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A Comparative Study of Palatal Shapes And Flexural Properties of Edentulous Maxillary Conventional Heat Polymerised Acrylic Resin Denture Bases With Glass Fibre/Metal Mesh Reinforced Bases.

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Abstract
OBJECTIVES: - *This in vitro study was performed to determine the relationship of depth of palatal vault and fracture strength of permanent conventional denture bases with the glass fibre & metal mesh reinforced conventional denture bases keeping one standard thickness.*
METHODS*: - Edentulous maxillary cast of shallow, medium and deep palatal vault were selected. Each cast was duplicated twenty four times. 8 cast of each group of palatal vault configuration were made. Casts of each palatal vault depth form were waxed to 2.00mm thickness. These patterns were processed with DPI Mumbai India heat polymerized acrylic resin. The thicknesses of the denture bases of conventional reinforced with glass fibres & metallic mesh were measured. These denture samples were kept with non tissue side on the platform of universal testing machine and the load is applied at the rate of 5mm/min. Flexural strength was evaluated and the results were analyzed with Mann – Whitney test.*
RESULTS: - *Results revealed that a direct relationship exists between the fracture load and the denture base reinforced with glass fibres & metallic mesh. As the denture base is reinforced, load required to fracture also increased proportionally. The effect of different shapes of palatal vault configuration on fracture strength revealed that denture bases fabricated on shallow palatal vault of 2mm thickness fractured at lower values of load. Thus denture bases on the shallow palatal vault of 2mm thickness are inherently weaker than denture bases on medium and deep palatal vault configurations.*
CONCLUSION: - *DPI Mumbai India Heat polymerized acrylic resin denture bases on shallow palatal vault are inherently weaker and less resistant to fracture than denture bases fabricated on medium and deep palatal vault configurations. Reinforcing the denture bases significantly increases the fracture load and fracture energy and hence increases the fracture strength of the denture base on a shallow palatal vault.*
Keywords: *Flexural strength; palatal vault; denture base resins.*

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I. Introduction

The introduction of more satisfactory plastic denture base material occurred in 1937 when Dr Walter Wright described the results of his clinical evaluation of methyl methacrylate resin .The acrylic resin generally have been found to have relatively satisfactory qualities including appearance, dimensional stability and simple procedures for processing of denture . The patient is generally pleased with the color characteristics and function of the dentures.[1]

Despite of these excellent properties it is not free from disadvantages. One of the problems encountered in the provision of prostheses is limitation of its strength to meet the functional demands of the oral cavity. During function the denture base is subjected to various stresses like compressive, tensile and shear stress leading to denture fracture. In order to withstand these stresses, the denture base should posse's good mechanical properties. One of the important properties is flexural strength. A number of predisposing factors have been recognized for the incidence of denture fractures. These include unsatisfactory occlusion, poor fit of the prosthesis, deep frenal notches, and sharp changes in the contour of denture bases. Other factors which contribute to the denture facture are the morphology of edentulous denture base foundation which is capable of distributing the load applied, impression techniques as dictated by underlying condition of bone and the soft tissue, topography of the denture foundation and various laboratory procedures of denture fabrication which are carried out meticulously.[2]

The fractures of dentures in situ do occur, however as a result of fatigue. Both the number of the cycles imposed as well as the shape of the structure that undergoes cyclic loading determines fatigue. Deformation of denture bases occurs under masticatory loads and the numbers of flexions are estimated to be close to 50, 0000 per year. Over several years, the denture base thus experiences several million flexions during use. Maxillary denture bases will thus deform away from the palatal tissues and so fatigue might be a significant factor in fractures. Acrylic resin has relatively poor resistance to fatigue fracture, a fact that is responsible for number of denture repairs.[3]

An edentulous maxillary arch has a composite form that reflects the original contours from which disease, trauma, and body chemistry have subtracted teeth and alveolar bone. With the passage of time, unknown factors governing an individual response to oral trauma contrive to remodel the bone of the maxilla.

In the Prosthodontic literature, palatal shapes have been classified according to their cross-arch forms. Nicholas described the vault form in the edentulous maxilla as tapering, square, arched, or flat. Other researchers analyzed the contours and concluded that the cross-arch palatal forms could be categorized as "V "shaped, "U" shaped, flat, or high, medium, low, rounded or combinations thereof[4,5,6,7,8.]

In case of maxillary denture, palatal vault shape may influence the fracture strength of heat polymerized acrylic resin denture base. Generally palatal vault of various configurations can be classified into three groups as suggested by Johnson et al viz[:9]

a) Shallow
b) Medium
c) Deep

Methods to improve the inherent material properties of polymethylmethacrylate resin have included reinforcing agents such as particulates, and fibers. The first approach is to increase the strength of denture base polymer by adding a cross-linking agent of polyfunctional monomer such as polyethylene glycol dimethacrylate. Cross linking lowers strength and flexibility but increases solvent resistance, softening point, and hardness. Fatigue and impact strength are usually reduced. The second approach is to devise a reinforcement of denture base polymer with fibers or rods such as Metal fibers, stainless steel metallic denture mesh, Carbon fibers, Aramid fibers and Ultra high molecular weight polyethylene fibers.[10]

Various fibers available to improve the strength are Metal fibers, Carbon fibers, Aramid fibers, Polyethylene fibers and Glass fibers. Fiber reinforcement has increased the flexural and impact strength of denture base resin, but each of them has their own advantages and disadvantages. Metal fibers increase the strength but its use is limited because of the obvious effects on aesthetics. Carbon fiber has a springy nature in handling and is less aesthetic than other fibers. Aramid fibers are not esthetic and difficult to polish. In case of polyethylene fibers, the surface treatment to improve the adhesion between fibers and denture base polymer is complicated[11].

Numerous studies have been conducted on reinforcement of fibres and metal strengtheners to improve the strength of the denture bases. But it seems that very little work has been carried out to compare the flexural properties of resin denture bases with that of palatal shapes by reinforcing the glass fibres and stainless steel denture mesh.

II. Methodology

This invitro study was conducted in the Department of Prosthodontics, The oxford college of Dental sciences and research Bangalore, and the Department of Applied Mechanics–Load Testing Department, Composites Technology Park, Bandimutt, Kengeri Satellite town Bangalore, for the evaluation of the relationship between the fracture strength of the maxillary permanent denture bases, reinforced with glass fibres & metallic mesh over the conventional maxillary heat cure denture bases for the different palatal vault configurations.

Study was conducted on the denture base fabricated on edentulous maxillary cast to determine the effect of reinforcement of the heat cure denture bases with glass fibres and metallic mesh, with that of the conventional heat cure denture bases in three different shapes of palatal vault configuration for the fracture strength of the denture bases. For this, three edentulous maxillary cast of patient were selected to group them as;

1. Shallow palatal vault
2. Medium palatal vault
3. Deep palatal vault.

Based on the methods suggested by Johnson et al. and Avci et.al.

