10.5005/jp-journals-10024-1463
ORIGINAL RESEARCH

Palatal Vault Depth Influence on the Flexural Strength of Two Heat Cure Acrylic Denture Base Resins: An *in vitro* Study

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ABSTRACT

Complete dentures often fracture during normal masticatory function. The reason could be due to the shape of the palate, i.e. deep, medium or shallow palatal vault. This *in vitro* study was performed to determine the relationship of palatal vault depth and flexural strength of two different permanent denture base resins. Edentulous maxillary casts of patients were collected from the department of prosthodontics, among these the cast with the deepest palatal vault was selected. The specimens were then subjected for flexural strength on universal testing machine. The results revealed that the denture bases fabricated on medium palatal vault depth were best in the flexural strength and denture bases on shallow palatal vault depth faired the least. Among the resins the denture bases fabricated using high impact heat cure resin, were better than the denture bases fabricated using regular heat cure resin. All these results were statistically significant except the results between the regular heat cure denture bases and high impact heat cure denture bases fabricated on the deep palatal vault depth. Also the comparison of fracture energies of denture bases fabricated on deep palatal vault with high impact heat cure resin to denture bases fabricated on medium and shallow palatal vaults with high impact heat cure resin were not significant. It was also observed that all the specimens have fractured in the midline.

Clinical implications: Palatal vault depth significantly affected the flexural strength of heat cure resin. The most frequent mechanical failure of heat cure resin is fracture especially at the midline. The denture bases fabricated using high impact heat cure resin had best flexural strength than the denture bases fabricated using regular heat cure resin which reduced the fractures.

Keywords: Flexural strength, Palatal vault, Denture base resins, Complete dentures.

How to cite this article: Reddy BMM, Himabindu M, Padmaja BI, Sunil M, Reddy NR. Palatal Vault Depth Influence on the Flexural Strength of Two Heat Cure Acrylic Denture Base Resins: An *in vitro* Study. J Contemp Dent Pract 2013;14(6):1131-1136.

Source of support: Nil

Conflict of interest: None

INTRODUCTION

Edentulism is a matter of great concern to the majority of people and their replacement by artificial substitute, such as denture is vital to the continuance of normal life. One of the requirements of the denture is its ability to function for a minimum required period.

The material most commonly employed in the construction of denture base is polymethylmethacrylate. Despite its popularity in ease of manipulation, esthetic qualities and repair ability, it is far from ideal in fulfilling the mechanical requirements.[1] The most frequent mechanical failure of polymethylmethacrylate is fracture. The fracture of denture base is the most common in maxillary arch and especially so when maxillary denture base opposes the mandibular natural teeth. The fracture may be due to two different types of force, i.e. impact force and flexural force. The impact force may fracture denture base when they are dropped. Flexural fatigue occurs due to repeated flexing of the denture base. This type of failure can be explained by the development of microscopic cracks in areas of stress concentration. It is also reported that frenal notch, foreign particles, gas inclusion and surface irregularities acts as stress concentrators and leads to the fracture of denture base.[2]

There are two approaches for preventing denture fractures; one is to strengthen the denture base material, and the other is to reduce the stress at the midline. Chemists have produced grafted polymethylmethacrylate, which show increased resistance to impact force but the question arises as to whether these resins are resistant to flexure fatigue.[2]

Palatal vault depth of edentulous patients has been the subject of several studies. The palatal vaults are classified as shallow (flat), medium (u-shaped) and deep palatal (v-shaped) vault based on palatal vault depth.[3] Many studies have been carried out and have reported that the different palatal vault depths affected the retention of maxillary denture base[4] but very few studies have been carried out to know the effect of different palatal vault depths on the flexural strength of heat cure resin. Hence, if the hypothesis that the different palatal vault depth has an effect on the denture base could be proved and future behavior of denture base could be predicted based on these different vaults, then steps to prevent fracture may be initiated.

Earlier *in vitro* studies have been done using rectangular strips of denture base resin as per the ADA specification but very few studies have been done to simulate the maxillary arch configuration. In addition comparisons of flexural strengths of regular and high impact heat cure resin in different palatal vaults with uniform denture base thickness has not been considered. Hence the present study was designed to compare the effect of palatal vault depth on flexural strength between regular and high impact heat cure denture base resin with recommended uniform denture base thickness.

MATERIALS AND METHODS

The *in vitro* study was conducted to evaluate and compare the flexural strength of commercially available denture base resins in three different palatal vault depths.

This study is conducted on the maxillary edentulous denture bases to determine the effect of three different palatal vault depths on the flexural strength of two different heat cure denture base resins.

For the study, from the department of prosthodontics an edentulous cast with deep palatal vault was procured. The basis for selection was on the method suggested by Johnson et al[3] and Mehmet Avcl et al.[16] A surveyor, a scale and a divider were used to measure the depth of the palate (Fig. 2).

