between the teeth and Valplast material leaving remnants of Valplast thermoplastic resin in the modifications (retention means created in the teeth) and this was adhesive failure because the remnants of the denture base material was retained due to the undercuts in the modified retentive means.

DISCUSSION

In general the bond strength of the teeth to heat cure acrylic denture base material (27.25 N/mm²) was greater than that with Valplast thermoplastic denture base material (18.0625 N/mm²). This could be the result of the difference in the nature of the bond between the teeth and the two different materials. With heat cure acrylic denture base material the bond was purely chemical.^(7,14,16,22) On the Contrary, with the Valplast denture base material the nature of the bond was purely mechanical.^(19,20) It was obvious from the results that the chemical bond in general was greater in strength than the mechanical bond although other forms of retention are present and the hole and groove were the means used in this research. This difference in the nature of the bond lead to different bond failure between the teeth and denture base, Valplast was purely adhesive while heat cure acrylic resin was adhesive and/or cohesive.

The increase of bond strength in group AMT was attributed to the wetting of the ridge laps of the teeth with monomer which increased the chemical bond between the acrylic teeth and the heat cure acrylic denture base material by 88 % from 18.875 N/mm² to 35.625 N/mm².

Chemical bonding between acrylic resin teeth and polymers depends on the penetration of the acrylic resin monomers into the teeth and the formation of an interwoven polymer network.^(22,23) Vallittu ⁽⁷⁾ stated that wetting the ridge laps of the acrylic teeth with monomer of denture base polymer dissolved the surface before the acrylic resin dough was packed. Also, Vallittu et al.⁽²⁴⁾ suggested that wetting the acrylic teeth with monomers caused a swelling phenomenon of acrylic resin polymer teeth and this lead to diffusion of the monomer into the interpenetrating polymer network of acrylic resin teeth during processing. This increased the bond strength between the teeth and the denture base resin because the denture base acrylic resin polymer diffused into the interpenetrating polymer network of the

tooth during polymerization. Meng et al.⁽¹⁴⁾ in their investigation found that the treatment of the denture tooth surface with the methylacetate-based bonding agent dissolved the acrylic resin component of the denture tooth and caused the surface to swell, permitting the diffusion of repair acrylic resin to form an interpenetrating polymer network with the treated denture tooth surface.

The monomer could have dissolved any remnants of wax or contaminants of alginate mold seal on the ridge laps of the teeth allowing for a stronger chemical bond. As previously indicated by Schoonover et al.⁽²⁵⁾ and Cunningham & Benington⁽²⁶⁾, this may be the prime reason for the tooth to resin bond failure in denture service, although Cunningham & Benington⁽²⁶⁾ found no significant difference in bond strength when the ridge laps were contaminated with alginate mould seal.

The results of this research were in agreement with Sorensen & Fjeldstad⁽²⁷⁾ and Cunningham & Benington⁽²⁶⁾ who both found an increase in bond strength when the teeth were treated with monomer. Meng et al.⁽¹⁴⁾ noticed an increase in bond strength of acrylic resin teeth although they used a methylacetate-based experimental bonding agent as a wetting agent for the acrylic teeth and not monomer of denture base polymer. Marra et al.⁽²⁸⁾ showed that wetting acrylic teeth with monomer increased the bond strength with Lucitone denture base resins and decreased the bond strength with QC-20. Spratley⁽³⁾ noticed a decrease in the bond strength due to wetting of the ridge laps with monomer. He may have differed in the duration of wetting because he didn't mention the wetting duration, which has been shown to be an important factor in the adhesion between acrylic resins.⁽²⁹⁾ Morrow et al.⁽³⁰⁾ suggested that painting unmodified ridge laps of plastic teeth with monomer actually decreased bond. This may be associated with the long period adapted in their study of 10 minutes between placement of monomer and packing, while only 5-10 seconds separated the time of monomer placement to packing of acrylic resin in this study. Barpal et al.⁽⁸⁾ used two types of high impact denture base resins bonded to acrylic resin teeth (Ivoclar) in their study and stated that the addition of monomer did not significantly increase the bond strength of Lucitone resin, while it significantly decreased the bond strength for Ivocap resin. The conflicting results obtained by previous authors could be attributed to the different methods or materials used, as stated by some authors like Vallittu⁽⁷⁾, Barpal et al.⁽⁸⁾, & Marra et al.⁽²⁸⁾ and further studies should be conducted.

