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ORIGINAL ARTICLE

Comprehensive Analysis of Repair/Reinforcement Materials for Polymethyl Methacrylate Denture Bases: Mechanical and Dimensional Stability Characteristics

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Abstract Fracture of complete denture is a common problem as acrylic resins hold inherent limitations. This necessitates affirmation of a selection criterion by evaluating the critical requirements of repair materials. The study intended to evaluate mechanical properties and dimensional stability of common denture base repair and reinforcement materials under standard experimental protocol. Seven types of denture reinforcement materials were chosen. Forty cuboidal samples were made in accordance with ISO 178 for three point bending test and divided to eight groups of five samples each. One group acted as control and samples of seven groups were sectioned and repaired with chosen materials. Five mechanical properties—fracture load, deflection, flexural strength, fracture toughness and elastic modulus were evaluated for all groups. Forty mandibular complete denture specimens were utilized for evaluating fracture load and deflection under loading. Dimensional stability after repair with seven different repair materials was analyzed in two planes (Linear and curvilinear) utilizing separate set of denture samples. Heat cure polymethyl methacrylate with polyethylene fiber was affirmed as material of choice based on this study as it accomplishes the most critical norms of requirement.

Keywords Edge profile · Curvilinear · Fatigue · Fracture · Deflection · Cyclic loading and micro-flaws

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Introduction

Repair and reinforcement of the polymethyl methacrylate (PMMA) resin denture base with different materials have been tried and documented in the literature which include stainless steel alloy wires [1–4], polyethylene fibers [5–10], glass fibers [11–14], carbon fibers [15], polyaramid fibers [16] and alloy mesh [17]. Among the materials employed, the superiority of one over the other has not been clearly analyzed in the literature and the basic requirements for a repair material have not been affirmed. Considering the major shortcomings of PMMA resins that include fatigue failure [18], susceptibility to fracture [19] and dimensional instability [20], this study was intended to establish a material of choice for denture repair by analyzing seven different repair and reinforcement materials that are commonly used and comparing their mechanical and dimensional stability properties with that of unreinforced PMMA resin.

Materials and Methods

The seven types of denture reinforcement that were evaluated in the study included:

- Autopolymerizing PMMA—*DPI-RR Cold cure*®, India [®—Trade name].
- Autopolymerizing PMMA resin—*DPI-RR Cold cure*®, India—with 18-8 stainless steel wire of 21 gauge thickness,
- Autopolymerizing PMMA resin—*DPI-RR Cold cure*®, India—with vitallium mesh—(cobalt chromium alloy meshwork of 0.5 mm thickness and 3 cm length).
- Heat-activated PMMA resin—*DPI heat cure*®, India.

- Heat-activated PMMA resin with polyethylene fibers—*DPI Heat cure*®, India + ultra high modulus polyethylene fibers—Industrial: CIPET, Guindy, Chennai, India.
- Bis-acrylic resin—*Unifast Trad*®—GC Corporation, Tokyo, Japan.
- Light activated polyether urethane dimethacrylate temporary material [PEUDA]—*Revotek LC*®—GC corporation, Tokyo, Japan.

The manipulation characteristics and standardization of the different acrylic resins used as reinforcement materials in this study were listed in Table 1.

The cobalt–chromium alloy meshwork used as reinforcement material was a pre-formed framework mesh of wires, 0.5 mm in thickness, 1.5 cm in width and 4 cm in length. The mesh can be bent, condensed and adapted to the denture surface for reinforcement of the denture. The metal wire used as reinforcement material was 18-8 stainless steel wire of 21 gauge thickness.

Fabrication of Cuboidal Block Samples

Cuboidal block samples were made to the dimensions 80 mm length, 10 mm width and 4 mm height in accordance to ISO 178 standardization for testing mechanical properties of materials.

