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Research Article

The effect of glass transition on the bond strength at the interface between denture teeth and denture base

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ABSTRACT

The bond strength at the interface between denture teeth and denture base was studied under conventional processing and additional secondary heat above glass transition temperature.

Twenty denture teeth were processed with heat activated denture base material with conventional compression molding technique. 10 specimens were exposed to the additional secondary heat treatment above the glass transition temperature, at 120°C for 45 minutes, while other 10 specimens were stored in the water at room temperature. All specimens were retrieved from the flasks and subjected to oblique shear force to fracture and the load of failure was reported as the bond strength. Data were analyzed by one-way ANOVA.

The secondary heat treatment above glass transition temperature resulted in a significantly increased bond strength between the denture teeth and the denture base ($p<0.05$). The load to failure of conventionally processed group was 259±40 N and the secondary heat-treated group was 313±33 N. In addition, the failure mode on the denture teeth-base interface with conventional processing was adhesive failure while cohesive failure within the denture base was observed on the secondary heat-treated group.

Within limitations of this study, it can be concluded that secondary heat treatment above glass transition temperature can significantly increase the bond strength of conventionally processed denture teeth-base interface.

Introduction

The acrylic denture teeth and poly-methylmethacrylate (PMMA) denture base materials have been widely used for denture fabrications. A sufficient bond strength leads to the intact denture teeth-base interface while fracture occurs within either material [1]. Previous surveys have reported that 26% to 33% of denture repairs were associated with debonded teeth [2, 3]. The failure modes can be classified as cohesive, adhesive, and combination depending on the location of fractures. Adhesive failure occurs at the interface between two materials and cohesive failure occurs within either denture teeth or denture base with intact interface [4].

The contributing factors for bond failure include fatigue, excessive stress, insufficient tooth cleaning during denture base acrylic resin placement, contamination by wax and tinfoil substitute, and improper heat polymerizing procedures [5]. Many attempts have been made to improve bond strength between acrylic denture teeth and the denture base, such as bonding agents, ridge lap grinding, ageing, solvents or monomer-polymer solution application, various tooth material,

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diatorics, various denture base materials, crosslinking agents, thermocycling, polymerization temperature rise and microwave polymerization [1, 5-17].

In the unpublished previous study on the characterization of the glass transition temperature (Tg) for PMMA denture base at different stages of processing, it was found that the conventionally heat processed denture base exhibited decreased Tg than denture base powder but remained above 100°C. Moreover, a secondary heat treatment above Tg has shown the alteration of thermal property of processed denture base and resulted increased Tg that was not significantly different from the denture base powder. In addition, the tissue portion of the denture teeth has shown similar range of Tg as conventionally processed denture bases. Therefore, it can be postulated that the glass transition would occur on both tissue portion of denture teeth and the denture base upon a secondary heat treatment above Tg. The interaction between denture teeth and the base can be intensified upon glass transition due to polymer blending effect [18].

Therefore, the aim of present study was to evaluate the effect of the secondary heat treatment above Tg on the bond strength between PMMA denture base and denture teeth. The null hypothesis was that the bond strength between denture teeth and the PMMA denture base will not change by a secondary heat treatment above Tg.

Materials and Methods

Sample Preparation

Two maxillary second premolar denture teeth (Mold N6; SR Orthotyp DCL, Ivoclar Vivadent Inc.) were used to create stone index for standardized specimen trimming. With the stone index, twenty denture teeth were uniformly trimmed to 1 mm below the cervical line and the trimmed tissue surface formed 60° to the long axis. Then, the trimmed denture teeth were waxed onto the 30° beveled surface of rectangular wax blocks. The slope of the beveled surface of wax block was aligned with the denture teeth so the long axis of the teeth was 90° from the base of the wax block. The specimens were randomly divided into control group and experimental group.