Group VT was the least in value (14.25 N/mm²) when compared with all the test groups. The bond failure was purely adhesive between the acrylic teeth and Valplast denture base material due to the nature of the bond and the difference in material, as mentioned earlier. Also, visual inspection of the broken sample pieces which showed no remnants of the denture base material adhered to the ridge laps of the acrylic teeth or in the prefabricated retentive means. Thus, the reduced value of the bond strength was that it depended entirely on mechanical retention of the Valplast denture base material in the prefabricated retentive means of the acrylic teeth.^(19,20) Also, the other reason could be the cause of the processing shrinkage that the Valplast nylon underwent which was about 2.5% in comparison to the conventional PMMA which was 0.9%, as stated by Parvizi et al.⁽³¹⁾. This decreased the amount of nylon engaging the undercuts in the teeth with prefabricated retentive means, so reducing the bond between the teeth and Valplast denture base material.

When comparing the bond strength of group VT (14.25 N/mm²) with group VMT (21.875 N/mm²), it was noticed that group VMT was significantly greater. Modifying the prefabricated retentive means increased the bond strength by 58 % by increasing the amount of undercut in the retentive means, thus preventing the disengagement of the material from the undercuts. The bond strength in such a situation depended entirely on the tensile strength of the Valplast denture base material at the neck of the projection of the material into the retentive means. This was backed by the fact that the point of failure for group VMT was at the neck of the tooth leaving remnants of Valplast

thermoplastic resin in the modifications. This was in agreement with Darbar et al.⁽¹⁾ & Vallittu et al.⁽³²⁾ who both suggested mechanical retention in the form of a diatoric placed in the ridge lap of denture teeth because of the majority of denture tooth-to-denture base failures were adhesive failures. Zukerman⁽⁹⁾ stated that denture teeth separated from denture bases without evidence of damage to the teeth or denture bases suggesting adhesive failure and insufficient mechanical retention to preserve the bond. Vallittu⁽⁷⁾ stated that often the methyl methacrylate did not penetrate into the diatoric during processing, but this didn't affect the bond strength since he noticed that the fracture of the denture base material was at the level of the ridge laps leaving the projections of the denture base material in the diatoric of the teeth. Barpal et al.⁽⁸⁾ had different findings which stated that the use of a diatoric significantly decreased the failure load in Lucitone resin, but actually increased it in Ivocap resin denture base material. They had difficulty explaining the reason, although they noticed penetration of both the Ivocap and Lucitone resins into the diatoric.

Modification of the prefabricated retentive means for group VMT gave rise to a bond strength (21.875 N/mm²) which was greater to that of group AT (18.875 N/mm²), although it was closer in value than to any other group. Thus, the disadvantage of decreased bond strength when using Valplast denture base material with acrylic teeth of prefabricated retentive means could be partially resolved by enhancing the undercuts in the teeth to achieve a bond strength greater than that of the conventional heat cure acrylic resin and acrylic teeth.

In conclusion, the bond strength of acrylic teeth to heat cure acrylic resin denture base material could be increased by wetting the ridge laps of the teeth with acrylic monomer before processing. Also, the drawback of the bonding strength of acrylic teeth to Valplast thermoplastic denture base materials could be partially dealt with by modifying the prefabricated retentive means to increase the undercuts, thereby increasing the bond strength to reach values equal to or greater than that of acrylic teeth bonded to conventional heat cure acrylic resin denture base material.

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