Blocks of this exact dimension were constructed by using the pre-formed metal molds that were milled in Central Institute of Plastic Engineering and Technology—(CIPET, Guindy, Chennai, India*)* to dimensions 0.2 mm more in length, width and thickness than the required dimension. Wax pattern was made in this mold with type II inlay wax—*Krohenwachs*®—Bego—ADA no. 4 and the block wax pattern was invested and cast in cobalt–chrome alloy—vitallium alloy. The cuboidal metal casting which was 0.2 mm more in dimension overall was milled to attain the exact required dimension using CAD CAM milling machine—*Hecktomark*®. Heat-activated polymethyl methacrylate—PMMA resin specimens were fabricated by indexing the cuboidal metal with polyvinyl siloxane putty consistency material,—*Virtual Refill*®—Ivoclar Vivadent—making wax blocks with modeling wax—*Modelling wax no.2*®—HDP and processing them with DPI heat cure® resin by compression molding at 74° for 90 min.

Fabrication of Denture Samples

A total of 40 mandibular denture samples were made of heat-activated PMMA resin with identical dimensions by duplication technique stated by McCarthy [21]. Petroleum jelly was applied to the tissue surface of the mandibular denture that was to be duplicated and a stone cast was made of type IV gypsum dental stone—*Ultrarock*®—Kalabhai—after block out of undercuts. An index of the denture polished surface and teeth was made with silicone impression material of high viscosity—*Virtual Refill*®—Ivoclar Vivadent. Cross linked, autopolymerizing PMMA resin—*DPI Tooth Molding Powder*®—was mixed and packed into the silicone index covering up to the line representing the termination of denture teeth in the index. A temporary denture base was made on the stone cast with autopolymerizing PMMA resin. After the denture teeth resin set, it was removed from the index; excess resin in the cervical margins was trimmed and repositioned in the index. Modeling wax was melted and dispensed into the index, the stone cast along with temporary denture base was inverted over the index and the assembly held in position for 5–6 min in cold water. The index was removed and the temporary denture in wax was finished and processed by

Table 1 Denture base acrylic repair materials

Material	Commercial name	ADA specification number	Mixing ratio and Processing technique	Curing cycle method and time
Heat activated PMMA	DPI heat cure®, India	12	Powder:liquid = 3:1 by volume	Compression molding technique−74°: 90 min
Autopolymerizing PMMA	DPI-RR cold cure®—India	12	Powder:liquid = 3:1	Fluid resin technique
Heat-activated PMMA with polyethylene fibers	DPI heat cure®, India + Ultra high modulus polyethylene fibers (Industrial*)	12	Fiber added to polymer	Compression molding technique—74°: 90 min
Auto-polymerizing bis-acrylic	Unifast Trad®, GC, Japan	12	Powder:liquid = 2:1	Fluid resin technique
Visible light activated PEUDA	Revotek LC®, Japan	12	–	Visible light of the spectrum of 425–525 ηm for 100–120 s

PMMA polymethyl methacrylate, *PEUDA* polyether urethane dimethacrylate, *ADA* American Dental Association, ® trade names

* Central Institute of Plastic Engineering and Technology, Guindy, Chennai, India

compression molding technique with heat-activated PMMA resin. By employing this technique, a total of 40 mandibular complete denture samples were made with identical dimensions.

Fabrication of Denture Samples with Pins

Additional set of 40 mandibular complete denture samples were made in same dimensions by duplication method mentioned earlier. Two parallel pins of stainless steel of 21-gauge thickness were placed in the pin holes prepared in the dentures lingual to the anterior denture teeth and fixed with autopolymerizing resin. The pins were placed in such a way that they were separated from each other by a distance in the linear direction which can be measured using a caliper before and after fracture and repair.

The 40 cuboidal block specimens were divided into eight groups of five specimens in each. Of these groups, one group acted as control (Group A1). A silicone matrix—putty consistency addition silicone—*Virtual Refill*®—Ivoclar Vivadent and dental stone matrix of the specimens were made for re-orienting the specimens after fracture. Specimens of the remaining seven groups were sectioned in the middle by using 1.5 mm thick stone disc to create a gap width of 20 mm which was checked by using the positioning matrix of dental stone that helped in re-orienting the specimens. The joint surface was prepared with round vulcanite trimmer to create a rounded edge profile. Round edge profile has been shown to provide better bond strength than other types of joints in the literature [32]. Hence it was taken as a standard for this study. Dovetail shaped grooves were made on joint surfaces of either segments.

