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Effect of Curing Cycle on the Tensile Strength of the Bond Between Heat Cured Denture Base Acrylic Resin and Acrylic Resin Denture Teeth

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Abstract - *The effect of different curing cycles on the tensile strength of the bond between one brand of cross-linked acrylic resin teeth and three heat cured denture base acrylic resins was tested. There were differences in the tensile bond strength between the three heat cured denture base acrylic resins and the three curing cycles used. The bond strength of the acrylic resin denture base material made by the same manufacturer as the cross-linked acrylic resin denture teeth was higher. The bond strength following the short cycle was lowest in all cases, individual differences between curing cycles failed to reach statistical significance.*

KEY WORDS: Acrylic resin, Denture teeth, Bond strength

INTRODUCTION

Detachment of teeth from acrylic resin dentures remains a problem[1,2] due to the unreliability and inconsistency of the bond between the teeth and the base acrylic resin[3]. To obtain an adequate bond between acrylic resin teeth and the denture base, the free monomer radicals present in the denture base dough must penetrate the outer layers of the tooth and remain in contact for an adequate period of time to promote bonding of the monomer. On curing, the monomer polymerises across the junction and forms a union between both the surfaces and thus a bond is achieved[4,5].

Factors which have been shown to affect the strength of the bond between the denture teeth and the base acrylic resin are mechanical modification of the ridgelap of the denture teeth[6,7,8], chemical modification of the ridgelap of the denture teeth[9,10], the type of denture base resin used[11,12,13,14], the type of denture teeth[11,15] and the presence of any residuals on the ridgelap such as wax and sodium alginate mould seal[16,17,18].

The transverse strength of acrylic resin base material is affected by the curing cycle. However, it has been suggested that over a period of time, manufacturers have changed the formulation of their products in such a way that long curing cycles are no longer necessary[19,20]. Indeed, Attar and colleagues [21] recommended following the curing cycle suggested in the manufacturers' instructions for each individual product. The effect of different curing cycles on the bond strength of modern heat cured acrylic resins to denture teeth is not well understood. Therefore, the aims of this study were to determine the effect of different curing cycles on the tensile bond strength of cross-linked acrylic resin teeth to heat cured denture base acrylic resins and to compare the tensile bond strength of one brand of cross-linked acrylic resin denture teeth to three commercially available heat cured denture base acrylic resins. The null hypotheses to be tested were that there was no effect of different curing cycles on the tensile bond strength of cross-linked acrylic resin teeth to heat cured denture base acrylic resins and that there was no difference in the tensile bond strength between cross-linked acrylic resin teeth and the three heat cured denture base acrylic resins.

MATERIALS AND METHOD

Three heat cured denture base acrylic resins were selected owing to their commercial popularity and ease of availability, Trevalon C, Meadway and Pegasus Plus which is produced by the same manufacturer as the Enigma teeth used in this study. According to the information provided by the manufacturer, the teeth were made from cross-linked poly(methylmethacrylate) and the whole tooth is homogeneous with only colour variations in the body and enamel.

Dumbbell-shape tensile specimens were prepared as previously described by AlBarghouty *et al* [22]. In brief, 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 dumbbells. 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.

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The flasks were transferred to a spring clamp, 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. All specimens underwent conventional wet curing in a water bath using either a short, medium or long curing cycle.

After processing and deflasking the dumbbells were turned to standard dimensions on a lathe (27.5 mm length and 4 mm diameter, the head diameter 7mm). Specimens (15 per group) were stored in water at room temperature (20˚C ± 2˚C) for one month before testing for tensile strength. Specimens were tested on an Instron 1195 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 1000 N. Load was increased to the point of catastrophic failure at which time the test cycle was stopped.

Three groups of specimens (Table 1) were made using each combination of Enigma denture teeth and base acrylic resin. Each group was sub-divided into three sub-groups, each of which was subjected to a different curing cycle.

Statistical analysis

Data conformed to a Normal distribution. Two-way analysis of variance (ANOVA) was used to determine whether there were differences in load at failure between cycling lengths and materials. Subsequently, one way ANOVA with a post hoc Scheffe test was used to test for differences between cycles within materials and between materials within cycles.

