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Comparison of Impact Strength, Flexural Strength and Flexural Modulus of Three Commercially Available Flexible Denture Base Materials: An in Vitro Study

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ABSTRACT

Aim- The aim of the study was to evaluate and compare impact strength, flexural strength and flexural modulus of commercially available three flexible denture basematerials.

Materials and Method- Three commercially available denture base materials (Lucitone FRS, Unbreakable &Sebilex) were used. Thirty specimens with size of 65x10x3 mm^3 were prepared from each flexible denture base materials. For impact strength, 2J Izod impact tester was used, while flexural strength and flexural modulus were evaluated using three point bending testing device mounted on universal testing machine. The data were analysed by One way ANOVA (Analysis of variance) and Scheffe’s post hoc test using SPSS (IBM v.23).

Results- Lucitone FRS had highest (57.53±4.45 kJ/m^2) compared to Unbreakable (45.13±2.47 kJ/m^2) and Sebilex (40.73±2.31 kJ/m^2). Sebilex had least (minimum) impact strength. Flexural strength of Lucitone FRS had maximum value (67.96±3.42 MPa) compared to Unbreakable (57.05±3.12 MPa) and Sebilex (61.07±3.06 MPa). Unbreakable had least (minimum) flexural strength. Flexural modulus of Lucitone FRS had maximum value (1359.47±19.03 MPa) compared to Unbreakable (1258.40±18.86 MPa) and Sebilex (1334.47±12.49 MPa). Unbreakable had least (minimum) flexural modulus. All these differences were found to be statistical significant with one-wayANOVA($p<0.001$).Intergroup comparison between these materials by Scheffe’s Post-hoc tests also showed statistically significant difference ($P<0.01$)

Conclusion- Lucitone FRS had the highest impact strength, flexural strength and flexural modulus. Sebilex had least impact strength, while Unbreakable had lowest flexural strength and flexural modulus.

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Keywords- flexible denture base materials, impact strength, flexural strength, flexural modulus

INTRODUCTION

During lifetime, a person may lose his teeth & oral structures due to trauma or any dental diseases. To rehabilitate such patients, dentist prepares a prosthesis which will help to restore functions and esthetics.[1]

Previously PMMA (Poly methyl methacrylate) was the choice of material for removable prosthesis. However, it was found to have limitations such as polymerization shrinkage and allergy due to the residual monomer content.[2,3] Some of the recent developments in the field of science of dental materials have enabled to overcome some of the drawbacks of acrylic denture base materials. Moreover, these flexible denture base materials were found to have beneficial properties like superior esthetics, strength, accuracy, management of undercuts, biocompatibility, provisional dentures, management of midline fracture and better comfort to patients over traditional denture base materials.[4-6]These flexible denture base material were found to be particularly useful in cases with severe tissue undercuts where surgery iscontraindicated.[7]

Presently, the use of flexible denture base material is limited in clinical practice because of less information provided by the manufacturers and insufficient scientificevidence as less number of studies comparing flexible denture base material is available. So, the purpose of this in vitro study was to evaluate and compare impact strength and flexural properties like flexural strength, flexural modulus of three commercially available flexible denture base materials. The null hypothesis of this study was that no significant difference will be found in these properties between three different commercially available flexible denture base materials.

MATERIAL AND METHOD

Ethical approval was taken from the institute prior to commencement of the study. In this in vitro study, Lucitone FRS (Densply, USA), Unbreakable (TCS, USA) &Sebilex (Ivair, Germany) flexible denture base materials were used for comparison of impact strength, flexural strength and flexuralmodulus.