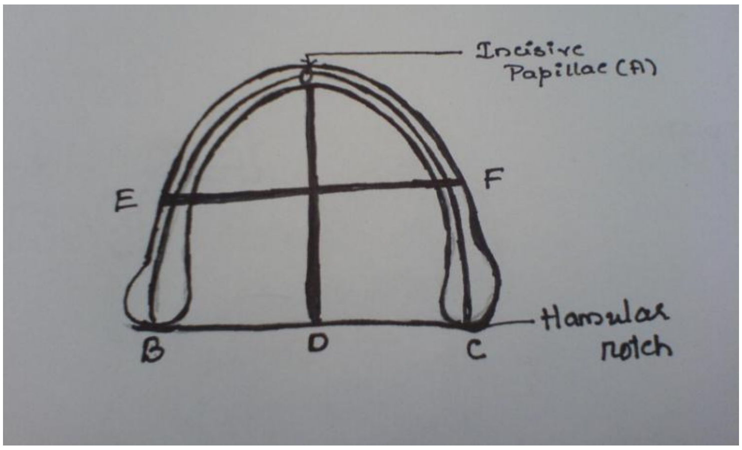


Fig. 1 Maxillary cast with measurement lines

The crest of incisive papilla (A) and the highest point on the hamular notchs (B) and (C) were marked. The midline of palate (AD) and interhamular notch line (BC) were drawn on the cast. One cross arch imaginary line (EF) was drawn from the crest of the ridge on one side to another side perpendicular to the midline midway between the incisive papilla and the interhamular notch line. **(Fig 1)**

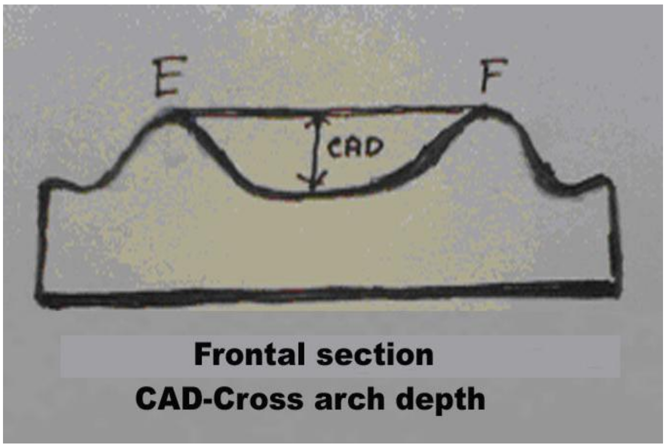


Fig. 2 CAD- CROSS arch depth

In the sagittal cross section, a perpendicular was drawn from the deepest point on the cast to the midpoint of the imaginary line joining the incisive papilla and midpoint of interhamular notch line. The length of this perpendicular distance was measured with the help of dial plunger. Likewise, in the frontal section, a perpendicular was drawn from the deepest point on the cast to the midpoint of the cross arch imaginary line passing through the crest of the ridge midway between the incisive papilla and interhamular notch line. The length of this perpendicular was also measured.

Cross arch palatal forms were categorized according to their similarity with the basic ‘U’ shape, ‘V’ shape or flat contour. The outlines were assigned to the shallow or flat group if the depth was less than ¼ inch. **(Fig 3)** Those between ¼ inch and ½ inch were described as medium or U shaped **(Fig 4)** and those exceeding ½ inch were described as high vaulted or ‘or deep V’ shaped. **(Fig 5)**

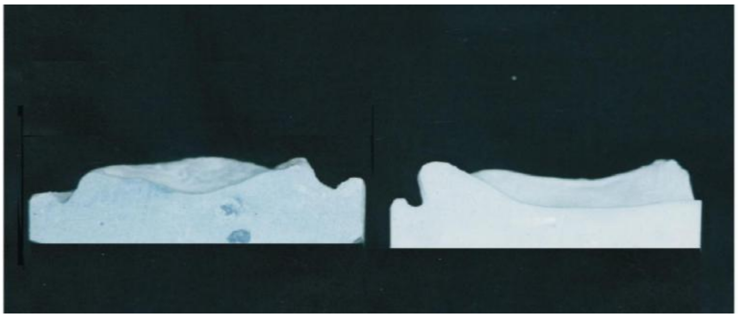


Fig. 3 Shallow Palatal vault

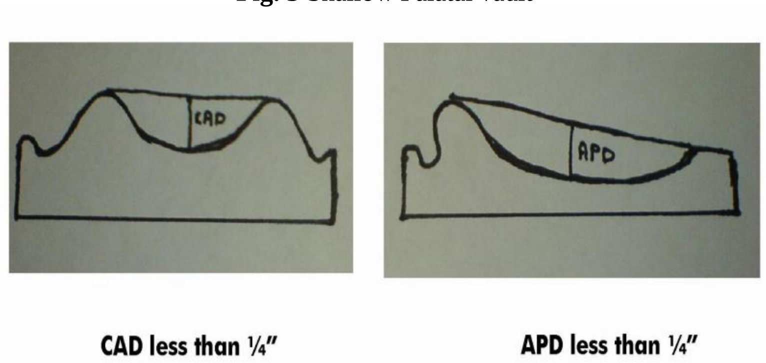


Fig. 4 Cross Sectional profile of shallow palatal vault

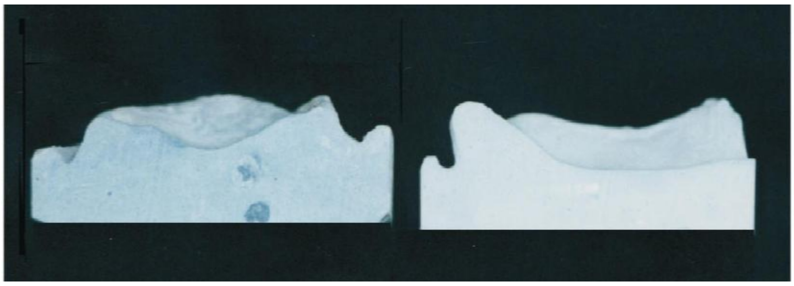
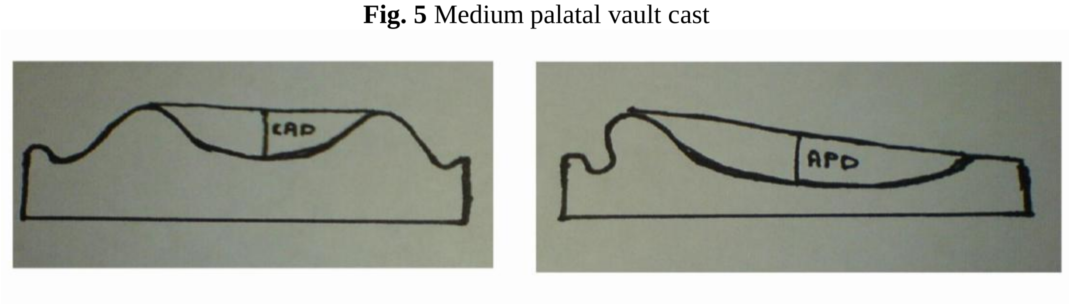


