Original Article

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Dentistry Section

Comparative Evaluation of Flexural and Impact Strength of different commercially available High Impact Denture Base Materials: An In Vitro Study

ABHIJEET R KORE[1], ASHWINI S BALGUDE[2], TANZILA A BANGI[3], SUSHMA RAMASWAMY[4], PRONOB K SANYAL[5]

ABSTRACT

Introduction: Acrylic resin is the most common material used for the prosthodontic and orthodontic removable appliances. Many brands have come up with High impact resins to overcome its inherent drawbacks of relatively poor resistance to impact and flexural forces, which might affect lifespan of the denture. Now-a-days, use of the high impact denture base materials is very common and hence, clinicians should be aware of the properties of high impact denture base materials available in market.

Aim: To evaluate and compare the impact strength and flexural strength of different brands of high impact denture base materials.

Materials and Methods: The present study was a comparative in-vitro study carried out in Krishna Institute of Medical Sciences Deemed to be University, Karad, Maharashtra, India from January 2017 to August 2017. Three high impact denture base materials used in the study were TRIPLEX (Ivoclar, Vivadent, Liechtenstin), LUCITONE 199 (Dentsply International Inc. Degu Dent GmbH Hanau, Germany) and DENTEK (SP Dental, India). Flexural and impact strengths of these three brands of high impact denture base materials were evaluated and analysed statistically using One-way analysis of variance (ANOVA) test with the help of SPSS version 21.0© software (IBM Corporation, Armonk, NY, USA).

Results: The mean impact strength values of three groups showed that Group III (DENTEK) (8.45 KJ/mm^2) had the highest mean impact strength value followed by Group I (TRIPLEX), (8.19 KJ/mm^2) and Group II (LUCITONE 199) (5.43 KJ/mm^2). The difference between Groups III and I was insignificant but the difference was significant between Group III and Group II as well as between Group I and Group II. Group II showed highest mean flexural strength (103.45 Mpa) followed by Group I (95.95 Mpa) and Group III (86.22 Mpa). But difference was statistically insignificant among the three groups for flexural strength.

Conclusion: The study concluded that highest impact strength recorded was with DENTEK followed by TRIPLEX and LUCITONE. The highest flexural strength recorded was with LUCITONE followed by TRIPLEX and DENTEK.

Keywords: Acrylic reinforcement, Denture fracture, Polymethylmethacrylate, Torsional forces

INTRODUCTION

Dentures are prosthetic devices used to replace the missing teeth which take support from surrounding hard and soft tissues of the oral cavity. In ancient times, dentures were made up of ivory, animal horns, bone or wood [1,2]. Vulcanised rubbers came in use as a denture base material in 18th century [3]. Acrylic resin was developed in 1937 by Dr. Walter Wright during the early years of the Second World War when the use of natural rubber for dental vulcanite was prohibited [4,5]. An ideal denture base material should possess several properties such as biocompatibility, ease of repair, high bond strength with teeth, good esthetics and adequate physical and mechanical properties [6,7]. No such material has been introduced till today, which possesses all the above mentioned properties and the research continued to prosper in the respective field.

Even after 80 years of its invention, acrylic resins are the most common material used for the prosthodontic and orthodontic removable appliances [2]. Acrylic resin is basically derived from acrylic acid, methacrylic acid or compounds related to them. Most commonly used acrylic resin is Poly Methyl Methacrylate (PMMA) [6,7]. Adequate strength, excellent esthetic properties, low water sorption, biocompatibility, facility of repair, and simple processing technique are some of the advantages of PMMA material [8,9]. At the same time the material has some inherent drawbacks as relatively poor resistance to impact and flexural forces which might affect lifespan of the denture [10-13]. Denture fractures are very common and pose a problem for patient, dentists as well as the laboratory technicians. Denture fractures usually result from two types of forces as flexural fatigue and impact force. Flexural fatigue is responsible for the midline fracture while denture fracture because of the sudden fall of the denture is a result of impact failure [11]. Denture fracture also may be due to a multiplicity of factors rather than just denture base material properties itself as thin denture base, prominent frenum-usually labial, prominent midpalatine raphe, single complete denture opposing natural dentition without any reinforcement etc., [14-19]. Midline fracture is the most common site of denture fracture which usually coincides with the notch for the relief of labial frenum of either the maxillary and mandibular complete denture (59%) [15-17,20]. Denture fracture thus shows that adequate flexural strength and impact strength are a common requisite to overcome these fractures.

