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The Effect of Monomer/Polymer Mixing Ratio, Time Between Mixing and Packing of Heat Cured Acrylic Resin Denture Base Material and Bond Assisting Agents on the Bond Strength to Acrylic Resin Denture Teeth

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Abstract - *The aim of the study was to investigate the effect of varying the monomer/polymer mixing ratio, the time from mixing to packing heat cured acrylic resin and the effect of two bond assisting agents on the strength of the bond between denture base acrylic resin and acrylic resin denture teeth. Statistical differences were found in bond strength with monomer/polymer ratio and time between mixing and packing with one of the heat cured resins investigated. The benefit of using the bonding agents was not demonstrated.*

KEY WORDS: Acrylic resin, Mixing ratio, Time, Bonding agent

INTRODUCTION

The bond between acrylic resin denture teeth and the denture base acrylic resin seems to be technique sensitive in that it may fail in service[1], even though it is possible to create a bond with strength equivalent to the strength of the denture base resin alone[2]. The strength of the bond between the denture tooth and the base acrylic resin has been shown to be influenced by many factors, chemical[3,4], mechanical modification of the ridgelap of the denture teeth[5,6,7], the type of acrylic resin base material used[8,9,10], the type of denture teeth[11,12], the presence of residual materials such as wax and sodium alginate mould seal on the ridgelap surface[13,14] and the curing cycle[15,16,17,18].

The aim of the first part of this study was to investigate the effect that varying the monomer/polymer mixing ratio may have on the bond strength between denture base acrylic resin and acrylic resin denture teeth. The aim of the second part of the study was to investigate the effect of varying the time between mixing and packing. Anecdotal evidence suggests that in busy dental laboratories it is common practice to pack several denture flasks with a single mix of acrylic resin dough and often the materials are not pre-measured in the proportions recommended by the manufacturers. These are practical problems, which could affect the strength of the bond between the acrylic resin of the base and the denture teeth.

Recently new bonding agents have been introduced, which their manufacturers' claim improve the bond between the denture teeth and denture base acrylic resin. The purpose of the third part of this study therefore was to test two of these bonding agents.

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MATERIALS AND METHODS

Experiment 1

For the first part of the investigation one heat cured denture base acrylic resin Trevalon C was selected, with two different brands of denture teeth, Basic 6, and Enigma. In the first series of experiments, the amount of monomer used was varied. Two groups of specimens were prepared: the first group used Basic 6 teeth and the second group used Enigma teeth. Each group was sub-divided into three sub-groups of 20 specimens each: a group using 10% less than the manufacturer's recommended amount of monomer with the recommended amount of polymer, a second group used the manufacturer's recommended monomer/polymer mixing ratio and the third group used 10% more monomer for the recommended amount of polymer.

Experiment 2

In the second set of experiments the manufacturer's recommended polymer/monomer mixing ratio was used but the time between mixing and packing, and hence the viscosity of the dough was varied. Two groups of specimens were prepared, one using Basic 6 teeth and the other Enigma teeth. Each group was sub-divided into three sub-groups (20 specimens): in the first, the monomer and polymer was mixed according to the manufacturer's instructions at an ambient temperature of 17 $^{+2^{o}}$ C, timed to dough stage (45 minutes) and packed. This standard dough stage was determined by an experienced technician based on trial runs and allowing for ambient conditions. The second sub group was packed 10 minutes before reaching dough stage of the first (after 35 minutes) and the third was packed 10 minutes after reaching dough stage of the first (after 55 minutes) under the same conditions.

Experiment 3

In the third series of experiments the tensile bond strength of the joint between two different brands of heat cured denture base acrylic resins (Trevalon C, Pegasus Plus) and one type of cross linked acrylic resin denture teeth (Enigma) with and without the use of two proprietary makes of bond assisting agents (Palabond and HS Cross-Liquid) was tested.

SPECIMEN PREPARATION

For all three experiments dumbbell-shaped tensile specimens were prepared as previously described[12,18,19]. Sections of the selected teeth 2mm thick to be incorporated into the test specimens were prepared. Standard aluminium dumbbells 37.1mm long, 5mm diameter in the test portion and 7.9mm at the dumbbell ends were invested in a standard denture flask and after removal from the flask, a tooth section was positioned in the centre of the dumbbell and packed with acrylic resin to produce the experimental dumbbell specimens. All denture base acrylic resin was mixed according to the manufacturers' instructions.

