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Tensile Bond Strength of Heat and Self-Cured Acrylic Denture Base Resins to the Inner and Outer Layers of Two-Layered Acrylic Resin Denture Teeth

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Abstract - *The tensile bond strength of the inner and outer layers of two-layered acrylic resin denture teeth to heat cured and self-curing acrylic resin denture base material was tested. The bond between the heat-cured resin and the inner layer of the denture teeth was significantly stronger than the bond between the heat-cured resin and the outer layer of the denture teeth. The bond between both layers of the denture teeth and the self-curing acrylic resin was significantly weaker than with the heat-cured acrylic resin. In situations where excessive reduction of the teeth is required there may be a case for choosing teeth with a homogenous structure.*

KEY WORDS: Acrylic resin, denture teeth, bond strength

INTRODUCTION

It has been reported that over sixty percent of the acrylic resin dentures produced by the National Health Services of Britain and Northern Ireland required repair within two years of being produced[1]. Tooth de-bonding accounted for about one third of these repairs[1,2]. The bond between acrylic resin denture teeth and the denture base has remained unreliable, inconsistent and unpredictable[3]. The optimal combination of acrylic resin denture tooth, denture base material and processing method has not yet been achieved[4].

The strength of bond between the denture tooth and the denture base depends on a combination of a number of factors: the properties and dimensions of the materials that comprise the parts; adhesion of the parts to one another, and the mechanical connection of the parts to one another. It is reasonable to assume that if the union of the parts can resist separation until one of the materials fails, the joint will have fulfilled its functional requirements[3].

Factors that may influence the bond strength of the denture tooth/base joint which have been studied by investigators fall into five categories: mechanical modifications of the ridge lap of the denture tooth[5-7]; chemical modifications of the ridge lap of the denture tooth[8,9]; the type of acrylic resin denture base used[4,11-13]; the type of denture teeth[10,14,15]; the presence of residuals such as wax or sodium alginate mould seal, which may stay on the ridge lap and consequently reduce the bond strength[16-18].

Manufacturers have continued to develop their products. One innovation has been to manufacture denture teeth in several layers. The outer covering of the crown is designed for abrasion resistance and is heavily cross linked whereas the neck of the tooth is less cross linked to improve bonding to the base acrylic resin. Whilst this system might be expected to produce a better bond between the neck of the denture tooth and the base acrylic resin this may not always be the case. There are situations such as with overdentures, where the supporting elements take up space within the denture. This requires the ridgelap area of the tooth to be reduced thereby removing the part of the tooth designed for bonding. Furthermore, the bond in the gingival cuff region may be less good if the base acrylic resin is in contact with the outer covering of the crown of the tooth.

The aim of this study was to investigate the bond strength of the inner layer and the outer layer of multi-layered denture teeth to heat-cured and self-cured denture base resin.

MATERIALS AND METHODS

This study was based on Myerson Special cross-linked teeth which are made in two layers. An inner layer or core, including the neck of the tooth and an outer layer confined to the crown. They conform to the American Dental Association's specification ASDI/ADA No.15 for synthetic resin teeth, as well as ISO 3336:1993 and carry CE mark 0473. To facilitate specimen preparation single layer teeth were prepared and supplied by Myerson's factory, Levantile, Port-of-Spain, Trinidad. Half of these teeth were constructed of the inner layer only and half were constructed of the outer layer only. This ensured that sufficient bulk of material was available to make the specimens to be tested.

Dumbbell-shape tensile specimens were prepared. Standard aluminium dumbbells, 37.1mm long, 5mm diameter in the test portion and 7.9mm at the dumbbell ends, were used as a basic pattern. Round 1mm diameter profile dental wax was wrapped around the circumference at the centre of the aluminium dumbbell and sealed in place.

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A mould of dental stone was produced using an upper denture flask. The prepared pattern was invested to just below the diameter of the pattern cross-section. Laboratory silicon putty was used to produce the reverse side of the mould for each denture flask to a maximum thickness of approximately 3mm. Separating medium was applied to exposed investing stone and allowed to dry. The second part of the denture flask was positioned and the balance of the mould was poured in dental stone. The mould was left to set for a minimum of 1 hour. The flask was immersed in boiling water for 10 minutes then opened and flushed with clean boiling water. The aluminium pattern was removed. The assembly was cleaned using a brush and powder detergent for complete wax elimination. After drying, sections of the selected teeth (2mm thick) were placed in each mould using tweezers to avoid contamination. Acrylic resin was packed in the mould and processed. Two groups of specimens were prepared for each of the inner and outer layers of the teeth.

The first group, was heat-cured acrylic resin. The acrylic resin was mixed according to the manufacturer's instructions. At the early dough stage it was packed into the mould space which already had the tooth section in place. The flask was assembled and closed slowly up to a pressure of 100kp/cm² for a period of 20 minutes in a hydraulic press. The flasks were then transferred to spring clamps tightened with a torque of 36Nm to ensure the pressure exceeded that of the hydraulic press[19]. The assembly was then subjected to a long curing cycle (6 hours at 72˚ C followed by two hours at 95ºC) in a thermostatically controlled water bath and left to cool slowly overnight before deflasking.

The second group of specimens was prepared in a similar mould but produced in self-cured acrylic denture base resin.

After removal of the acrylic resin dumbbells from the flask they were turned to the appropriate size (27.5 mm length and 4 mm diameter, the head diameter 7mm) in a lathe. All specimens were stored in water at room temperature 20˚C ± 2˚C for one month before testing for tensile strength. Forty heat-cured acrylic resin specimens were prepared in 2 batches. Twenty were bonded to the inner layer of the denture teeth and 20 to the outer layer. However, only fifteen specimens of self-cured acrylic denture base resins bonded to each layer of the denture teeth were produced because the bond was so weak that they fractured during machining. All 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. The machine was calibrated before the testing commenced and was checked following every tenth specimen. 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. The load at failure of the specimen was taken from the chart recorder plots.