Fig. 5 Medium palatal vault cast



CAD in between ¼ inch & ½ inch **APD in between ¼ inch & ½ inch**

Fig. 6 Cross sectional profile of medium palatal vault

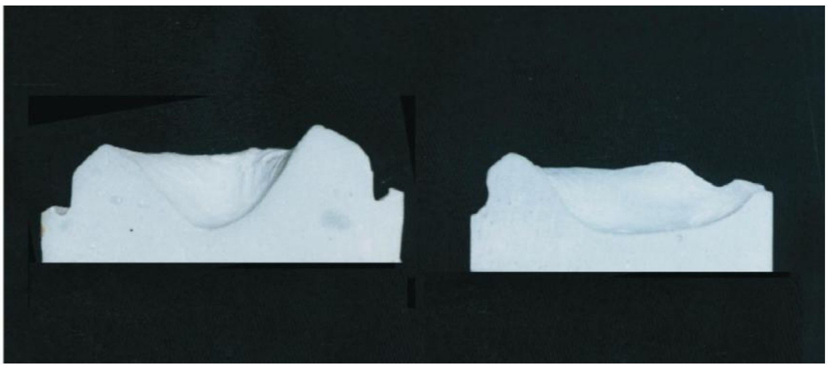


Fig. 7 Deep palatal vault cast

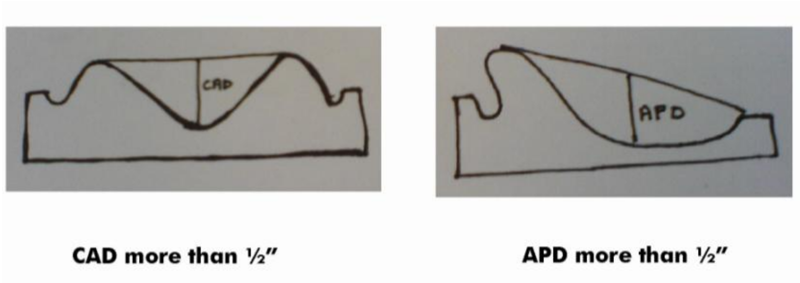


Fig. 8 Cross sectional profile of deep palatal vault

Duplication of the edentulous cast

Each selected cast was duplicated using the putty impression material. Putty impression material - Poly Siloxane Putty Material, 3MESPE, Dentsply, Co.India, was mixed by taking 1:1 ratio of base and catalyst material to form uniform dough. The impression of the cast to be duplicated was made, taking care to cover the tissue surface and land area of the cast. After this the cast was recovered and we had the cast duplicating impression mould. Thus finally three-impression moulds were made of the three different groups of palatal vault configurations. **(Fig 8)**

Using this impression 8 casts of each group of palatal vault configuration were made in dental stone. The dental stone - Kalstone, Kalabhai, (Mumbai) was mixed according to the manufacturer's recommendation and correct water: powder ratio and then gradually vibrated into the impression using vibrator, (Kavo, EWL-TYP, 5403) obtain bubble free master cast. A total of 24 casts in each group of palatal vault were made. Thus a total of 72 (24 x 3) casts in three groups were made.

Preparation of heat polymerized acrylic denture base test specimen

Test specimens were prepared on the 72-duplicated edentulous maxillary cast. These were subdivided into 3 subgroups as Shallow,Medium, & Deep.

8 casts of each type of palatal vault configuration were taken. A uniform layer of modelling wax sheet - Hindustan Modelling Wax No. 2, (Hyderabad) was adapted on these casts to obtain the waxed up cast of wax thickness 2 mm. **(Fig 10)** The thickness of the wax was approximately verified using the calibrated periodontal probe so as to have control over thickness of denture base several points on the adapted wax sheet were tested to assure the required thickness. Thus, eight waxed up cast of each type of palatal vault configuration were made with the wax thickness of 2.0mm. Thus 24 patterns (8 x 3) in three types of palatal vault configuration were made to obtain a total of 72 patterns (24 x 3) on casts. These patterns were invested, dewaxed and processed under the following groups.

PREPARATION OF POLYMETHYL METHACRYLATE RESIN SPECIMENS

Group A -- Control Group, 24 casts of non reinforced resin (Conventional) denture Bases.

The appropriate amount of heat cured acrylic resin–(DPI, Mumbai,India) required to fill the mould was prepared by mixtures of monomer and polymer in the ratio of 1:3 by volume as per the manufactures instructions, and then the resin was taken in a clean porcelain jar and mixed under the similar conditions of temperature.

After the material reached the dow stage, it was kneaded and placed in the mould. Two trial closures were carried out using the hydropress (Kavo EWL-W.Germany) and each time the flash was removed. For the final closure, the flask was clamped in the hydropress (4 bars and the pressure was maintained for 30 minutes) to allow proper penetration of monomer into the polymer.

The flask was immersed in an electric acrylizer, (Unident Acrliser,NewDelhi). Polymerization was started in water bath at room temperature and gradually the temperature was raised to polymerize the dentures at 74°C (165° F) for 1 ½ hours and then raised to 100°C (212° F) for 30 minutes.

After completion of the curing cycle, the flask was removed from the water bath For the purpose of simplicity the measurements were carried out at randomly selected points such as:

1. Midline
2 First premolar region – Right and Left
3. Second molar region – Right and Left
4. Anterior region.

The readings were recorded for each specimen. 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 one week.

Group B -- Preparation of PMMA Denture Base Reinforced with Stainless Steel Metallic Denture Mesh.

The stainless steel strengtheners (COMET, Corp, Mumbai,India) are adjusted for 8 of the each palatal vaults. The mesh strengtheners, which are supplied in a square form 10x10cm, 0.4mm thickness, were cut slightly oversize for the shallow, medium and deep palatal vaults and then were adjusted to the duplicate model (cast) by applying positive pressure to the blanks or by the hard counter die constructed in autopolymerising acrylic resin. **(Fig 12)** By increasing the pressure, the mesh was adapted to the contours of the duplicate model. The edges of the strengtheners were trimmed to extend just beyond the alveolar crest. Dorsally, the strengthener was terminated 2.0 mm in front of the intended posterior border of the denture base.

A soft spacer,5”x5”(12.7cmx12.7cm),2mm(0.080”) **(Fig 11)** (Biostar Ultradent Co.U.S.A) for the shallow, medium and deep palatal vaults was constructed on the master cast using a pressure forming machine (Medes Easy Vac Co.) and then it was cut 2-3mm short of sulcus & trimmed with carborundum bur.