Flexural strength is the stress in a material just before it yields in a flexure test [6,21]. High flexural strength of the material resists the torsional forces in function for the longer clinical service of the prosthesis, while Impact strength is the measure of the energy absorbed by a material when it is subjected to sudden load [22]. Thus, flexural strength indicates material performance under the conditions of static load while impact strength is a measure of energy absorbed by the material before fracture [23,24].

Literature suggests two approaches to strengthen PMMA material [12,25,26]. One is to increase the impact strength by incorporating a rubber phase in bead polymer [12,25]. Rodford RA described the development of these high impact denture base materials using Butadiene-styrene rubber [27]. The Butadiene-styrene rubber particles help to achieve better bond with PMMA. These high impact denture base materials are so-called because of greater impact strength and fatigue properties. The second approach is a reinforcement of PMMA resin denture base with high modulus fibres, for example, carbon fibers, glass fibers, ultra-high modulus polyethylene, titanium derived fillers, silver nanoparticles, zirconium oxide nanoparticles etc., [25-31].

Many brands of acrylic resins are available as "High impact resins". There have been many studies comparing regular heat cure resins but very few studies are available comparing high impact resins. At present, use of high impact denture base materials is very common and hence clinicians should be aware of the properties of high impact denture base materials for selection of better material from the different available brands. So, the purpose of this study was to evaluate and compare the flexural and impact strength of three different brands of high impact denture base resins.

MATERIALS AND METHODS

This was a comparative in-vitro original research study. The study was carried out in the Department of Prosthodontics, School of Dental Sciences, Krishna Institute of Medical Sciences Deemed to be University (KIMSDU), Karad, Maharashtra, India during January 2017 -August 2017. The approval from the KIMSDU ethical committee (Protocol no. 2016-17/228 and letter no. KIMSDU/IEC/04/2016) was obtained. The materials selected for the study based upon fact that these were the commonly used materials in the western Maharashtra region and sufficient scientific literature was not available regarding their comparative mechanical properties.

Three high impact denture base materials used in the study were:

Group I: High Impact heat cure PMMA-TRIPLEX (Ivoclar, Vivadent, Liechtenstin)

Group II: High Impact heat cure PMMA-LUCITONE 199 (Dentsply International Inc. Degu Dent GmbH Hanau, Germany)

Group III: High Impact heat cure PMMA-DENTEK (SP Dental, India).

Three Stainless steel dies of dimensions 64 × 10 × 3 mm each as per the ISO standardisation (ISO: 1567:1999) required for testing flexural strength of denture base acrylic resin (10 in each group) were fabricated. Similarly, another three Stainless steel dies of dimensions 60×8×3 mm each as per the ISO standardisation (ISO: 1567:1999) required for testing impact strength of denture base acrylic resin (10 in each group) were fabricated.

Preparation of the Mould

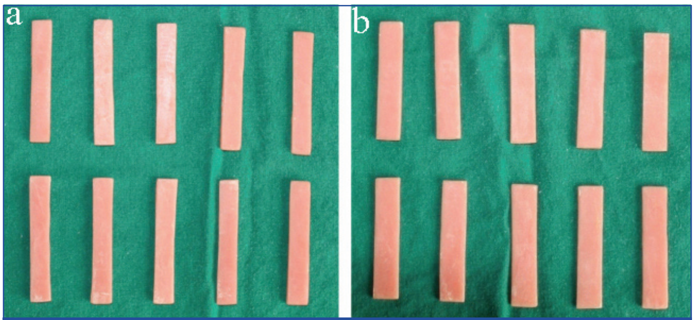
A. For impact strength: Three Metal dies of dimension 60×8×3 mm each (ISO: 1567:1999) were flasked (Jabbar Varsity Flask. India) using standard flasking protocols with Type III Dental stone (Kalstone, Kalabhai, India). After the stone was set, the metal dies were removed thus creating space for the resin [Table/Fig-1].

[Table/Fig-1]: Sample fabrication.

B. For flexural strength: In a similar way, moulds were prepared for the impact strength samples with the use of metal dies of dimension 64×10×3 mm each (ISO: 1567:1999).

Preparation of the Acrylic Specimens

The monomer-polymer ratio was maintained as per the manufactures' instructions for all three resin brands. The monomer-polymer ratio for Triplex resin was 1:2.3 while it was 1:2.1 for Lucitone 199 and 1:2.5 for Dentek. After packing, the flasks were allowed to bench cure for 1 hour under hydraulic press (Sirio P400, SIRIO DENTAL S.R.L. Meldola, Italy) at pressure and then transferred on manual press [7]. The acrylic specimens were cured with long curing cycle in a digitally controlled acryliser (Wasserman 170980, Hamburg, Germany). The acrylic specimens were retrieved after deflasking followed by their finishing and polishing [Table/Fig-2]. The polished specimens were measured using a digital vernier calliper (Aerospace 0-150 digital calliper pr17, India). This procedure was repeated until there were 10 specimens of the 3 brands each thus making 30 specimens available for flexural strength testing and 30 specimens for impact strength testing. The specimens then stored in 3 different water baths (20 specimens in each bath) according to the brand to avoid the mix up [Table/Fig-3]. The specimens were stored in a water bath for 24 hour so that the residual monomer from acrylic specimens could leach out.