Fabrication of flexible denture base resin specimens:-

Three wax blocks of modeling wax (dimension 65x10x3 mm^3) were invested in lower portion of injection molding denture flask using type III dental stone (fig 1)[8]. After stone had set, de-waxing was done and the metal flask was opened. Then three different flexible denture base materials (Lucitone FRS, Unbreakable, Sebilex) which are supplied as a single component in cartridge form were injected into the mold. An injection molding machine was used to inject the heated flexible denture base material from cartridge into the mold (fig 2). After cooling, specimens were de-flasked. Gross irregularities on both side of the each acrylic resin specimen were removed with a tungsten carbide bur and laboratory micromotor. Each acrylic resin specimen was polished with carbide papers (3M) followedbypolishing using lathe with rag wheel and pumice polishing pastes. Thus a highly smooth polished surface was obtained. Water was used during polishing to avoid excessive heat.[8]

Total 90 specimens were fabricated with 30 specimens of each type of denture base material. Now these 30 specimens from each flexible denture base materials were further divided into two parts: 15 specimens were used for impact strength testing and 15 specimens were used for flexural strength and flexural modulus testing. Thus total 45 specimens were used for impact strength testing and 45 specimens were used for flexural strength and flexural modulus testing. These specimens were stored in distilled water at 37ºC in an incubator for 7 days.

Measurement of properties:-

The samples were taken out from the incubator 5 minutes before the test and transferred to room temperature. The tests for mechanical properties were carried out in accordance with the conditions laid down in the ISO specification no. 1567 for denture base polymers.[8]

(A) Impact strength(IS):-

After finishing & polishing of the specimens, a notch was cut in the middle of the specimens to depth of 1.2±0.1 mm. This notch was cut with 0.5 mm thickness. Length of the notch was 3.6 mm. The notch was then sharpened with a razor blade and extended 0.2 to 0.3 mm. For impact strength measurement, 2J Izod impact tester was used (fig 3). Impact testing machine measured the impact energy required to fracture the testing specimen (fig 4).

The impact strength was measured by following formula:

$IS=E_c/hb$

[Where, IS – Impact strength, E_c – absorbed energy, h – specimen thickness (mm), b – width below notch (mm)]

(B) Testing for Flexural Strength(FS):-

The testing of the flexural strength was performed with the universal testing machine (Instron) using 3 point bending testing device (fig 5)[9-11]. Specimens were placed on two support separated by 50mm and then loaded at a cross head speed set at 5mm/ min (fig 6). Each specimen was placed with its flat surface symmetrically on the supports. The force of loading plunger was increased from zero and maximum distance moved by the specimen on applied load was measured.

The flexural strength was calculated from the formula,

$FS = 3\ fl /2\ b\ h_2$

[Where, FS - Flexural strength, f - maximum load exerted (N), l - distance between the supports (mm), b - width of the specimens (mm), h - depth of the specimens (mm)]

(C) Flexural Modulus(E):-

The testing of the flexural modulus was performed with the universal testing machine (Instron) with a cross head speed set at 5 mm /min (fig 5)[9-11]. Each specimen was placed with its flat surface symmetrically on the supports. The ring length measured 50 mm. The force of loading plunger was increased from zero and maximum distance moved by the specimen on applied load was measured (fig6).

The flexural Modulus was calculated from the formula,

$E = l_3\ f/\ 4\ bh_3d$

[Where, E- flexural modulus, f - maximum load exerted (N), l - distance between the supports (mm), b - width of the specimens (mm), d - deflection corresponding to load f at a point in the straight line portion of trace, h - depth of the specimens(mm)]

The results were statistically analyzed using one way ANOVA (Analysis of Variance) with Scheffe's post hoc tests.

RESULTS

Data were collected from total 90 specimens (30 specimens from each denture base material). These 30 specimens from each material was further divided in two parts 15 specimens for impact strength and 15 specimens for flexural strength and flexural modulus making sample size of 15 (n=15). Then collected data tabulated using Microsoft Excel. Statistical Tests- Mean, Standard Deviation (SD), One way ANOVA with post-hoc tests were performed using SPSS Software (IBM SPSS Statistics ver 23). Level of significance was set at 0.05.