After boil out was complete it was adapted on the definitive cast, with a sheet of polythene placed on the spacer. Then lower half of the flask was packed with heat polymerized acrylic resin in a doughy stage and trial packing was performed by adding top half of the flask. Then the strengthener was introduced in the recess during preliminary packing of the resin by removing the soft spacer. **(Fig 14)**

Subsequent to the second trail closure the remaining space is filled with the additional resin and then the denture was processed in the similar manner as described in group A. Care was taken that the mesh is not exposed and completely covered by the acrylic resin during any polishing or trimming of the denture. **(Fig 17)**

Group C -- Preparation of 24 PMMA Denture Base Reinforced with Glass Fibres

For the reinforcement of the glass fibres into the denture bases, the fibers of (Dow Corning Owen OCF Co,) 60x50”, 10-15 micron in diameter 0.820 gms of wt, in chopped strand mat form were taken. A soft spacer (Biostar Ultradent Co.U.S.A) was constructed on the master cast using a pressure forming machine (Medes Easy Vac Co.) The spacer was cut 2-3mm short of sulcus & trimmed with carborundum bur as described for the mesh. Then the chopped strand mat form of fibres were treated with the Ceramic Primer (3M, ESPE Rely ^{X} TM), and air dried for about twenty minutes.

After the usual flasking & boil out procedures, the spacer was placed in the upper half of the mould of the palatal contours. The fitting surface i.e. cast was coated with sodium alginate and packed with acrylic resin, followed by trial closure with a polythene sheets to allow the excess flush to be removed. Then the flask was kept under pressure for about 30 min with the spacer still in place. The fibers and resin were preweighed before placing.

Then the silanised chopped mat fibre inserts **(fig.13)** which were cut into the required shapes i.e. shallow, medium & deep palatal shapes were soaked in MMA liquid, in a Petri dish for about ten min to allow better wetting of the fibres. The woven insert was then removed from the monomer & any excess of it was allowed to drain away. Then the inserts were carefully positioned on the top of the packed resin in the recess created by the spacer & using polythene separating sheet light pressure was applied in a bench press.

Then the flask was reopened & checked for the correct positioning of the fibres. Then the second mix of acrylic resin was packed by ensuring that any excess resin will only relate to the space taken by the fibres. After the final closures it was processed in a similar manner as described for group A.

Experiment

The prepared heat polymerized acrylic denture base specimens were tested for their fracture threshold according to ISO 1567:1999 on the universal testing machine **(fig19)** to obtain two vital parameters, that is the load to which denture bases fractures (fracture load) and the amount of deflection before fracture (fracture deflection).Using these two parameters third parameter of fracture energy was calculated using standard formula.

The samples of the permanent denture bases were kept with the non-tissue side i.e. the polished surface on the platform of the LLYODS K50 universal-testing machine (UTM) (fig.) A flat end round ended plunger of diameter 5 mm mounted in the upper jaws of the test machine 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 failure of the base (in kilograms) and the corresponding deflection to the time of fracture were recorded.

Calculations

The load to fracture threshold was taken directly from the internal chart recorder of the universal testing machine and the deflection to the time of fracture was noted. So this reading was converted into `cm' by doing the following calculation:

If the deflection gauge reading is 'X', then to convert it into `cm' use the formula:

$$\frac{\text{Deflection in mm, X}}{10}$$

From the above two values, fracture energy were calculated by using the standard formula:

Fracture Energy = ½ x fracture load (in kg) x deflection (in cm) at the time of fracture.

The readings were recorded and the mean was calculated initially for each specimen and finally for each sample group of eight samples.

Fig. 9 Materials used

Fig. 10 Armamentarium

Fig. 11 Cast duplicating impression mould of shallow, medium and deep palatal vault

Fig. 12 Duplicated casts of Shallow Palatal vault

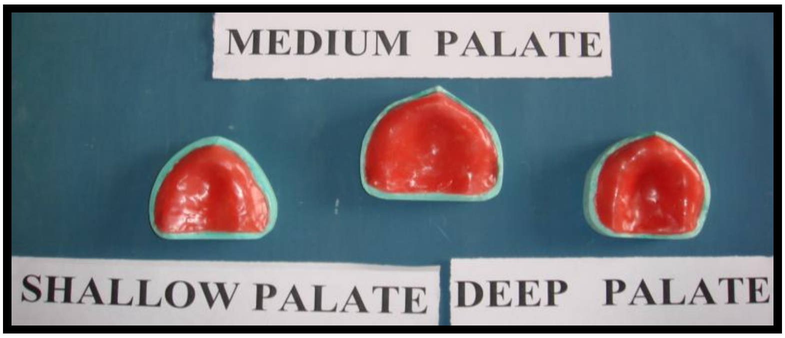


Fig. 13 Adaptation of Wax

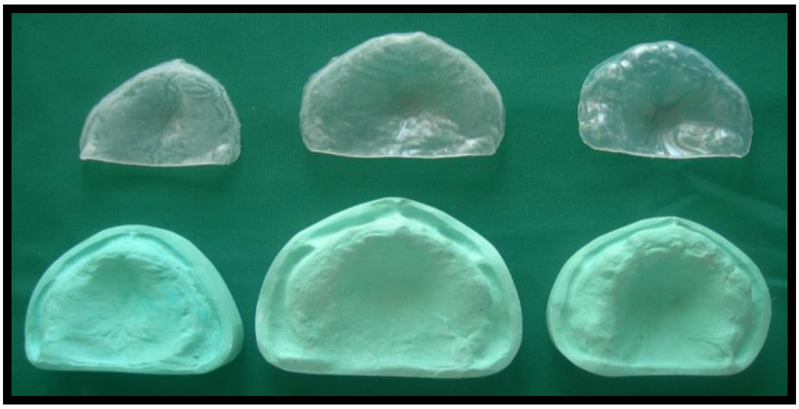


Fig. 14 Vacuum formed spacers

Fig. 15 Adaptation of Denture Mesh on the autopolymerising resin Casts

Fig. 16 Cutting of the glass fibres into the shallow, medium & deep palatal shapes

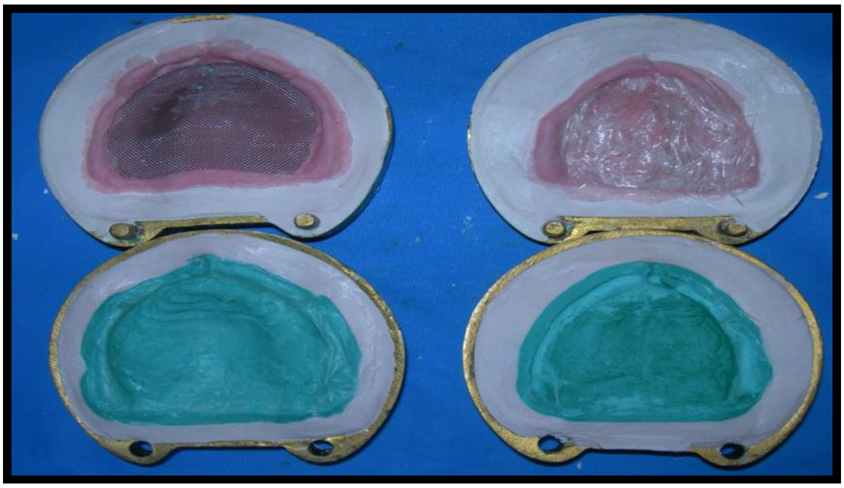


Fig. 17 Placing of the denture mesh & glass fibres in the recession formed by spacers