The second group of specimens—Group A2—were oriented by silicone matrix, waxed up at the joint spaces, flasked, de-waxed and packed with heat-activated PMMA resin—*DPI heat cure*®—by compression molding technique.

Third group—Group A3—specimens were repaired by fluid resin technique with autopolymerizing PMMA resin—*DPI-RR cold cure*® by placing the segments in the silicone matrix, packing the resin dough and placing in pressure pot for 15 min.

The fourth group—Group A4—of specimens were repaired with autopolymerizing PMMA resin—*DPI-RR cold cure*®—after adaptation and placement of a 21-gauge thick 18-8 stainless steel wire in the groove prepared in each specimen, packing resin and placing in pressure pot for 15 min.

The fifth group—Group A5—of specimens were repaired with autopolymerizing resin by fluid resin technique after adaptation and placement of chrome-cobalt—vitallium—mesh of 0.5 mm thickness, 1.5 cm width and 4 cm length in the groove created in the specimens.

The sixth group—Group A6—of specimens was repaired with the auto-polymerizing bis-acrylic resin—*Unifast Trad*®—GC Corporation, Tokyo—by fluid resin technique.

The seventh group—Group A7—of specimens were repaired with visible light activated Polyether urethane dimethacrylate—PEUDA—*Revotek LC*®—GC corporation—resin by molding the resin in the mold space and curing it under the visible light of the spectrum of 480–580 ηm for 60 s in increments of 2 mm as per the manufacturer's instructions.

The eighth group—Group A8—of specimens were repaired by compression molding technique with heat-activated PMMA resin—*DPI heat cure*®—after incorporating polyethylene fibers—Ultra high modulus polyethylene fibers—Industrial: CIPET, Guindy, Chennai—into polymer of PMMA at a fiber:polymer ratio of 1:5 by weight.

Fig. 1 Denture samples stored in distilled water at 37 °C for 2 days prior to testing

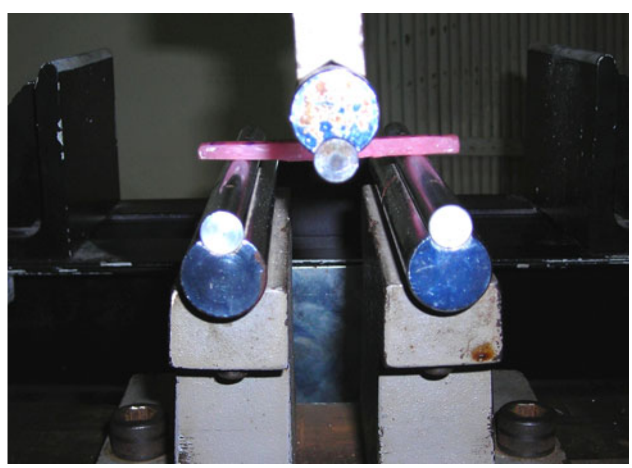

Fig. 2 Three-point bending test: cuboidal samples positioning with 50 mm span length

The 40 denture specimens were divided into eight groups of five in each.

One group acted as the control group (Group B1) and remaining seven groups (Groups B2–B8) were sectioned to create a gap width of 15 mm at base, surface prepared for round joint and repaired with seven different materials taken for the study by techniques stated earlier.

The 40 denture samples with two pins were divided into eight groups of five in each. One group acted as the control group (Group C1) and remaining seven groups were sectioned, joint surface prepared for round edge profile and repaired with seven different materials taken for the study (Groups C2–C8).

All the repaired and reinforced cuboidal and mandibular denture specimens including the control group were stored in distilled water at 37 °C for 2 days prior to testing in accordance with the ADA standard specification for denture base materials considering the deliberation that storage in water or simulated oral fluid can alter the mechanical properties of resins—Fig. 1.