The conventional flasking, wax loss, compression molding, and heat processing were carried out to process all 20 specimens. The heat cure poly-methylmethacrylate denture base (LUCITONE 199, DENTSPLY International Inc.) was mixed with recommended powder/liquid ratio, 21G (32 cc)/10 mL, compressed, and processed according to the manufacturers' instruction, 74 C° for 9 hours in the water bath processor. The control group was composed of 10 specimens within the flasks which were kept in water at room temperature. The experimental group flasks, kept in the clamps, were subjected further to secondary heat treatment above glass transition temperature (Tg) by using a pressure cooker (Big Boss, Emson, NY) for 45 minutes under pressure of 30 psi (15 psi above atmospheric pressure), at which the boiling point of water reaches 120 °C. After cooling down to room temperature, all twenty specimens of both groups were retrieved by deflasking and prepared for loading test.

Oblique Shear Loading

All specimens were subjected to oblique sheer force by using Instron testing machine (Instron 5500R; Instron Corp.). The load was applied at 90 degrees to the long axis of the denture teeth, which results in oblique shear force 30 degree to the denture tooth-based interface, with 1 mm/min crosshead speed until fracture and the load at the failure was recorded and analyzed (Fig.1).

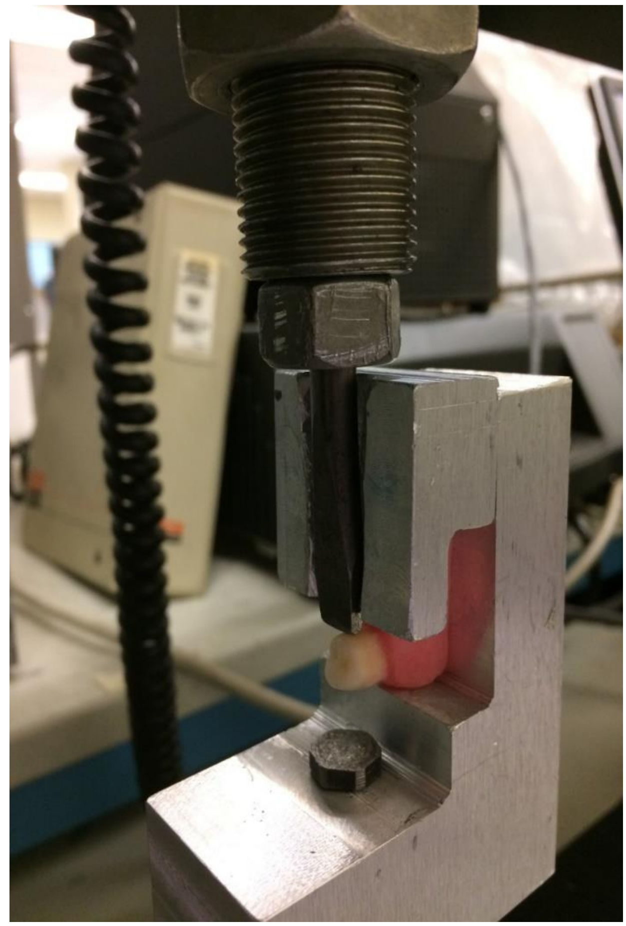

Figure 1: Shear force applied at 90 degrees to the palatal surface of a denture tooth result in 30-degree oblique shear force on the interface between denture teeth and the base

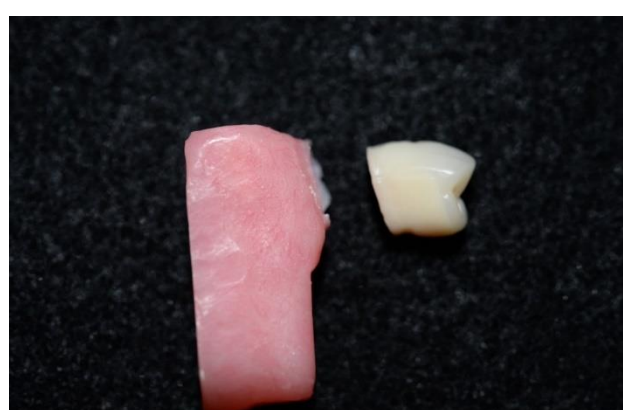

Figure 2: The adhesive failure, the fracture predominantly occurred between the denture base and the denture teeth

Figure 3: The Cohesive failure, the fracture predominantly occurred within the denture base

The failure mode was studied and categorized as either adhesive or cohesive failures. The adhesive failure was determined when there was no evidence of denture base material on the surface of the tooth after fracture (Fig.2). On the other hand, the presence of denture base material on the surface of the denture tooth or fractured portion of the denture tooth on the denture base material would indicate cohesive failure (Fig.3). All procedures were performed under uniform atmospheric circumstances of 25.0 ± 1 and 50% ± 1 % relative humidity. Data were analyzed by one-way analysis of variance (ANOVA).