The materials were carefully packed into the flasks so as not to disturb the tooth discs. The flasks were placed under a bench press using a pressure of 100kp/cmsq to close the flasks until a uniform pressure was maintained. The flasks were transferred to a spring clamp and a torque of 36Nm was applied to the spring clamp using a torque bar. This allowed the pressure achieved in the flasks under the bench press to be maintained in the spring clamp[20]. All specimens underwent conventional wet curing in a water bath using a medium curing cycle (2 hours at 70°C followed by 2 hours terminal boil).

After careful deflasking the dumbbells were turned to standard dimensions on a lathe (27.5 mm length and 4 mm diameter, the head diameter 7mm). Specimens were stored in water at room temperature for one month before testing for tensile strength. The tensile bond strength was tested for using an Instron 5569A Universal testing machine. Tests were carried out at a cross-head speed of 1mm/minute with the integrated chart recorder speed set at 1mm/second. Calibration of the testing machine was carried out before the testing commenced and was checked following every tenth specimen and the full scale of the chart recorder was set at 1000N. Load was increased to the point of catastrophic failure at which time the test cycle was stopped.

STATISTICAL ANALYSIS

In the first and second experiments data were tested for normality followed by one-way analysis of variance (ANOVA) for each type of tooth. Post-ANOVA multiple comparisons (Bonferroni method) were carried out when statistically significant differences were indicated. Statistical significance was implied where $p<0.05$. In the third part of the experiment the variable 'load at failure' showed a slightly skewed distribution and was transformed to the square of the variable for analysis. Two-way ANOVA was carried out to examine the effect of denture base and bonding agent, followed by Bonferroni-adjusted post-ANOVA contrasts for pair-wise comparisons.

RESULTS

Experiment 1

Variation in the monomer/polymer ratio resulted in no statistically significant difference in the strength of the bond between the acrylic resin and the Basic 6 teeth. A statistically significant difference was observed in the bond strength between the denture base acrylic resin and Enigma teeth between the recommended monomer/polymer ratio and the reduced monomer ratios (Table 1).

Experiment 2

No statistically significant differences in the bond strength between Basic 6 teeth and acrylic resin were found with early, recommended or late packing of the dough. Statistically significant difference was found in bond strength of Enigma teeth to the base acrylic resin when the dough was packed at the early and recommended stages (Table 2).

Experiment 3

Table 3 shows the mean and standard deviation of load at failure (N) and bond strength (MPa) by denture base and bonding agent. The strength of the bond between the Trevalon C denture base material (control) and the denture teeth was statistically significantly stronger than the bond strength to HS Cross Liquid group ($p<0.001$) but not the Palabond group. The bond strength between Pegasus Plus denture base material (control) and the denture tooth was statistically significantly stronger than HS Cross Liquid group.

DISCUSSION

Within the limitations of the study Experiment 1 showed that only the bond between the acrylic resin base material and the Enigma teeth was weaker when the monomer was reduced by 10% whereas in Experiment 2 a stronger bond was found between the Enigma teeth and the base acrylic resin when the dough was packed at the early dough stage. Experiment 3 did not demonstrate any advantage to the use of bonding agents.

Overall the results of the first two parts of this study are, to some extent, reassuring in that the parameters tested, variations in monomer/polymer ratio and time between mixing and packing, are perhaps the two parameters that are most abused in dental laboratory practice. Monomer/polymer mixing ratios are rarely measured accurately by weight or volume and if several cases are packed from a single mix the degree of doughing and hence the amount of available monomer must vary from case to case. Within the parameters of this study the bond between the base acrylic resin and the cheaper Basic 6 teeth were less sensitive to variations in monomer/polymer ratio in that no statistically significant differences were found. The more expensive Enigma teeth showed statistically significant less strength with the reduced monomer/polymer ratio than with the recommended ratio. No statistical difference was found when the monomer/polymer ratio was increased by 10%.

The ideal doughing time is more difficult to judge because the time from mixing to doughing is dependent on several factors notably ambient temperature and technicians' per-

Table 1. *Mean and standard deviation of load at failure in Newtons and strength in Megapascals for variation of monomer/polymer ratio*

Specimen type	*Basic 6 N/MPa*	*Enigma N/MPa*
-10% monomer	392.5 (85.6)N 31.3 (6.8)MPA	307.8 (102.9)* N 24.5 (8.2)MPA
Recommended ratio	387.3 (54.1) N30.08 (4.3)MPA	406.5 (87.1)*N 32.4 (6.9)MPA
+10% monomer	432.8 (68.2)N 34.5 (5.4)MPA	341.5 (78.1)N 27.2 (6.2)MPA