Specifications for Selecting Deep Palatal Vault Cast

The crest of the incisive papilla (A) and the highest point on both the hamular notches (B) and (B') were joined and the midpoint of this line was marked as point (C). The midline of palate was drawn by joining point A and C. A point (D) corresponding to the center of (AC) was marked on line (AC). Two perpendicular lines were drawn from D on either side of ridge E and E' which are parallel to line BB'. This pointed to a spot which is the center of the cast. On cross arch line (ee') the surveyor was placed and the length of the surveyor tool that relates to the depth of the palate was measured with a scale (Fig. 1).

Classification of the Cast based on Palatal Vault Depth

If the depth was

i Less than ¼ inch it was classified as shallow or flat group.[3]

ii Between ¼ inch and ½ inch were classified as medium.[3]

iii Exceeding ½ inch was classified as high or deep palatal vault cast.[3]

After the selection of the cast with deep palatal vault depth, it was used as master specimen for deep palatal vault. The cast was duplicated to get two more casts. These two were modified into medium and shallow vault cast by adding plaster mix only in the deep part of the palatal surface area such that it satisfies the parameter of medium and shallow palatal vault depth, there by maintaining the ridge configuration as a standard with the change only in the palatal depth and surface. Molds were made for the shallow, medium and deep palatal vault casts using silicone duplicating material.

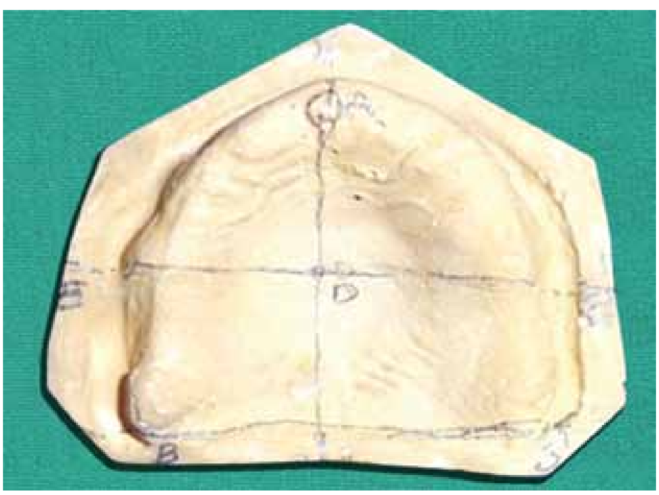


Fig. 1: Maxillary cast with measurement lines

Fig. 2: Armamentarium used in the study

Table 1: The specimens were grouped as follows

Groups: Based on the type of vault	*Subgroup: based on material used*	*Number of specimens*	*Nomenclature*
Group A—deep palatal vault	Subgroup I—regular heat cure resin (AI)	7	AI 1-7
	Subgroup II–high impact heat cure resin (AII)	7	AII 1-7
Group B—Medium palatal vault	Subgroup I—regular heat cure (BI)	7	BI 1-7
	Subgroup II—high impact heat cure resin (BII)	7	BII 1-7
Group C—shallow palatal vault	Subgroup I—regular heat cure (CI)	7	CI 1-7
	Subgroup II—high impact heat cure resin (CII)	7	CII 1-7

Table 2: Statistical comparisons of means of energy to fracture between different heat cure resins

Type of vault	*Heat cure*	*Mean ± SD*	*p-value*	*Significance*
Shallow	Regular	8.05 ± 0.22	0.0001	p < 0.05
	High impact	10.52 ± 0.36		
Medium	Regular	19.00 ± 0.04	0.328	p < 0.05
	High impact	25.10 ± 0.20		
Deep	Regular	16.25 ± 0.15	0.648	p > 0.05
	High impact	19.00 ± 0.17		

Fig. 3: Specimens stored in distilled water

Fourteen casts of each group of palatal vault were made in dental stone. The dental stone was mixed according to the manufacturer's recommendations and then gradually vibrated into the mold using vibrator. A total of 42 casts in 3 groups were made and coded (Table 1).

Preparation of the Test Specimens

A uniform layer of 2 mm modeling wax sheet was adapted on the cast. The thickness of the wax was verified using the calibrated periodontal probe so as to have control over thickness of denture base. The pattern was invested, dewaxed and packed with heat cure acrylic resin (DPI), using trial closures and processed. Regular heat cure resin was used to pack seven flasks in each group and high impact heat cure resin for the other seven flasks. Acrylization was done following the short curing cycle (74°C for 1½ hours and then at 100°C for 30 minutes) in the electrical acrylizer. Bench cooling was carried out for first 30 minutes in air and next 15 minutes in water. After deflasking, the permanent denture base was recovered and the thickness of the permanent denture bases was verified using thickness measuring gauge. Finishing and polishing was carried out using conventional technique as used for complete denture. The finished samples were stored in water at room temperature for 48 hours (Fig. 3).