[Table/Fig-2]: Samples: a) Impact strength Samples; b) Flexural strength Samples.

Triplex (Group I) N=20	Lucitone 199 (Group II) N=20	Dentek (Group III) N=20
• Group I A-For flexural strength (N=10) • Group I B- For imapct strength (N=10)	• Group II A- For flexural strength (N=10) • Group II B- For imapct strength (N=10)	• Group IIIA- For flexural strength (N=10) • Group III B- For imapct strength (N=10)

[Table/Fig-3]: Final division of the specimens.

Evaluation of Impact Strength

Impact strength of the samples was determined using the Izod/Charpy Impact testing machine (Computerised, Software based), Company: International Equipments, India, Serial No. 430. Impact strength is the measure of the energy absorbed by a material when it is subjected to sudden load [14-17]. Impact strength is calculated by using the formula:

Impact Strength=(Impact Energy)/(Area of the Sample)

Evaluation of Flexural Strength

Universal testing machine {(Computerised, software based) Company: Star Testing System, India. Model No. STS 248} was used to determine the flexural strength of the samples. Accuracy of the machine: ±1%, C/h speed: 5mm/minutes, Distance between supports: 50mm. The maximum load before fracture was recorded for all the specimens with the help of Universal testing machine. To calculate the flexural strength, following formula was used:

$FS=3FL/2bd^2$ [32] where,

FS=Flexural strength

F=the force at fracture point (N) L=the length

b=width, d=thickness.

STATISTICAL ANALYSIS

Mean value along with the standard deviation for the three groups was calculated for both impact and flexural strength records. One-way analysis of variance (ANOVA) was used to statistically compare the study groups using SPSS version 21.0© software (IBM Corporation, Armonk, NY, USA).

RESULTS

Impact and flexural strengths were measured for three different commercially available high impact heat cure PMMA. The results were as follows.

Impact Strength

Energy absorbed to break the specimens of Group I ranged from 0.18 J to 0.40 J with a mean of 0.287 J. For Group II it was from 0.16 J to 0.28 J with a mean of 0.222 J and for Group III from 0.20 J to 0.46 J with a mean of 0.30 J.

Impact strength ranges from 5.14 KJ/m^2 to 11.42 KJ/mm^2 with a mean of 8.195 KJ/mm^2 for Group I. For Group II and Group III the mean Impact strength was 5.439 KJ/mm^2 and 8.45 KJ/mm^2, respectively [Table/Fig-4,5].

The comparative statistics of Impact strength showed in [Table/Fig-4]. The mean impact strength values of three groups [Table/Fig-5] showed that Group III had the highest mean impact strength value followed by Group I and Group II. Also the comparison showed that the difference between Group II and Group III (p=0.002) and that of between Group I and Group II (p=0.005) was statistically significant. However, the difference between Groups I and III was insignificant [Table/Fig-6]. So Group III can be considered the most superior among the three groups in terms of impact strength.

Flexural Strength

For Group I, the force required to fracture the specimen was in the range of 140.53 to 260.28 N. while it was in the range of 117.89 to 265.38 N and in the range of 117.31 to 204.82 N. for Group II and Group III, respectively [Table/Fig-7]. The mean flexural strength was 95.95 Mpa, 103.45 Mpa and 86.22 Mpa for Group I, Group II and Group III, respectively [Table/Fig-8]. The mean Flexural strength values of the three groups showed that Group II had the highest mean Flexural strength value followed by Group I, Group III. However, the differences between these Groups were statistically insignificant [Table/Fig-9].

Comparative evaluation of Impact and Flexural strength of all 3 study groups along with the standard deviation showed in [Table/Fig-10,11], respectively.