One Way ANOVA shows highly statistically significant difference ($p<0.001$) in impact strength, flexural strength and flexural modulus of these three different flexible denture base materials (Table 2, Table 4, Table 6). Impact strength of Lucitone FRS was (57.53$\pm$4.45 kJ/m^2), Unbreakable was (45.13$\pm$2.47 kJ/m^2) and Sebilex was (40.73$\pm$2.31 kJ/m^2). Flexural strength of Lucitone FRS was (67.96$\pm$3.42 MPa), Unbreakable was (57.05$\pm$3.12 MPa) and Sebilex was (61.07$\pm$3.06 MPa). Flexural modulus of Lucitone FRS was (1359.47$\pm$19.03 MPa), Unbreakable was (1258.40$\pm$18.86 MPa) and Sebilex was (1334.47$\pm$12.49 MPa).

Table 1: Mean & SD of different properties of flexible denture base materials (n=15).

Flexible Denture Base Material	Sample Size	Impact Strength (kJ/m^2)		Flexural Strength (MPa)		Flexural Modulus (MPa)	
	n	Mean	SD	Mean	SD	Mean	SD
Lucitone FRS	15	57.53	4.45	67.96	3.42	1359.47	19.03
Unbreakable	15	45.13	2.47	57.05	3.12	1258.40	18.86
Sebilex	15	40.73	2.31	61.07	3.06	1334.47	12.49

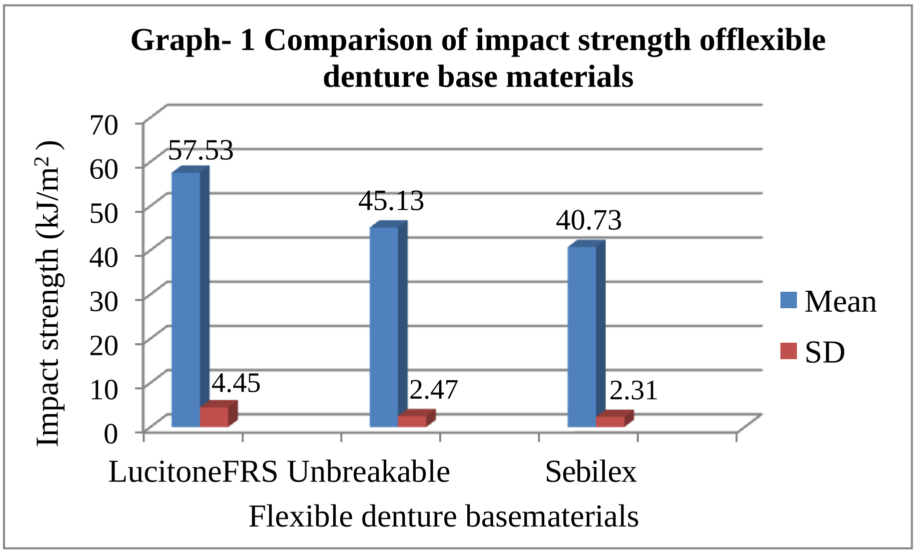


Table 2: One way ANOVA for impact strength of different flexible denture base materials.

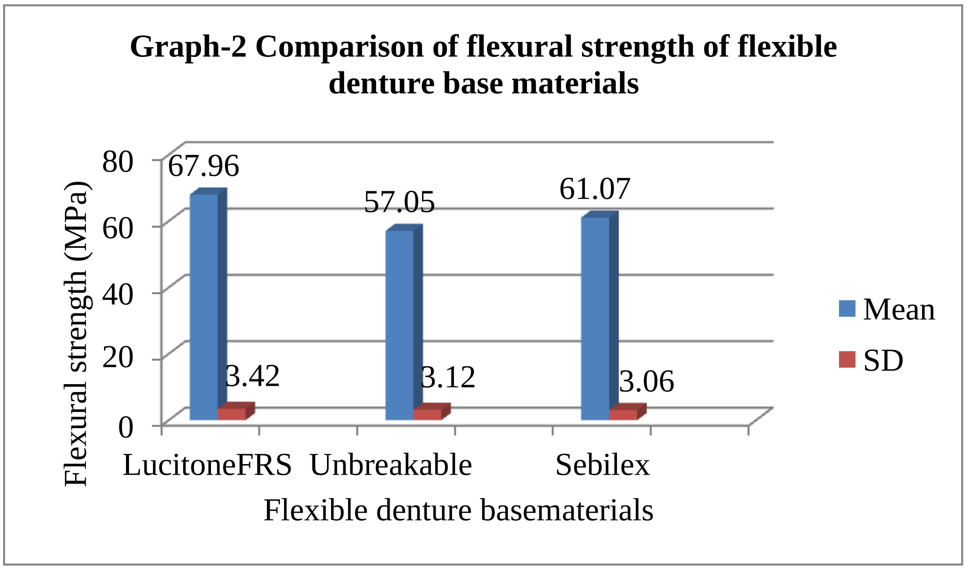
Source	Sum of Squares (SS)	df	Mean Square (MS)	F	*P*-value Significance
Treatment	2276	2	1138.40	109.062	<0.001 Significant
Error	438.40	42	10.4381		
Total	2,715.20	44			