Testing of the Specimens

The prepared heat polymerized acrylic denture base specimens were tested for their fracture threshold on the universal testing machine to obtain two vital parameters, that is the load to which denture bases fracture (fracture load) and the amount of deflection before fracture (fracture deflection). Using these two parameters third parameter that is fracture energy was calculated using the standard formula.

The samples of the permanent denture bases were kept with the nontissue side that is the polished surface on the platform of the universal testing machine (UTM). A round plunger of diameter 5 mm was placed in midline on the most prominent point of palate between premolar and molar region. With the help of UTM, the load in compression was gradually applied at the rate of 5.0 mm/min to the tissue side. The load to fracture of the denture bases (in kilograms) and the corresponding deflection (in centimeters) to the time of fracture were recorded (Fig. 4).

CALCULATIONS

The load to fracture of the base (in kilograms) and the corresponding deflection (in centimeters) to the time of fracture were recorded. From the above two a value, fracture energy was calculated by using the standard formula:

Fracture energy = ½ × fracture load (kg) × deflection (cm) at the time of fracture.

The readings were recorded and the mean was calculated (Table 2).

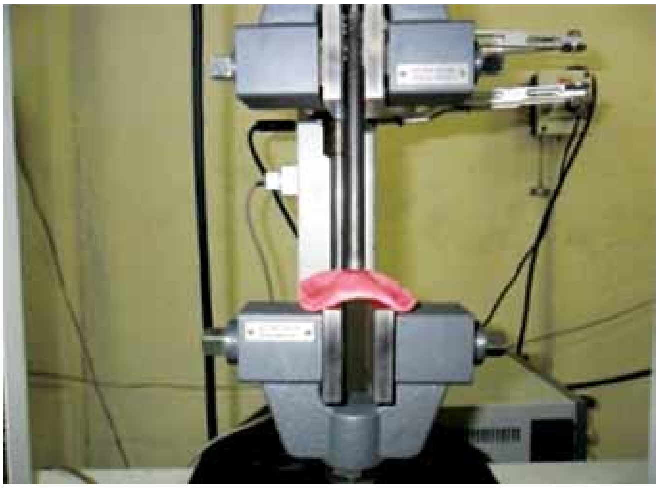
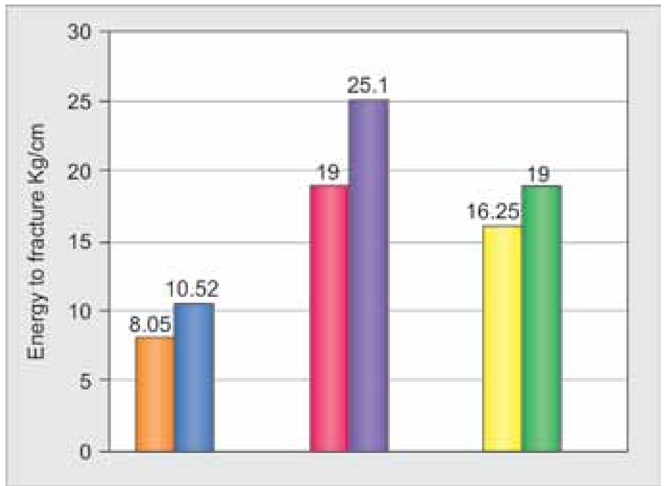


Fig. 4: Specimen on universal testing machine



Graph 1: Comparison of mean flexural strength of high impact heat cure resin in shallow, medium and deep palatal vault

Statistical Analysis

Following statistical methods were applied in the present study:

1. Descriptive statistics
2. Student paired 't' test.

Results and Discussion

Dentures are used as artificial substitute when a number of teeth are missing. The denture base is that part of the denture which rests on the soft tissues and does not include the artificial teeth. Since denture base materials must withstand forces during function and while in service, the mechanical properties are important. Because no single property can give a true measure of the quality of the denture, it is essential to understand the principles involved in a variety of mechanical properties if maximum service is to be obtained. Quantities of force, stress, strain, strength, hardness and others can help identify the properties of a material.[15]

Materials used in the construction of denture bases may be classified as metallic and nonmetallic. The ideal denture base material must satisfy a list of physical, chemical, mechanical and biological requirements. However to date, no known denture base material adequately fulfills all these requirements.