DISCUSSION

Acrylic resin is universally accepted and used widely today as a denture base material. The resistance to fracture of acrylic dentures depends on two important properties- flexural and impact strength of that material. Denture fractures usually occur because of insufficient flexural strength and impact strength [16]. Over the years, various modifications were attempted to improve overall properties of the Poly Methyl Methacrylate (PMMA). The modifications include chemical modification or mechanical reinforcement. The autoclave processing technique is another method to improve properties of acrylic resins in comparison to conventional water-bath processing technique [33]. Focus of this study was to evaluate the impact and

Group A: Triplex			Group B: Lucitone			Group C: Dentek		
Sample No.	Impact energy (J)	Izod impact strength (KJ/m^2)	Sample No.	Impact energy (J)	Izod impact strength (KJ/m^2)	Sample No.	Impact energy (J)	Izod impact strength (KJ/m^2)
No. 1	0.26	7.42	No. 1	0.28	6.86	No. 1	0.28	7.84
No. 2	0.30	8.57	No. 2	0.22	5.39	No. 2	0.36	10.08
No. 3	0.24	6.85	No. 3	0.20	4.90	No. 3	0.46	12.88
No. 4	0.32	9.14	No. 4	0.24	5.88	No. 4	0.20	5.60
No. 5	0.24	6.85	No. 5	0.20	4.90	No. 5	0.28	7.84
No. 6	0.32	9.14	No. 6	0.22	5.39	No. 6	0.22	6.16
No. 7	0.40	11.42	No. 7	0.22	5.39	No. 7	0.34	9.52
No. 8	0.38	10.85	No. 8	0.24	5.88	No. 8	0.28	7.84
No. 9	0.18	5.14	No. 9	0.16	3.92	No. 9	0.36	10.08
No. 10	0.23	6.57	No. 10	0.24	5.88	No. 10	0.24	6.72
Average	0.287	8.195		0.222	5.439		0.30	8.45

[Table/Fig-4]: Comparative statistics of Impact strength.

Group	No. of points	Mean	Standard deviation	Standard error of mean	Median
1	10	8.195	1.988	0.6287	7.995
2	10	5.439	0.7816	0.2472	5.390
3	10	8.456	2.200	0.6957	7.840

[Table/Fig-5]: Mean Impact strength of three study groups.

		Mean difference	p-value	F-value
Triplex	Lucitone	2.75	0.005*	8.915
	Dentek	-0.26	0.942	
Lucitone	Dentek	-3.017	0.002*	

[Table/Fig-6]: One-way ANOVA- impact strength.

Group A: Triplex			Group B: Lucitone			Group C: Dentek		
Sample No.	Flexural load (N)	Flexural strength (MPa)	Sample No.	Flexural load (N)	Flexural strength (MPa)	Sample No.	Flexural load (N)	Flexural strength (MPa)
No. 1	157.58	83.48	No. 1	230.59	122.16	No. 1	144.35	76.47
No. 2	203.25	107.67	No. 2	170.61	90.38	No. 2	186.39	98.74
No. 3	140.53	74.45	No. 3	121.52	64.37	No. 3	163.26	86.49
No. 4	162.48	86.07	No. 4	117.89	62.45	No. 4	204.82	108.50
No. 5	158.95	84.21	No. 5	207.76	110.06	No. 5	157.38	83.37
No. 6	176.40	93.45	No. 6	253.23	134.15	No. 6	176.79	93.65
No. 7	144.45	76.52	No. 7	265.38	140.59	No. 7	152.19	80.62
No. 8	187.96	99.57	No. 8	230.60	122.46	No. 8	117.31	62.14
No. 9	219.32	116.19	No. 9	207.80	110.24	No. 9	161.89	85.76
No. 10	260.28	137.89	No. 10	125.85	77.64	No. 10	163.26	86.49
Average		95.95			103.45			86.22

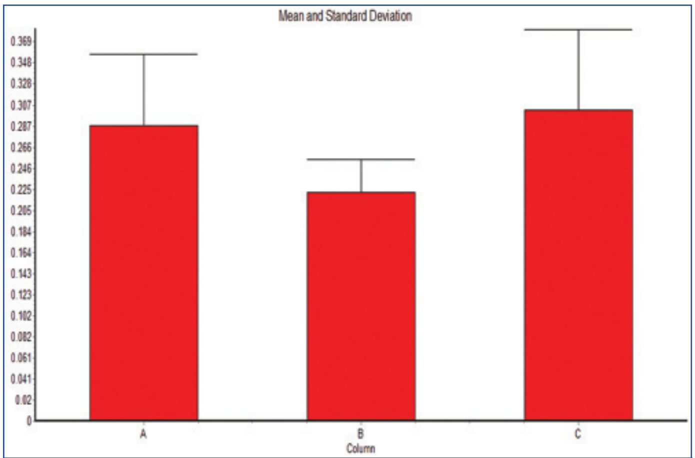
[Table/Fig-7]: Comparative statistics of Flexural strength.