RESULTS

Table 2 describes the means and standard deviations of strengths in megapascals (MPa). The strength of Trevalon C and Meadway increased with length of curing cycle whereas the medium cycle of Pegasus Plus produced specimens with the highest tensile bond strength. The short cycle of all the three materials produced specimens of lower bond strength. Analysis of variance suggested some differences between materials ($p=0.028$) and cycles ($p=0.049$) with marginal statistical significance. Subsequent detailed analysis indicated a difference between Trevalon C and Pegasus Plus when subjected to the medium cycle ($p=0.031$) and a borderline significant increase in tensile bond strength between the medium cycle and short cycle

Table 1. *Processing cycles*

Materials	*Manufacturer*	*Short cycle*	*Medium cycle*	*Long cycle*
Group1 Trevalon C	Dentsply Caulk, Milford, U.K.	Place flask in cold water and slowly raise temperature to boiling point (within 30 minutes) continue boiling for a further 30 minutes. Allow to cool slowly in water.	2 hours at 70˚C followed by 2 hours terminal boil.	6 hours at 70˚C with a terminal boil of 2 hours.
Group 2 Meadway	MR Dental Supplies Ltd, Woking, U.K.	Immerse the flask in boiling water and turn off the heat for 20 minutes. Then re-heat to boiling temperature and boil for 20 minutes. Allow to cool slowly in water.	2 hours at 70˚C followed by 2 hours terminal boil.	6 hours at 70˚C with a terminal boil of 2 hours.
Group 3 Pegasus Plus	Davis Schottlander & Davis Ltd, Letchworth, U.K.	Immerse the flask in cold water and raise temperature to boiling point slowly over 30 minutes, and maintain at boiling temperature for 30 minutes. Allow to cool slowly in water.	2 hours at 70˚C followed by 2 hours terminal boil.	6 hours at 70˚C with a terminal boil of 2 hours.

Table 2. *The mean and standard deviation (SD) of strength in megapascals for the nine groups*

Materials	*Value*	*Short cycle*	*Medium cycle*	*Long cycle*
Trevalon C	Mean	35.4 MPa	36.3 MPa	42 MPa
	SD	(8.6)	(7.2)	(10.8)
Meadway	Mean	39 MPa	38.7 MPa	43.4 MPa
	SD	(10.1)	(8.6)	(5.6)
Pegasus Plus	Mean	38.7 MPa	41.9 MPa	41.2 MPa
	SD	(4.7)	(8.2)	(9.1)

for Pegasus Plus (p=0.057). Fig. 1 represents the tensile bond strength in megapascals (MPa) for the individual specimens of all the three heat cured acrylic resins. The short cycle of the Trevalon C group shows one-third of its specimens below the assumed standard of 31MPa (ADA specification No.15). The short and medium cycle of the Meadway group shows a quarter of its specimens below the assumed standard as compared to Pegasus Plus short cycle which has all its specimens above the accepted assumed standard. The long curing cycles of all the three heat cured acrylic resins showed most specimens with values above the assumed standard.