Fig. 18 After curing

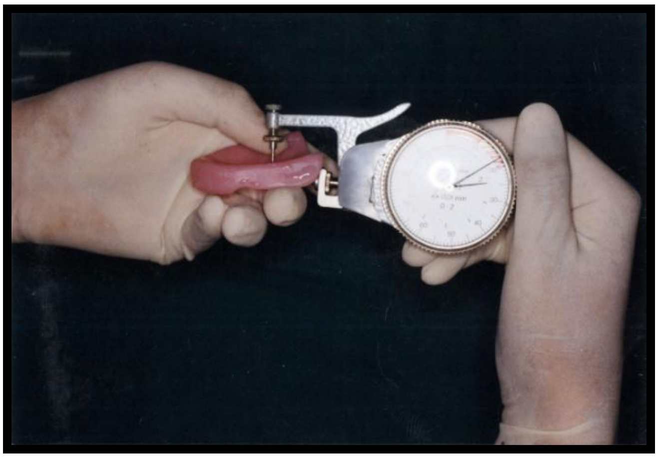


Fig. 19 Measuring the thickness of denture base using dial gauge

Fig. 20 24 Stainless steel mesh reinforced denture bases of shallow, medium & deep palatal vault

Fig. 21 24 Glass fiber reinforced denture bases of shallow, medium &deep palatal vaults

Fig. 22 Instron testing machine

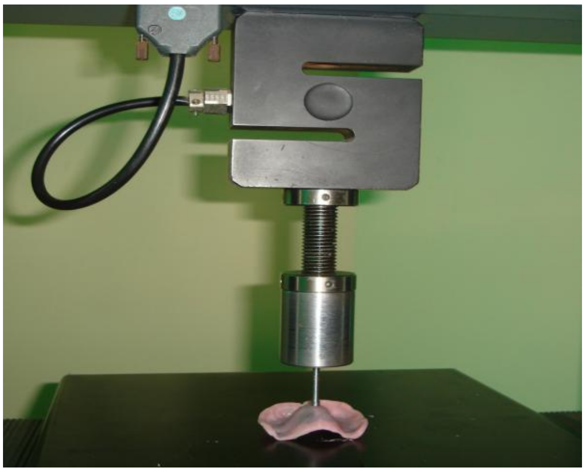


Fig. 23 Denture bases on UTM

III. Results

Statistical Methods: Analysis of variance (ANOVA) has been used to find the significance of Load and Energy between different materials. Post-hoc Tukey test has been used to find the pair wise significance of Load and Energy between pair of materials

1. *Analysis of Variance*: F test for K Population means

Objective: To test the hypothesis that K samples from K Populations with the same mean.
Limitations: It is assumed that populations are normally distributed and have equal variance. It is also assumed that samples are independent of each other.

Method. Let the j^{th} sample contain n_j elements (j=1,2,…K). Then the total number of elements is

$$N = \sum nj \qquad x.j = \sum \frac{xij}{nj}$$

$$S_1^{\ 2} = \frac{\sum \sum_{i-1}^{n1} (x1 - \overline{x.j})^2}{N-K} \qquad S_2^{\ 2} = \frac{\sum_{i-1}^{n1} nj(\overline{x.j} - \overline{x..})^2}{K-1}$$

$F=S_2^2/S_1^2$ which follows F distribution (K-1, N-K)

2. Significant figures

+ Suggestive significance $0.05<P<0.10$
* Moderately significant $0.01<P \leq 0.05$
** Strongly significant $P \leq 0.01$

This static loading experiment was conducted to determine the flexural strength of acrylic resin in different shapes of palate for Conventional denture base and metal mesh reinforced and glass fibre reinforced denture bases keeping one standard thickness.

Table 2 – 10 shows the fracture energy using fracture load and fracture deflection applied in different palatal vault configurations for normal, denture mesh & glass fibre reinforced denture bases with their calculated means and standard deviations.

In **Table 2** for the Conventional denture bases of group A on shallow palatal vault configuration, total mean fracture load was 41.629kg with the standard deviation of 7.074; total mean fracture deflection was 0.260 cm with the standard deviation of 0.027; and the total mean fracture energy was 5.443 kg/cm with the standard deviation of 1.271

In **Table 3** for the denture bases of group B stainless steel denture mesh reinforced, shallow palatal vault configuration, total mean fracture load was 61.531 kg with the standard deviation of 7.950; total mean fracture deflection was 0.281 cm with the standard deviation of 0.051; and the total mean fracture energy was 8.524 kg/cm with the standard deviation of 1.063

In **Table 4** for the denture bases of group C glass fibre reinforced shallow palatal vault configuration, total mean fracture load was 104.956 kg with the standard deviation of 4.386; total mean fracture deflection was 0.319 cm with the standard deviation of 0.044; and the total mean fracture energy was 16.464 kg/cm with the standard deviation of 2.131

In **Table 5** for the conventional denture bases of group A , on medium palatal vault configuration, total mean fracture load was 106.519 kg with the standard deviation of 4.463; total mean fracture deflection was 0.226 cm with the standard deviation of 0.021; and the total mean fracture energy was 12.074 kg/cm with the standard deviation of 0.849

In **Table 6** for the stainless steel mesh reinforced denture bases of group B medium palatal vault configuration, total mean fracture load was 113.013 kg with the standard deviation of 11.072; total mean fracture deflection was 0.324 cm with the standard deviation of 0.040; and the total mean fracture energy was 17.691 kg/cm with the standard deviation of 1.598

In **Table 7** for the glass fibre reinforced denture bases of group C on deep palatal vault configuration, total mean fracture load was 135.268 kg with the standard deviation of 11.250; total mean fracture deflection was 0.285 cm with the standard deviation of 0.022; and the total mean fracture energy was 19.008 kg/cm with the standard deviation of 1.060

In **Table 8** for the conventional denture bases of group A, deep palatal vault configuration, total mean fracture load was 71.420 kg with the standard deviation of 9.888; total mean fracture deflection was 0.283 cm with the standard deviation of 0.136cm; and the total mean fracture energy was 8.06 kg/cm with the standard deviation of 1.002

In **Table 9** for the medium stainless steel denture mesh reinforced denture bases of group B, deep palatal vault configuration, total mean fracture load was 111.808 kg with the standard deviation of 6.944; total mean fracture deflection was 0.326cm with the standard deviation of 0.027cm; and the total mean fracture energy was 18.128 kg/cm with the standard deviation of 1.127

In **Table 10** for the glass fibre reinforced denture bases of group C, deep palatal vault configuration, total mean fracture load was 140.045 kg with the standard deviation of 27.942; total mean fracture deflection was 0.304cm with the standard deviation of 0.054cm; and the total mean fracture energy was 20.742 kg/cm with the standard deviation of 1.1907

Table 11 compares the fracture load and fracture energy in three different palatal vault shapes for normal and reinforced denture bases Group A. The statistical comparison of the fracture load and fracture energy was performed using tukey test as post hoc.