The three-point bending test of the cuboidal samples to evaluate the mechanical properties of the cuboidal samples was conducted in the Universal testing machine—*Lloyd Universal Testing Machine* with a cross head speed of 0.5 cm/min. The specimens were positioned in the specimen holder with both ends stabilized in the platform so that the span length was kept at 50 mm—Fig. 2. Fracture load and deflection were noted down for each specimen. The other mechanical properties were derived using formulae.

Fracture load and deflection of the mandibular denture samples was also evaluated in *Lloyd Universal testing machine* with a cross head speed of 0.5 cm/min—Fig. 3.

The dimensional stability of denture samples before and after repair was tested in two planes—linear and curvilinear were measured with group C. The linear dimensional stability was evaluated by measuring the distance between the parallel pins incorporated in the denture before and after repair. An electronic caliper—*Digimatic Mitutoyo electronic caliper*—with a calibration of 0.01 mm minimum range was used for the analysis of linear dimensional variance. Distance between the pins was measured before and after repair by placing the caliper between the pins thereby measuring the distance between the inner surfaces (medial) of the pins. The values for each specimen in the group were recorded with the minimum accuracy range of 0.01 mm.

The curvilinear dimension was measured by using a profile projector—*Deltronic Profile projector*—Fig. 4. Dentures were placed on the platform of the projector with lingual border being projected on the screen and the curvilinear dimension of the distance between the borders of both sides were measured and recorded before repair. These values were compared and analyzed with the measurements obtained after the fracture and repair of the dentures.

The mean values of mechanical properties were statistically analyzed using one way ANOVA for analysis of variance between groups and within group analysis was done by using Post Hoc test. The fracture load values for mandibular denture samples were tabulated and statistical analysis between groups was done by one way ANOVA and within groups analysis was done by Post Hoc test. t Test analysis was carried out to determine the statistical significance in variance of linear dimensional disparity

$$\text{Transverse strength / modulus of rupture / flexural strength} = \frac{3 \times (\text{Fracture load in N}) \times (\text{distance between supports in mm})}{2 \times (\text{Width of specimen in mm}) \times (\text{thickness of specimen in mm})^2} \quad [\text{Unit: N/mm}^2] \tag{1}$$

$$\text{Fracture toughness} = 1/2 \times (\text{fracture load in N}) \times (\text{deflection at fracture in mm}) \quad [\text{Unit: Nm}] \tag{2}$$

$$\text{Modulus of elasticity} = \frac{(\text{fractureloadinN}) \times (\text{distancebetweenthesupportsinmm})^3}{4 \times (\text{deflection at point P}) \times (\text{height in mm}) \times (\text{width in mm})^2} \tag{3}$$

(P---initial point of deformation curve) [Unit: N/mm^2].

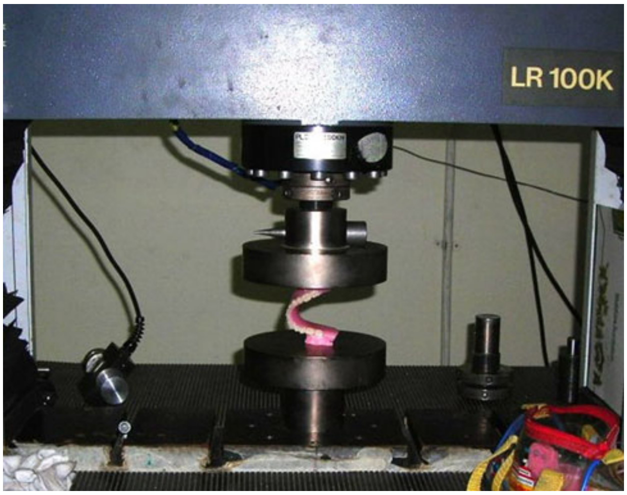

Fig. 3 Evaluation of fracture load and deflection—positioning of mandibular denture samples