Acrylic resin meets most of the requirements of an ideal nonmetallic denture base material. It has a number of advantages such as good esthetics, ease of fabrication, low capital cost and good surface finish while its disadvantages are low impact strength, flexural strength low enough to penalize poor denture design and short fatigue life.[6] Mechanical properties of heat polymerized acrylic denture bases indicate that the acrylic resin is weak, flexible and soft. However, provided the base is of adequate thickness, both strength and rigidity are generally adequate to resist failure. Failure of a denture may be due to a number of causes such as deficiency in design, defective occlusion,[12] and presence of a deep frenal notch or a diastema,[7,8] sharp changes in the contour of the denture base.[7,8] Other causes include an edentulous denture base foundation that fails to distribute the applied load evenly,[9] failure to carry out laboratory procedures meticulously,[2] fracture from flexural fatigue,[5,10] failure to use the suitable impression technique as dictated by supporting tissues, poor fit of the prosthesis, and limitation of the material itself. Thus a denture fracture is multifactorial.

Deformation of the denture base occurs under masticatory load and the number of flexions it undergoes is estimated to be close to about 500,000 per year. Over several years the denture base will thus experience several million flexions during use. Acrylic dentures flex in function to a much greater degree than expected.[11,13] Maxillary denture base deforms during functional and parafunctional activity such as chewing, biting, swallowing and clenching. It deforms away from the palatal tissues causing internal stresses. Therefore fatigue stress might be a significant factor in fracture.

There are two approaches for preventing denture fractures; one is to strengthen the denture base material, and other is to reduce the stress at the midline. Several methods have been suggested to strengthen the denture base material; by the chemical modification of a denture base material such as copolymerization with a rubber graft copolymer or the addition of cross-linking agents, and the reinforcement of PMMA with other materials, such as carbon fibers, glass fibers (fiberglass), and ultrahigh modulus polyethylene fibers. Dentures designed to reduce stress at the midline have also been investigated, such as increasing the denture base thickness, arranging artificial posterior teeth on the inner side of the residual ridge, and the use of a strengthener. Increasing the denture base thickness in the anterior region is not desirable because it reduces the tongue space and thus affects phonetics, and the artificial posterior teeth must be arranged with consideration of not only the shape of the maxillary and mandibular residual ridge but also the relationship between them.[17]

The present study deals with the effect of the flexural strength on denture base which is of 2 mm uniform thickness. The primary objective of this study was to determine the correlation between various depth of palatal vault (i.e. shallow, medium and deep) and flexural strength of heat polymerized acrylic resin denture base.

The stresses to which a denture base is subjected are complex. In our study we tested three different depth of the palatal vault because the depth of the palate may have a role in the distribution of stresses that occur during functional and parafunctional movements of the jaw.[1]

Acrylic resin denture bases were processed on 42 casts and each specimen was subjected to loading on a Universal-testing machine. The load was applied by a 5 mm diameter flat end plunger mounted in the upper jaw of the machine at the rate of 5 mm/min to fracture the test specimen. At the point of fracture of denture base two vital parameters, i.e. fracture load and fracture deflection were noted for each specimen. Fracture energy was then calculated by using the standard formula – half the product of the fracture load (in kg) and fracture. The results of this study indicate that the flexural strength of shallow palatal vault is less when compared to medium and deep palatal vault. This finding correlates with the findings of Morris JC, Khan Z and Von Fraunhofer[13] who concluded that the denture bases fabricated on the shallow palatal vault configuration were inherently weaker and less resistant to fracture than the denture bases for medium and deep palatal vault.

The results also indicate that medium palatal vault has better flexural strength compared to deep palatal vault. This finding is not correlating with the previous study by Morris JC, Khan Z and Von Fraunhofer[13] where they have stated that there is no statistical significant difference between medium and deep palatal vault. The reason might be that in their study they selected different edentulous maxillary cast with varying palatal vault wax up for the fabrication of denture base was not standardized. Whereas in our study, to standardize the method, 50 edentulous maxillary casts of patients were collected and among these the deepest palatal vault cast was selected based on classification given by Johnson et al[3] and it was modified to medium and shallow palatal vault to standardize the dimension of the cast and to control the thickness of the denture base, wax pattern was made and the thickness of the wax was verified using the calibrated periodontal probe.

The reason for different flexural strength of different palatal vault could be as suggested by Schneider[14] that the fulcrum created in a denture at the mid-palatal suture contribute to variation in resistance of the denture bases to fracture in different palatal vault configurations.

CONCLUSION

Within the limitations of the study, the following conclusions were drawn:

i Among the designs, denture bases fabricated on medium palatal vault depth had best flexural strength and denture bases on shallow palatal vault depth had the least (Graph 1).
ii Among the resins the denture bases fabricated using high impact heat cure resin had best flexural strength than the denture bases fabricated using regular heat cure resin.

All these results were statistically significant except the results between the regular heat cure denture bases and high impact heat cure denture bases fabricated on the deep palatal vault depth. Also the comparison of fracture energies of denture bases fabricated on deep palatal vault with high impact heat cure resin to denture bases fabricated on medium and shallow palatal vaults with high impact heat cure resin were not significant. It was also observed that all the specimens have fractured in the midline.

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