Data were analysed using Stata software. Kaplan-Meier failure analysis was followed by Cox proportional hazards model survival analysis.

RESULTS

The study investigated the tensile bond strength between the inner and the outer layer of the denture teeth to heat cured and self cured acrylic resin. The results of the load at failure of the specimens are summarised in Table 1. The data was normally distributed. The mean for specimens of the heat cured acrylic resin bonded to the outer layer was 353N with a confidence interval of 50N, range (575-222). The mean for specimens of the heat cured acrylic resin bonded to the inner layer was 429N with a confidence interval 81N at range (771-160). The mean for specimens of the self-cured acrylic resin bonded to the outer layer was 165N with a confidence interval 29 N at range (274-110). The mean for specimens of the self-cured acrylic resin bonded to the inner layer was 228N with a confidence interval of 40N at a range of (382-150).

These results were subjected to Kaplan-Meier survival estimation, which showed a difference existed between groups ($p \leq 0.01$). Subsequent Cox survival analysis showed bonding of heat cured acrylic resin to the inner layer of the denture teeth to be significantly higher than to the outer layer ($p \leq 0.01$). Self-curing resin was significantly weaker than heat cured, but there was no significant difference between the bond strength of self-curing resin to the inner or outer layers of the denture teeth.

DISCUSSION

This study was undertaken to test the tensile bond strength of heat and self-cured acrylic resins bonded to both outer and inner layers of acrylic denture teeth. In order to facilitate preparation of suitable specimens the teeth used were cross-linked acrylic resin and were specially custom made by the manufacturer as single layer teeth, one set of teeth comprising the outer layer only and the other comprising of the inner layer only. Bond strength was determined by testing acrylic resin specimens in tension. ADA standard No.15 for acrylic resin teeth was used as a protocol for measuring tensile bond strength. However, the protocol was modified using a larger specimen size of 20, instead of 3 in order to increase reproducibility.

The highest value for bond strength was for bonding to the inner layer of the teeth with heat cured acrylic resin. The mean bond strength of the groups in descending order of efficiency was heat cured resin bonded to the inner layer of the teeth (34 Mpa), heat-cured resin bonded to the outer layer of the teeth (28 Mpa), self cured resin bonded to the inner layer of the teeth (17 Mpa) and self-cured resin bonded to the outer layer of the teeth (13 Mpa).

Table 1. *Descriptive statistics giving the sample size, the mean value and the standard error (Newtons)*

Column	*Specimens No.*	*Mean*	*Std.Dev*	*Std. Error*	*C.I. of Mean*
Heat Cured outer layer	20	353	108	24	50
Heat Cured inner layer	20	429	174	38	81
Self Cured outer layer	15	165	52	13	29
Self Cured inner layer	15	228	72	18	40

Survival analysis demonstrated that the bond between the inner layer of the denture teeth and heat cured denture base resin was significantly higher than the bond between the outer layer of the teeth and the heat cured denture base resin ($p \leq 0.01$). The bond to heat cured denture base resin of both layers was significantly higher than to self-curing resin.

The heat-cured acrylic resin bonded to the inner layer gave a mean bond strength above the standard value of 31MPa quoted by the (ADA) No 15. The mean of the heat cured resin bonded to the outer layer is below the acceptable standard value of 31MPa. However, the self-cured acrylic resin gave both its mean values considerably lower than the standard. Self-cured acrylic resin is known to bond poorly to synthetic polymer teeth and this is recognised in ISO 1567. When self-curing resin is used with synthetic polymer teeth repair type resin designed for the purpose should be used.

The results of this study are clinically relevant. Clinical experience shows that in situations where there is a lack of space, as may occur, for example, with an overdenture supported either on a number of teeth or on implants with a bar for retention, it may be necessary to remove most if not all of the ridgelap part of the teeth. Very little of the inner layer will remain for bonding. The bond formed between the outer layer and the base resin may fail in service. There are basically three types of modern polymeric denture teeth, those which have the same acrylic resin throughout, those which are made in layers with different characteristics and those with a polycarbonate layer on the crown. In situations where excessive reduction of the ridgelap is required there may be a case for choosing teeth with a homogenous structure.

CONCLUSIONS

1. The tensile strength of the bond between the inner layer of the teeth tested and heat cured denture base acrylic resin was significantly higher than the bond between the heat cured denture base resin and the outer layer of the teeth.
2. The tensile strength of the bonds between the heat cured denture base resin and both the inner and outer layers of the denture teeth were significantly stronger than the bonds to self –curing resin.

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MANUFACTURER'S DETAILS

- Myerson Ltd, Harrow, UK.
- TQ International, Nottingham, UK.
- Chaplin and Jacobs, North Cheam, UK.
- Kaffir D, British Gypsum, Newark, UK.
- Varsity ejector type Buffalo N.Y. U.S.A.
- Zetalabor, Zhermack, Rovigo, Italy.
- Selectaplus H / Trevalon Dentsply Caulk, Milford, UK.
- Bego hydrolytic Bremer goldschlagene wilh Hcrbest Germany.
- Derotor Multicure, Quayle Dental Dominion, Worthing, UK.
- Auto cure repair powder, St George Technology. Handcross, UK.
- Colchester Bantam, The Colchester Lathe Company, Colchester, UK.
- Instron, High Wycombe, UK.
- StataCorp.2005. Stastical Software System: Release 9.1. College Station, TX: USA

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