Table 12 compares the fracture load and energy in three different palatal vault shapes for normal and reinforced denture bases for group B. The statistical comparison of the fracture load and fracture energy was performed using tukey test as post hoc.

Table 13 compares the fracture Load and energy in three different palatal vault shapes for normal and reinforced denture bases for group C.

Table 14 compares the fracture Load in three different palatal vaults for group A, B & Group C. The results are in mean values and the result shows a highly significant difference ($p<0.001$)

Table 15 compares the fracture energy in three different palatal vaults for group A, B & Group C with the in fracture energy P value ($p<0.001$)

Table 16 compares the statistical significance in three different palatal vaults for group A, B & Group C for fracture load and energy. From this table it shows that all the values are significant but there was not much difference in medium and deep palatal vaults.

Evaluation of the fracture load revealed that there was a highly significant difference ($p<0.001$) when the denture base was reinforced with mesh and glass fibre irrespective of the shape of the palate when compared to the conventional denture bases.

Similar results were obtained for fracture energy for all the shapes of the palatal vault configuration. However a highly significant difference ($p<0.001$) in fracture energy was found for shallow palatal vault when groups B and C were compared.

There was a highly significant ($p<0.001$) difference between fracture load and energy when the denture bases were reinforced with stainless steel mesh & glass fibres in shallow and medium palatal vaults, shallow and deep palatal vaults. However in the medium and deep palatal vaults, when the reinforcement of denture base were compared, the results were just significant ($p<0.002$)

In all the cases there was increase in the fracture load and energy for denture base was increased with the reinforcement irrespective of the shape of the palate when compared with the normal denture bases.

TABLE 1 GROUPING OF THE SAMPLES

	Conventional	**Reinforced denture bases**	
	Group A (Conventional)	**Group B (Metallic mesh reinforced)**	**Group C (Glass fibre reinforced)**
Shallow palate	8	8	8
Medium palate	8	8	8
Deep palate	8	8	8
Total no. Of specimen			**72**

TABLE 2
SHALLOW PALATAL VAULT
GROUP A (CONVENTIONAL)

Specimen No.	**Load (Kg)**	**Deflection (cm)**	**Energy (Kg/cm)**
1	38.860	0.206	4.000
2	50.030	0.275	6.870
3	35.530	0.260	4.610
4	49.060	0.263	6.450
5	40.130	0.250	5.010
6	39.120	0.255	4.980
7	49.280	0.299	7.360
8	31.020	0.275	4.260
Minimum	31.020	0.206	4.000
Maximum	50.030	0.299	7.360
mean	41.629	0.260	5.443
Standard deviation	7.074	0.027	1.271

TABLE 3
SHALLOW PALATAL VAULT
GROUP B (STAINLESS STEAL DENTURE MESH REINFORCED)

Specimen No.	Load (Kg)	Deflection (cm)	Energy (Kg/cm)
1	61.160	0.251	7.670
2	58.510	0.222	6.490
3	71.350	0.233	8.310
4	59.900	0.300	8.980
5	51.820	0.375	9.710
6	69.380	0.269	9.330
7	69.390	0.270	9.360
8	50.740	0.329	8.340
Minimum	50.740	0.222	6.490
Maximum	71.350	0.375	9.710
mean	61.531	0.281	8.524
Standard deviation	7.950	0.051	1.063

TABLE 4
SHALLOW PALATAL VAULT
GROUP C (GLASS FIBRE REINFORCED)

Specimen No.	Load (Kg)	Deflection (cm)	Energy (Kg/cm)
1	105.250	0.318	16.730
2	108.350	0.329	17.820
3	101.930	0.350	17.830
4	105.530	0.262	13.820
5	100.450	0.390	19.580
6	101.730	0.261	13.270
7	113.760	0.300	17.060
8	102.650	0.345	15.600
Minimum	100.450	0.261	13.270
Maximum	113.760	0.390	19.580
mean	104.956	0.319	16.464
Standard deviation	4.386	0.044	2.131

TABLE 5
MEDIUM PALATAL VAULT
GROUP A (CONVENTIONAL)

Specimen No.	Load (Kg)	Deflection (cm)	Energy (Kg/cm)
1	110.700	0.232	12.840
2	108.500	0.227	12.310
3	109.910	0.215	11.810
4	100.510	0.271	13.610
5	99.570	0.219	10.900
6	110.940	0.200	11.640
7	104.990	0.218	11.440
8	107.030	0.225	12.040
Minimum	99.570	0.200	10.900
Maximum	110.940	0.271	13.610
mean	106.519	0.226	12.074
Standard deviation	4.463	0.021	0.849

TABLE 6
MEDIUM PALATAL VAULT
GROUP B (STAINLESS STEAL DENTURE MESH REINFORCED)

Specimen No.	Load (Kg)	Deflection (cm)	Energy (Kg/cm)
1	115.340	0.375	17.500
2	113.380	0.350	19.840
3	120.380	0.253	15.220
4	97.680	0.361	17.630
5	98.540	0.316	15.560
6	112.130	0.330	18.500
7	131.700	0.287	18.890
8	114.950	0.320	18.390
Minimum	97.680	0.253	15.220
Maximum	131.700	0.375	19.840
mean	113.013	0.324	17.691
Standard deviation	11.072	0.040	1.598

TABLE 7
MEDIUM PALATAL VAULT
GROUP C (GLASS FIBRE REINFORCED)

Specimen No.	Load (Kg)	Deflection (cm)	Energy (Kg/cm)
1	116.810	0.312	18.220
2	141.990	0.270	19.160
3	120.380	0.300	18.050
4	134.250	0.280	18.790
5	140.480	0.260	18.260
6	139.750	0.316	20.610
7	138.360	0.265	18.330
8	150.120	0.275	20.640
Minimum	116.810	0.260	18.050
Maximum	150.120	0.316	20.640
mean	135.268	0.285	19.008
Standard deviation	11.250	0.022	1.060

DEEP PALATAL VAULT
GROUP A (CONVENTIONAL)