** significantly different (post-ANOVA contrast, p=0.003)*

Table 2. *Mean and standard deviation of load at fracture in Newtons and strength in Megapascals for variation of time of packing*

Specimen type	*Basic 6 N/MPa*	*Enigma N/MPa*
Early dough stage	491.0 (51.1)N 39 1 (4.1)MPA	490 0 (43.5)*N 39.0 (3.5)MPA
Recommended dough stage	451.5 (49.8)N 35.9 (3.9)MPA	434.0 (58.4)N 34.5 (4.6)MPA
Late dough stage	431.5 (82.0)N 34.4 (6.5)MPA	451.5 (42.9)N 35.9 (3.4)MPA

** significantly different (post-ANOVA contrast, p=0.048)*

Table 3. *Mean (standard deviation) of load at failure (N) and bond strength (MPa) by denture base and bonding agent. The superscript letters [a,b,c] indicate statistically significant differences between different groups (<0.01)*

	Bonding agent			
Denture base	*Control N/MPa*	*Palabond N/MPa*	*HS Cross Liquid N/MPa*	*p value*
Trevalon C	463 (55)^{a}N 36.7 (4.4)^{a}MPA	457 (35)^{b}N 36.2 (2.8)^{b}MPA	393 (53)^{ab} N 31.0 (4.2)^{ab}MPA	<0.001
Pegasus Plus	406 (68)^{c}N 32.2 (5.4)^{c}MPA	377 (63) N 29.9 (5.0)MPA	338 (57)^{c}N 26.7 (4.5)^{c}MPA	0.004
p value	0.004	<0.001	0.004	

ception of the correct dough stage for packing. In this study the standard dough stage was judged by an experienced dental technician and early and late stages set at plus and minus ten minutes. Reassuringly, these differences had no significant effect on the bond strength between the Basic 6 denture teeth and the denture base resin. However, with the Enigma teeth a statistically significant increase in the bond strength was observed when the dough was packed early.

At a practical level the results suggest that the best method is to follow the manufacturer's instructions but if these instructions are to be varied then a slightly higher amount of monomer and slightly earlier packing would perhaps be preferable.

The method used in this study was the same as previous studies from this laboratory[12,18,19] and load at failure and strength values recorded were comparable. Previous studies[18,19] have suggested that a stronger bond may be achieved when both denture teeth and acrylic resin base material come from the same manufacturer but in both previous studies there was only a trend suggesting this relationship rather than conclusive proof. The results in this present study were interesting in that in the third series of experiments the strongest bonds were achieved without the use of the bonding agents.

When using Trevalon C acrylic resin denture base, a statistically significant stronger bond was obtained when no bonding agent was used versus HS Cross Liquid. Palabond produced a stronger bond than with HS Cross Liquid. For the Pegasus Plus acrylic resin denture base test, a statistical significantly stronger bond was obtained when no bonding agent was used versus HS Cross Liquid.

According to the ADA Specification No. 15, the minimum required value of tensile bond strength is 31 MPa. The combinations, which conformed to the ADA Specification No. 15 were Trevalon C and no bonding agent (37 MPa), Trevalon C and Palabond (36 MPa), Trevalon C and HS Cross Liquid (31 MPa) and Pegasus Plus and no bonding agent (32 MPa). When Pegasus Plus acrylic resin denture base was used with Palabond and HS Cross Liquid bonding agents, the mean values of bond strength were below the 31 MPa tensile bond strength limit set.

Therefore, from the results of experiment 3 it can be concluded that Palabond and HS Cross Liquid bonding agents do not facilitate a superior tensile bond strength between denture base and acrylic teeth. It can be hypothesized that modern denture teeth are already engineered to produce the best possible bond with the denture base acrylic resin,

and the bonding agent rather than enhancing the bond in some way intercedes so that a weaker bond is formed.

CONCLUSION

Within the limits of this study, variation in the monomer/polymer ratio may weaken the strength of the bond between denture base acrylic resin and acrylic resin denture teeth when the monomer content is reduced. Packing the acrylic resin at the recommended stage or slightly early produces a stronger bond than if it is packed late. Bonding agents do not appear to improve the bond between denture teeth and acrylic resin denture base material**.**

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MANUFACTURERS' DETAILS

- Heraeus Kulzer Ltd, Newbury, U.K.
- Davis Schottlander & Davis Ltd, Letchworth, U.K.
- Derotor, Quayle Dental Mfg Co. Ltd, Worthing, U.K.
- Schutz Denatl GmbH, Dieselstrasse 5-661191, Rosbach, Germany.
- Dentsply Ltd, Weybridge, U.K

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