Group	No. of points	Mean	Standard deviation	Standard error of mean	Median
1	10	95.950	19.878	6.286	89.760
2	10	103.45	28.222	8.925	110.15
3	10	86.223	12.575	3.976	86.125

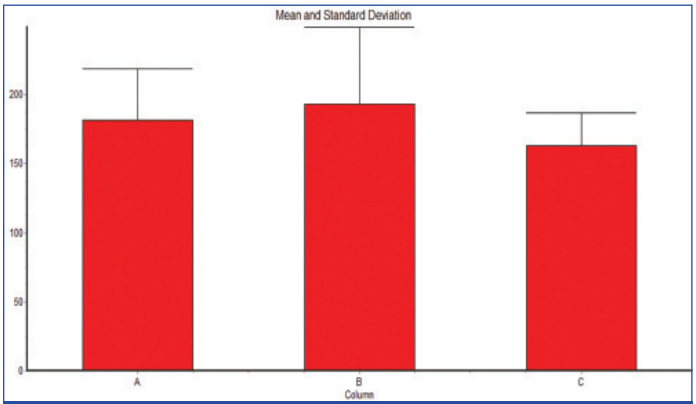
[Table/Fig-8]: Mean Flexural strength of three study groups.

		Mean difference	p-value	F-Value
Triplex	Lucitone	-7.5	0.712	1.658
	Dentek	9.72	0.568	
Lucitone	Dentek	17.227	0.183	

[Table/Fig-9]: One-way ANOVA- flexural strength.



[Table/Fig-10]: Impact strength of three study groups.



[Table/Fig-11]: Flexural strength of three study groups.

flexural strength of three different commercially available chemically modified high impact heat cure denture base resins. Results of the present study showed that the flexural and impact strength of different brands of high impact denture base materials were different. So, the null hypothesis was rejected in this study.

In a study done by Gupta A and Tewari RK the authors compared the impact strength and transverse strength of the high-impact materials- Trevalon Hi, DPI Tuff and Metrocryl Hi [12]. Trevalon was used as a control, which is a conventional heat polymerised resin; the study observed that incorporation of butadiene styrene rubber resulted in increase in impact strength as compared to the control group. Shibat Al Hamd YA and Dhuru VB compared the physical and mechanical properties of pressure-molded (Lucitone 199 and ProBase Hot) and injection-molded (SR-Ivocap) denture base materials [34]. It was seen that ProBase Hot had less bending deflection but higher flexural strength values than other two materials (p<0.05). At the same time Lucitone (PMMA-grafted resin) showed least flexural strength and higher bending deflection when compared to all other materials tested. In another study Ajaj-Alkordy NM and Alsaadi MH compared the flexural strength of Lucitone 199, a high-impact resin and Rodex, a conventional resin resulted into higher flexural strength (p=0.001) of Lucitone 199 [35]. Jagger DC et al., compared impact strength of five "high strength" acrylic materials with a conventional heat cured resin [36]. The results of the study demonstrated that the impact strength was highest for Metrocryl Hi and lowest for Trevalon. Three out of the five materials namely; Metrocryl Hi, Lucitone 199, and N.D.S Hi had higher impact strength than the control group (Trevalon) which was statistically significant. There was no significant difference between Enigma Hi-base (7.73 kJ m^{-2}) and Sledgehammer (7.40 kJ m^{-2}) as compared with the control (4.94 kJ m^{-2}).

Limitation(s)

In the present study, conventional denture base resin could have been used as a control group.

CONCLUSION(S)

The study concluded that DENTEK had the highest impact strength followed by TRIPLEX and LUCITONE while LUCITONE had the highest flexural strength followed by TRIPLEX and DENTEK but the difference between the three study materials in terms of flexural strength was statistically insignificant.

Similar studies can be undertaken in different clinical set-up to underline the results of this in-vitro study. So then clinician can choose the denture base material accordingly which will be an evidence based practice.

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PARTICULARS OF CONTRIBUTORS:
1. Reader, Department of Prosthodontics, School of Dental Sciences, Karad, Maharashtra, India.
2. B.D.S, Department of Prosthodontics, School of Dental Sciences, Karad, Maharashtra, India.
3. B.D.S, Department of Prosthodontics, School of Dental Sciences, Karad, Maharashtra, India.
4. Reader, Department of Prosthodontics, School of Dental Sciences, Karad, Maharashtra, India.
5. Professor, Department of Prosthodontics, School of Dental Sciences, Karad, Maharashtra, India.

NAME, ADDRESS, E-MAIL ID OF THE CORRESPONDING AUTHOR:
Abhijeet R Kore,
E405, Suncity Apartment, Malakapur, Karad, Maharashtra, India.
E-mail: abhijeet.kore@ymail.com

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