Highly statistically significant difference (*P*<0.001) was observed in impact strength of these three different flexible denture base materials.

Table 3: Scheffe's Post hoc test for intergroup comparison of impact strength.

Intergroup comparison	*P* - Value	Significance
Lucitone FRS v/s TCS Unbreakable	<0.01	Significant difference
Lucitone FRS v/s Sebilex	<0.01	Significant difference
TCS Unbreakable v/s Sebilex	<0.01	Significant difference

Statistically significant difference (*P*<0.01) is seen between all three flexible denture base materials by Scheffe's post hoc test for impact strength.



Graph-2 Comparison of flexural strength of flexible denture base materials

Table 4: One way ANOVA for flexural strength of different flexible denture base materials.

Source	Sum of Squares (SS)	df	Mean Square (MS)	F	*P*-value Significance
Treatment	912.9013	2	456.4507	44.45	<0.001 Significant
Error	431.3267	42	10.2697		
Total	1,344.2280	44			

Highly statistically significant difference (*P*<0.001) was observed in flexural strength of these three different flexible denture base materials.

Table 5: Scheffe's Post hoc test for intergroup comparison of flexural strength.

Intergroup comparison	*P* - Value	Significance
Lucitone FRS v/s TCS Unbreakable	<0.01	Significant difference
Lucitone FRS v/s Sebilex	<0.01	Significant difference
TCS Unbreakable v/s Sebilex	<0.01	Significant difference

Statistically significant difference (*P*<0.01) is seen between all three flexible denture base materials by Scheffe's post hoc test for flexural strength.

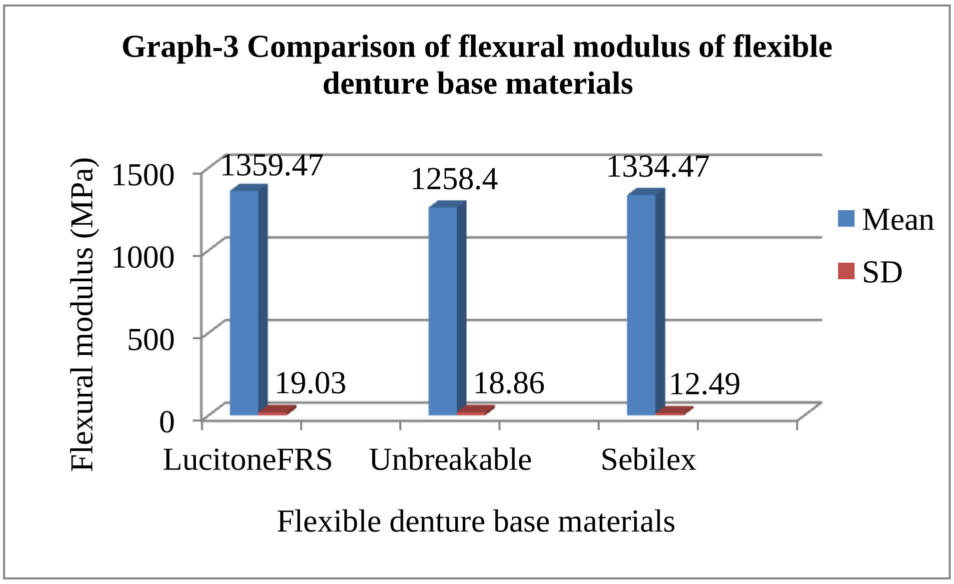


Table 6: One way ANOVA for flexural modulus of different flexible denture base materials.