Specimen No.	Load (Kg)	Deflection (cm)	Energy (Kg/cm)
1	78.53	0.615	6.47
2	62.61	0.241	7.54
3	76.2	0.253	9.63
4	85.47	0.215	9.18
5	80.7	0.2	8.07
6	63.7	0.24	7.64
7	59.28	0.272	8.06
8	64.87	0.23	7.46
Minimum	59.280	0.200	6.470
Maximum	85.470	0.615	9.630
mean	71.420	0.283	8.006
Standard deviation	9.888	0.136	1.002

TABLE 9
DEEP PALATAL VAULT
GROUP B (STAINLESS STEEL DENTURE MESH REINFORCED)

Specimen No.	Load (Kg)	Deflection (cm)	Energy (Kg/cm)
1	105.010	0.327	17.160
2	108.050	0.316	17.070

3	116.410	0.301	17.510
4	121.500	0.322	19.400
5	111.380	0.305	16.980
6	117.220	0.331	19.390
7	100.570	0.388	19.510
8	114.320	0.315	18.000
Minimum	100.570	0.301	16.980
Maximum	121.500	0.388	19.510
mean	111.808	0.326	18.128
Standard deviation	6.944	0.027	1.127

TABLE 10
(**DEEP PALATAL VAULT**)
GROUP C (GLASS FIBRE REINFORCED REINFORCED)

Specimen No.	**Load (Kg)**	**Deflection (cm)**	**Energy (Kg/cm)**
1	122.290	0.298	18.221
2	154.020	0.262	20.177
3	198.800	0.248	24.155
4	128.230	0.324	20.773
5	108.150	0.421	22.766
6	126.600	0.302	19.117
7	150.150	0.268	20.120
8	132.120	0.312	20.611
Minimum	108.150	0.248	18.221
Maximum	198.800	0.421	24.155
mean	140.045	0.304	20.742
Standard deviation	27.942	0.054	1.907

Table 11: comparison of Load and Energy in different shapes of palatal vault in Group AResults are presented in Mean ± SD (Min-Max)

Group A	Load (kg)	Energy (kg/cm)
Shallow palatal Vault	41.63 ± 7.07^{a} (31.02-50.03)	5.44 ± 1.27^{a} (4.00-7.36)
Medium Palatal vault	106.51 ± 4.46^{b} (99.57-110.94)	12.07 ± 0.84^{b} (10.90-13.61)
Deep Palatal vault	71.42 ± 9.88^{c} (59.28-85.47)	8.01 ± 1.00^{c} (6.47-9.63)
Significance	F=150.955 P<0.001**	F=80.365 P<0.001**

Non-identical superscripts are significant at 5% Level of significance by Post –hoc Tukey

Table 12: comparison of Load and Energy in different shapes of palatal vault in Group B
Results are presented in Mean ± SD (Min-Max)

Group B	Load (kg)	Energy (kg/cm)
Shallow palatal Vault	61.53 ± 7.95^{a} (50.74-71.35)	8.52 ± 1.06^{a} (6.49-9.71)
Medium Palatal vault	113.01 ± 11.08^{b} (97.68-131.70)	17.69 ± 1.59^{b} (15.22-19.84)
Deep Palatal vault	111.80 ± 6.94^{bc} (100.57-121.50)	18.13 ± 1.23^{bc} (16.96-19.51)
Significance	F=88.538 P<0.001**	F=142.440 P<0.001**

Non-identical superscripts are significant at 5% Level of significance by Post –hoc Tukey test

Table 13: comparison of Load and Energy in different shapes of palatal vault in Group CResults are presented in Mean ± SD (Min-Max)

Group C	Load (kg)	Energy (kg/cm)
Shallow palatal Vault	104.96±4.36[a] (100.45-113.75)	16.46±2.13[a] (13.27-19.56)
Medium Palatal vault	135.41±12.11[b] (116.81-150.12)	19.01±1.06[ab] (18.05-20.64)
Deep Palatal vault	139.26±26.95b[c] (108.15-194.80)	20.47±1.90[bc] (13.14-17.55)
Significance	F=9.129 P=0.002**	F=11.951 P<0.001**

Non-identical superscripts are significant at 5% Level of significance by Post –hoc Tukey test

Table 14: Comparison of Load (kg) between three groups Results are presented in Mean ± SD (Min-Max)

Load (kg)	Group A	Group B	Group C	P value
Shallow palatal Vault	41.63±7.07[a] (31.02-50.03)	61.53±7.95[b] (50.74-71.35)	104.96±4.36[c] (100.45-113.75)	<0.001**
Medium Palatal vault	106.51±4.46[a] (99.57-110.94)	113.01±11.08[ab] (97.68-131.70)	135.41±12.11[c] (116.81-150.12)	<0.001**
Deep Palatal vault	71.42±9.88[a] (59.28-85.47)	111.80±6.94[b] (100.57-121.50)	139.26±26.95[c] (108.15-194.80)	<0.001**

Non-identical superscripts are significant between three groups

Table 15: Comparison of Energy (kg/cm) between three groups Results are presented in Mean ± SD (Min-Max)

Energy (kg/cm)	Group A	Group B	Group C	P value
Shallow palatal Vault	5.44±1.27[a] (4.00-7.36)	8.52±1.06[b] (6.49-9.71)	16.46±2.13[c] (13.27-19.56)	<0.001**
Medium Palatal vault	12.07±0.84[a] (10.90-13.61)	17.69±1.59[b] (15.22-19.84)	19.01±1.06[bc] (18.05-20.64)	<0.001**
Deep Palatal vault	8.01±1.00[a] (6.47-9.63)	18.13±1.23[b] (16.96-19.51)	20.47±1.90[c] (13.14-17.55)	<0.001**

Table 16: Comparison of significance of different shapes and groups

Group	***Pair***	***Load(kg)***	***Energy (kg/cm)***
Group A	Shallow palatal vault Vs Medium palatal vault	**S**	**S**
	Shallow palatal vault Vs Deep palatal vault	**S**	**S**
	Medium palatal vault Vs Deep palatal vault	**S**	**S**
Group B	Shallow palatal vault Vs Medium palatal vault	**S**	**S**
	Shallow palatal vault Vs Deep palatal vault	**S**	**S**
	Medium palatal vault Vs Deep palatal vault	**NS**	**NS**
Group C	Shallow palatal vault Vs Medium palatal vault	**S**	**NS**
	Shallow palatal vault Vs Deep palatal vault	**S**	**S**
	Medium palatal vault Vs Deep palatal vault	**S**	**NS**
Shallow palatal vault	Group A vs. Group B	**S**	**S**
	Group A vs. Group C	**S**	**S**
	Group B vs. Group C	**S**	**S**
Medium palatal vault	Group A vs. Group B	**NS**	**S**
	Group A vs. Group C	**S**	**S**
	Group B vs. Group C	**S**	**NS**
Deep palatal vault	Group A vs. Group B	**S**	**S**
	Group A vs. Group C	**S**	**S**

	Group B vs. Group C	**S**	**S**

IV. Discussion

The fracture of acrylic resin dentures is an unsolved problem in removable prosthodontics despite numerous attempts to solve the problem. Fracture of the denture causes inconvenience to both the dentist and patient.