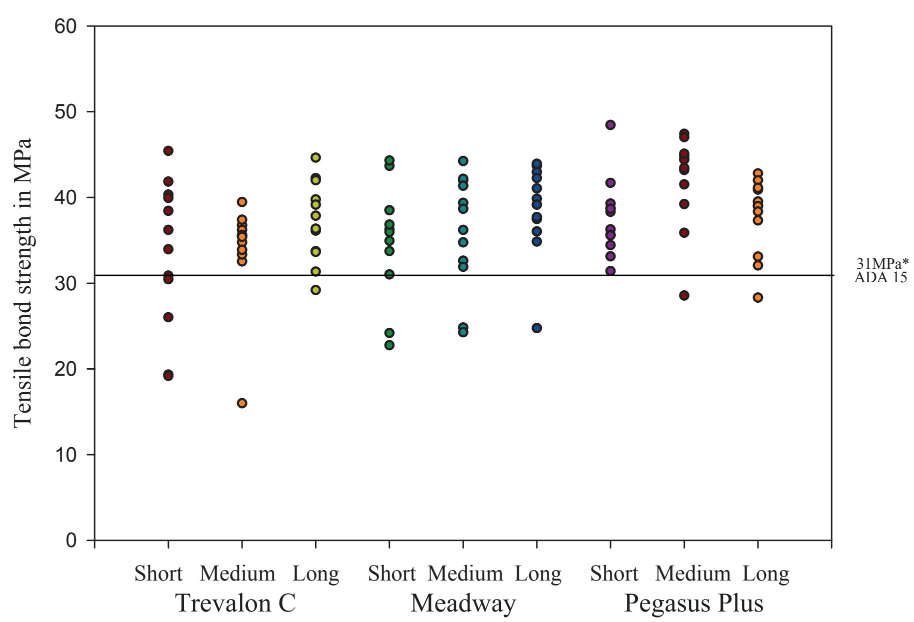
DISCUSSION

Three heat cured acrylic resins were investigated, Trevalon C, which is an internationally recognised acrylic resin and is easily available, Meadway, which is a budget acrylic resin and Pegasus Plus, which is a cross-linked acrylic resin produced by the same manufacturer as the Enigma teeth. According to the information supplied by the manufacturer, the teeth were made from cross-linked poly(methylmethacrylate) and the whole tooth is homogeneous with only colour variations in the body and enamel. Therefore, the acrylic resin tooth discs prepared can be regarded as having a composition and properties identical to those of the ridge-lap. The number of specimens used in this study was 15 per group, compared to 3 per group (ADA specification No.15), to minimise the scatter of results and increase the sensitivity of the statistical analysis.

The curing cycles used were, short cycle, which was the manufacturers' recommended short cycle respectively for all the three resins, medium cycle, which was recommended by the Pegasus Plus manufacturer for curing to obtain minimal residual monomer content. The long cycle was the traditional long curing cycle. After processing the flasks were cooled overnight in the water bath to minimise the internal stress developed by thermal shrinkage[23].

Post ANOVA comparisons confirmed a difference (p=0.031) between Trevalon C and Pegasus Plus materials processed by the medium cycle and a marginal difference between between Pegasus Plus specimens processed using the short and medium cycles (p=0.057). The results of the tensile test were obtained as load at failure in Newtons (N) and the tensile bond strength in megapascals (MPa) was calculated using the formula MPa = N/m^2. The ADA specification No.15 has quoted a standard acceptable value of tensile bond strength of 31MPa. The mean of the tensile bond strength of all the nine groups lie above the acceptable value. The short curing cycle of the Trevalon C group had 33.3% of its specimens below the acceptable value as compared to Meadway group which had 16.6% below acceptable value although, all 100% of Pegasus Plus specimens were above acceptable values. Even though the mean of the short cycle specimens was above the acceptable value, the specimens within the lower range had values that failed to reach the standard and therefore care should be taken while using the short cycle to process dentures as there is a possibility of tooth debonding to occur.

Although Athar *et al* [21] showed that specimens of acrylic resin processed by a short curing cyle achieved adequate transverse strength, the results of the current study show that the short cycle produced specimens of lower tensile bond strength between the acrylic resin and the denture teeth irrespective of heat cured acrylic resin used. Therefore, its effectiveness may be questioned against the background of cost to the British National Health Service of repairs following detachment of teeth from



*American Dental Association specification No.15 - Standard value for tensile bond strength 31MPa

Figure 1. *Scatter plot of individual specimen tensile bond strengths in Mpa (some plots overlap)*

dentures and the obvious convenience of a short curing cycle to dental laboratories. The long curing cycle for all three heat cured acrylic resins produced specimens of acceptable tensile bond strengths as shown in previous studies[19,27,28,29]. The medium curing cycle for Trevalon C and Meadway produced acceptable tensile bond strengths but, marginally higher tensile bond strength was obtained with the cross-linked heat cured acrylic resin Pegasus Plus and the cross-linked Enigma teeth, which were produced by the same manufacturer. This is a finding which should be investigated further with other matched denture teeth and acrylic resin as it may indicate an important technical point. Perhaps manufacturers design and engineer their denture base acrylic resin and their denture teeth together to obtain optimum strength of the bond between them. This has important implications in purchasing materials as it seems possible that there are advantages to buying a system of materials, which have been designed for use together rather than mixing and matching materials from different manufacturers on the basis of cost.

CONCLUSIONS

Within the limitations of this study, when compared to the ADA specification No 15, a short curing cycle produced specimens with low tensile bond strength irrespective of the type of heat cured acrylic resin used. Long and medium curing cycles produced specimens with acceptable bond strength. Pegasus Plus produced specimens with high tensile bond strength, perhaps because it is produced by the same manufacturer as the Enigma teeth used in this study.

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MANUFACTURERS' DETAILS

- Dentsply Caulk, Milford, U.K.
- MR Dental Supplies Ltd, Woking, U.K.
- Davis Schottlander & Davis Ltd, Letchworth, U.K.
- Bego Hydrofix, Bremer Goldschlägerei, Wilh, Germany
- Derotor, Quayle Dental Mfg Co. Ltd, Worthing, U.K.
- Colchester Bantam, the Colchester Lathe Company U.K.
- Instron, High Wycombe, U.K.

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