Source	Sum of Squares (SS)	df	Mean Square (MS)	F	*P*-value Significance
Treatment	83128.0444	2	41564.0222	142.66	<0.001 Significant
Error	12237.0667	42	291.3587		
Total	95365.1111	44			

Highly statistically significant difference ($P<0.001$) was observed in flexural modulus of these three different flexible denture basematerials.

Table 7: Scheffe's Post hoc test for intergroup comparison of flexural modulus.

Intergroup comparison	*P* - Value	Significance
Lucitone FRS v/s TCS Unbreakable	<0.01	Significant difference
Lucitone FRS v/s Sebilex	<0.01	Significant difference
TCS Unbreakable v/s Sebilex	<0.01	Significant difference

Statistically significant difference ($p<0.01$) is seen between all three flexible denture base materials by Scheffe's post hoc test for flexural modulus.

DISCUSSION

Poly methyl methacrylate (PMMA) is a rigid material. In order to improve some physical and mechanical properties of PMMA, various researches have been done which include addition of metal wires or plate, fibers, metal inserts and modification in chemical structure. Some studies showed that, to increase the strength of PMMA, carbon fibers can be incorporated. But it leads to increase in porosity, minor surface imperfections and ultimately weak final prosthesis.[12,13]

In 1950s, polyamide (flexible) resin was proposed as a denture base material. It had some advantages like higher elasticity, low toxicity in patient who are allergic to metal or acrylic and less polymerization shrinkage. So flexible denture base materials became boon in cases like severe undercuts where surgery is contraindicated, also used as provisional denture and in management of midline fracture.[14-16]

Impact strength is a measurement of the energy absorbed by material before the fracture. In this study, the samples were prepared with the notch. The denture base material with high impact strength should withstand high masticatory loads or impact caused by accidental dropping from patient's hand.

Impact strength depends on many factors which includes material selection, shape of specimens, stress concentration and position of specimen.[10,17-19]

Impact strength of Lucitone FRS had significantly maximum value (57.53 ± 4.45 kJ/m^2) compared to Unbreakable (45.13 ± 2.47 kJ/m^2) and Sebilex (40.73 ± 2.31 kJ/m^2). Sebilex had significantly least (minimum) impact strength as shown in Graph 1, Table 1 & Table 2. Statistically significant difference ($p<0.01$) is seen between all three flexible denture base materials (Table3).

GianlucaZappini compared the impact strength of notched and un-notched denture materials. He observed no difference despite of the type of specimen prepared. The resultshowed that impact strength testing was influenced by loading condition and specimen geometry.[20]Abhay P N et al also compared impact strength of four flexible denture base materials and their results showed that Valplast and De-flex had maximum impact strength compared to Lucitone FRS and Bre-flex.[17] Y Takahashi, concluded that thermocycling significantly decreased the impact strength of one of the polyamides (Lucitone FRS) and the polycarbonate (Reigning) & increased impact strength of the other polyamide (Valplast).[21]

The flexural strength of material is the combination of tensile strength, compressive strength and shear strength. As the compressive strength and tensile strength increases the force required to fracture the material also increases.[2,3,22-25]

Flexural strength of Lucitone FRS had significantly maximum value (67.96 ± 3.42 MPa) compared to Unbreakable (57.05 ± 3.12 MPa) and Sebilex (61.07 ± 3.06 MPa). Unbreakable had significanlty least (minimum) flexural strength as shown in Graph 2, Table 1 & Table 4. Statistically significant difference ($p<0.01$) is seen between all three flexible denture base materials (Table5).