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 fabrication and subsequently 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.[39]

Materials used in the construction of denture bases may be classified as metallic and non-metallic. 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.

From the available materials for a denture base, a logical choice should be made, and for the dentures to service in the mouth, mechanical and esthetic requirements demand high priority. Although opinion varies, most clinicians consider that the denture base should be rigid. A high value of modulus of elasticity is therefore advantageous. Also a high value of elastic limit is required to ensure that stresses encountered during biting and mastication do not cause permanent deformation. A combination of high modulus and high elastic limit would have the added advantage that it would allow the base to be fabricated in relatively thin section.[40]

Individual denture bases may be formed from metal or metal alloys; most denture bases are fabricated using common polymers. Such polymers are chosen based on availability, dimensional stability, handling characteristic, colour and texture of these materials to resemble natural gum tissue, compatibility with oral tissues and cost effectivity.

Polymers used in prosthetic dentistry are often multiphase acrylic resin systems made from prepolymerized powder beads (predominantly PMMA) and a liquid of monomers such as methyl methacrylate (MMA). Because such a polymer-monomer mixture or dough has relatively high viscosity adequate impregnation of the reinforcing fibers with resins has been difficult to achieve. Another problem when fiber reinforcement is used with dental resins was the difficulty of handling the fibers when fibers were cut with scissors the fibers frayed and were difficult to incorporate accurately in the desired region of the dental prosthesis. [41]

Thus a denture fracture is a composite result of many factors. 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 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. Lambert and Kydd showed that mastication and swallowing resulted in either an increase or a decrease in the curvature of the denture base at the midline indicating the need to improve the flexural strength of denture base resin [42]

Reinforcing will help to solve the problem of denture fractures. But this factor can be applied within a limited domain so that other factors of efficient denture service such as phonetics, comfort, retention are not adversely affected. Thus the present study deals with the effects of altering the usual denture base with reinforcement of stainless steel mesh and glass fibres. This study aimed to determine the correlation between various shapes of palatal vault configuration (i.e., shallow, medium and deep) and fracture strength of heat polymerized acrylic resin denture base. The heat polymerized acrylic resin denture base were fabricated on these selected edentulous maxillary cast and its fracture load and fracture energy was determined. Fracture strength of heat polymerized acrylic resin denture base was compared with average value of biting force. Thus optimal reinforcement of the denture base which may be required for different types of palatal vault configuration was estimated.

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

Each specimen was then 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 failure 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 as half the product of fracture load (in kg) and fracture deflection (in cm). The fracture load, deflection at fracture, and energy to fracture for the three palatal shapes and for the two base reinforcement were compared & evaluated statistically.

The results **(Table 2-12)** of this study indicate that as the reinforcement of the denture base with stainless steel mesh and glass fibres increased, the fracture load, fracture energy irrespective of the palatal vault configuration.

Smith in his study on the mechanical properties of poly methyl methacrylate stated that the most important mechanical property of a denture base polymer for its effective service in the oral cavity is its resistance to flexural fatigue.[43]

From the results (Table 14-16), it can be concluded that there exists a direct relationship between the denture base &the reinforcements with the glass fibres &stainless steel mesh and the load required to fracture the denture base.

Similar results were seen for the energy required to fracture the denture base. Irrespective of the shape of the palatal vault configuration there was a proportional increase in fracture energy as the denture base were reinforced.

Results (Table 2-16) indicate that there exists a highly significant ($p<0.01$) difference in the fracture load between the shallow and medium palatal vault configurations, and shallow and deep palatal vault configurations in all the three different types of denture base reinforcements. However there wasn't much difference in fracture loads for the medium and deep palatal vault configurations, even though reinforcing denture base with the stainless steel mesh & glass fibres. In this study Glass fibre reinforcement took only slight amount of more load than the mesh.

Schneider stated that anatomic considerations that can contribute to denture base fracture should be evaluated. He suggested that the fulcrum created in a denture at the mid-palatal suture might contribute to variation in resistance of the denture bases to fracture in different palatal vault configurations.[44]

Similarly, Farmer inferred that shallow ridges and flat palate increase the possibility of fracture of acrylic resin denture base and suggested the use of metal denture base and higher strength resin as a possible alternative.[45]

Hargreaves found that women seemed to break their dentures more frequently while eating than men and concluded that this is because the small arches commonly found in women imposed limits on the strength of the appliance. Masticatory loading in women may equal that of men but because of the above-mentioned factor the delicate appliance of women is more at risk.[1]

Chewing forces in denture wearers were of low magnitude when compared with those of natural dentition subjects. The force during closure in chewing averaged 4.6 lb (2.1 kg) in the denture wearers compared with 18.2 lb (8.3 kg) in the natural dentition subjects. Force at occlusion during chewing averaged 9.8 lb (4.4 kg) in the denture wearers, which was six times less than 58.7 lb (26.7 kg) recorded in the natural dentition subjects. Our present study (Table 2-12) shows that the fracture load of the test samples is well above the maximum force that the denture base can be subjected to in edentulous individuals.

V. Conclusion

Within the limitation of the study, the following conclusions were drawn, which evaluated the effect of varying shapes of palatal vault – shallow, medium, deep; and varying denture base thickness 2.0 mm, and on the fracture strength of heat polymerized acrylic resin denture bases reinforced with glass fibres and metallic mesh .

i) Heat polymerized acrylic resin denture bases on shallow palatal vault are inherently weaker and less resistant to fracture than denture bases fabricated on medium and deep palatal vault configurations.

ii) Reinforcing the denture bases with stainless denture mesh significantly increases the fracture load and fracture energy and hence increases the fracture strength of the denture base on a shallow palatal vault.

iii) Reinforcing the denture base with glass fibres proportionately increases the fracture strength irrespective of the shape of the palatal vault on which the denture base is fabricated.

iv) Reinforcing the denture base with glass fibres or stainless steel metal denture mesh for medium and deep palatal vault configuration will increase fracture strength.

v) The values of the fracture load for the test specimens were well above the average biting force to which dentures are subjected in the oral cavity in edentulous patients.

vi) A significant amount of increase in flexural strength has been noticed, and gives an inference that fiber reinforcement enhances the flexural strength when compared to the particulate reinforcement.

vii) It has been observed that the pretreated glass fibers by silence coupling agent improves a chemical bond with the acrylic polymer.

The majority of the midline fractures can be avoided by the application of established prosthodontic principles during denture construction. Determining the palatal vault configuration is important for the completely edentulous patient. The denture base is subjected to varying stresses during functional and Para functional movements of the jaw. The distribution of the stresses is a highly complex phenomenon with a number of factors involved. Therefore further investigations are required to evaluate the most desirable material and design related factors, which will improve the fracture strength, and thereby the long term service of the denture.

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