Results

Table. 1 shows the means and standard deviations of control group and experimental group. The load at failure was 259 ± 40 N for control group and 313 ± 33 N for experimental group. There was statistically significant difference between the two groups (*p*=0.0026).

The adhesive failure between denture teeth and denture base was observed in control group while consistent cohesive failure within the denture base was seen in experimental group (Fig. 2 and Fig. 3). No adhesive failure was recorded in the samples with secondary heat treatment above Tg.

Table 1: Load at Failure mean values and standard deviations between PMMA denture base and denture teeth.

Control Group mean (SD)	Experimental Group mean (SD)	F Value	*P*
259 ± 40 N	313 ± 33 N	12.21	0.0026

Discussion

The strength of bonding between PMMA denture base and acrylic denture teeth was investigated before and after secondary heat treatment above the glass transition temperature. Many factors that can affect bond strength have been studied such as resin types and brands, tooth types and brands, method of processing, temperature of processing, stress distribution, resin stage, and processing variables [14]. Studies have reported that the bond quality of acrylic teeth to denture base resin depends on the polymerization and diffusion of monomer across the interface to create an interpenetrating polymer network. The proficiency of the accomplishment of a strong bond depends essentially on the rate at which the monomer diffuses from the base resin mixture. Higher diffusion rate of the monomer of a denture base polymer mixture into the acrylic denture teeth is accomplished by rising the polymerization temperature [19-22]. The conventional denture processing technique limits the temperature under boiling point of water. To date, no attempt has been made to treat the denture bases above the glass transition temperature.

This study employed secondary heat treatment above Tg to the conventionally processed denture teeth-base complex, kept flasked within the clamp, to evaluate the effect of polymer diffusion/blending on bond strength between denture teeth and the base. Based on a differential scanning calorimetry (DSC) study on Tg for PMMA denture base at different stages of processing, the conventionally heat processed denture bases reaches the glass transition at 108°C ~ 110 °C. Also, it was found that the glass transition temperate of the acrylic resin tooth was ~113°C. It was reasonable to postulate that the secondary heat treatment at 120°C may introduce sufficient kinetic energy to promote “polymer blend” and improve “bond strength” between the denture teeth and the base.

The result showed a significantly increased “load to failure” in secondary heat-treated specimens, 313 ± 33 N over 259 ± 40 N for control group ($p < .05$). In addition, because all the specimens in secondary heat-treated group showed cohesive failure within denture base, it can be safely concluded that the bond strength between denture teeth and the base is significantly higher than that of conventionally processed denture.

The secondary heat treatment above the glass transition temperature (Tg) results in both the denture base and the tissue surface of denture teeth undergo reversed glass transition i.e. solid to glass phase. Due to spacial proximity, kinetic energy, and relatively active polymer chain micromotion, a promoted interaction between the denture base and tissue surface of the denture teeth seems to occur in the interface and to create “polymer blend” layer. This may explain adhesive failures in conventionally processed denture and cohesive failures in secondary heat-treated denture teeth and base block. Compatibility or Mutual solubility of two polymers is fundamental for the formation of the interwoven polymer and in addition for the strength of the bond [18].

In present study, the actual bond strength between the denture teeth and the base after the secondary heat treatment was not measured due to cohesive failure within denture bases with intact teeth-base interface. However, the load to cohesive failure was significantly higher than that of adhesive failure in conventionally processed denture teeth-base complex. So, it is safe to conclude that the secondary heat treatment above Tg leads to interpenetration at the interface to increase bond strength. Further study will be needed to measure the actual strength to provide clinical guidance for denture construction and prognosis.

Conclusions

Within limitations of this study, it can be concluded that the secondary heat treatment above Tg can promote interaction between denture teeth and base to improve bond strength. Further studies are needed to quantify the bond strength of the interface between denture teeth and the base after secondary heat treatment above Tg.

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