Flexural modulus of Lucitone FRS had significantly maximum value (1359.47 ± 19.03 MPa) compared to Unbreakable (1258.40 ± 18.86 MPa) and Sebilex (1334.47 ± 12.49 MPa). Unbreakable had significantly least (minimum) flexural modulud as shown in Graph 3, Table 1 & Table 6. Statistically significant difference ($p<0.01$) is seen between all three flexible denture base materials (Table7).

Takabayashi compared mechanical and physical properties of six thermoplastic denture resin materials (three polyamide, two polycarbonate, and a polyethylene terephthalate resin).[23] He concluded flexural strength and modulus of elasticity of polyamide type materials (Valplast, Lucitone FRS and Flexite Supreme) were lower than what was required according to the ISO standard. Y Takahashi, concluded that thermocycling significantly decreased the elastic modulus of one of polyamides (Valplast) and significantly increased the elastic moduliof the other polyamide (Lucitone FRS), the polyethylene terephthalate (EtheShot) and the polycarbonate (Reigning).[21]Abhay P N et al also compared flexural strength of four flexible denture base materials and their results showed that Bre-flex had maximum flexural strength and De-flex had minimum flexural strength.[17] The differences found in the properties of the flexible denture base material might be due to the different percentage of nylon, incorporated in the individual materials, by the manufacturers.[11-15]

Limitations and further scope of study:- Other properties of denture base resins are equally important like accuracy of denture base materials, masticatory load to material, effect of micro-organisms on denture base surface, water sorption, stain resistance, cytotoxicity and surface roughness etc.[26-30] All these need to be researched and need to correlate clinically. Further in vitro and in vivo studies should also be carried out to verify theseresults.

CONCLUSION

With considering the limitations of this study it could be concluded that:

Lucitone FRS had the maximum impact strength, flexural strength and flexural modulus. Unbreakable had the minimum flexural strength and flexural modulus, while Sebilex had minimum impact strength.

(1) The impact strength of Lucitone FRS was 57.53 kJ/m^2, Unbreakable was 45.13 kJ/m^2 and Sebilex was 40.73 kJ/m^2.

(2) The flexural strength of Lucitone FRS was 67.96 MPa, Unbreakable was 57.05 MPa and Sebilex was 61.07MPa.

(3) The flexural modulus of Lucitone FRS was 1359.47 MPa, Unbreakable was 1258.40 MPa and Sebilex was 1334.47 MPa.

Clinical implications of the study: Lucitone FRS has the maximum impact strength, flexural strength and flexural modulus compared to Unbreakable and Sebilex. So this material can be used in less undercut areas for long term as interim removable partial denture. Unbreakable has the lowest flexural strength and flexural modulus, but impact strength is more than Sebilex. Therefore, in severe undercut areas this material can be used for short term duration. Sebilex has the lowest impact strength but flexural strength and flexural modulus were in between Lucitone FRS and Unbreakable, so this material should not be indicated for clinical use.

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Figures

Fig 1. Wax blocks placed in lower portion of flask

Fig 2. Flask placed in injection molding system

Fig 3. Izod impact tester

Fig 4. Fractured specimen after impact strength testing

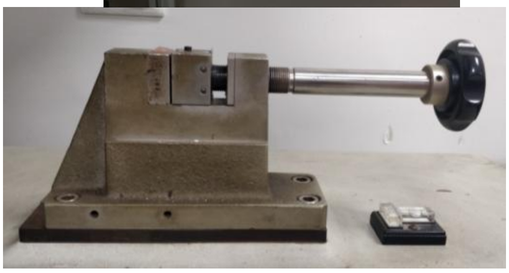

Fig 5. Instron universal testing machine

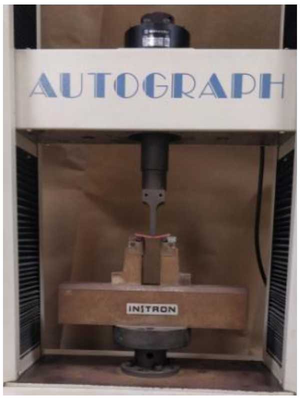

Fig 6. Specimen during testing