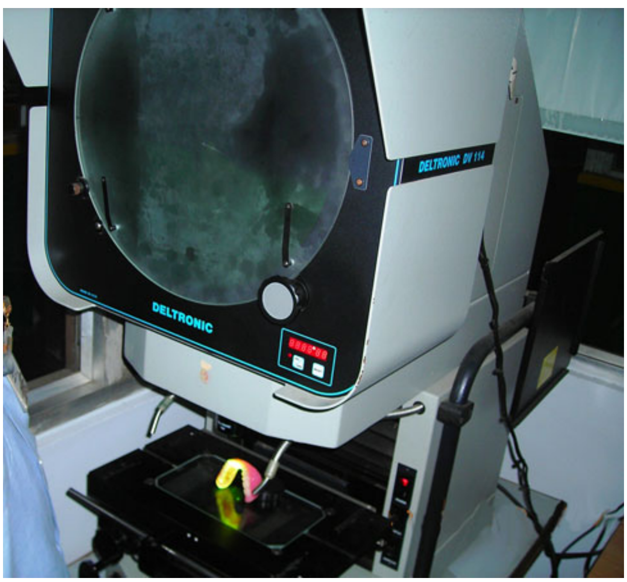

Fig. 4 Deltronic profile projector—evaluation of curvilinear dimensional variance

before and after repair between the groups. For analysis of variance within the groups, paired samples test was performed. For analysis of variance in curvilinear dimensional between the groups, One way ANOVA test between the groups and Post Hoc test was done to analyze the variance within the groups

Results

The results were tabulated and mean values of the mechanical properties for cuboidal samples calculated—Tables 2, 3, 4, 5 and 6. The fracture load values for mandibular denture samples were tabulated—Table 7, statistical analysis between groups and within the groups revealed that, among the repaired specimens, heat cure PMMA resin reinforced with polyethylene fiber had the best mechanical properties in both cuboidal as well as denture samples—Figs. 5 and 6.

The values obtained for dimensional stability in linear direction before and after repair were noted and the mean value for each group was calculated—Table 8. The percentage of dimensional change for different materials in curvilinear direction was tabulated—Table 9. Statistical analysis of the variance between and within groups revealed that samples repaired with bis-acrylic show minimal dimensional change—Fig. 7.

Discussion

Mechanical shortcoming of PMMA denture base resin is attributed to two basic reasons: fatigue failure and susceptibility to fracture. The first quandary, fatigue failure of PMMA dentures, occurs over a period of time due to continuous and repeated cyclic loading resulting in formation and propagation of micro-flaws within the resin matrix [22–25] Stresses beyond the proportional limit of PMMA resin lead to the second type of problem, abrupt fracture [26–30]. The selection of denture repair or

Table 2 Cuboidal specimens—fracture load (N)

Group name	Sample 1	Sample 2	Sample 3	Sample 4	Sample 5	Mean
A1: control	318.2	330.4	347.6	334.3	325.3	331.2
A2: heat cure repair	164.8	162.1	157.6	169.8	171.1	165.1
A3: self cure repair	136.4	154.7	138.7	112.7	126.5	133.8
A4: self cure + wire	152.1	155.3	161.3	151.8	136.2	151.3
A5: self cure + mesh	178.4	159.6	166.9	184.1	189.5	175.7
A6: bis-acrylic	183.7	179.2	165.1	199.3	201.7	185.8
A7: light cure	113.9	122.7	115.8	103.1	112	113.5
A8: heat cure + fiber	212.1	217.5	199.3	219.6	227.9	215.3

Table 3 Cuboidal specimens—flexural strength (N/mm^2)

Group name	Sample 1	Sample 2	Sample 3	Sample 4	Sample 5	Mean
A1: control	149.1	154.9	162.9	156.7	152.5	155.2
A2: heat cure repair	77.2	75	73.9	79.6	80.2	77.2
A3: self cure repair	63.9	72.5	65	52.8	59.2	62.7
A4: self cure + wire	71.3	72.8	75.6	71.1	63.8	71
A5: self cure + mesh	83.6	74.8	78.2	86.3	88.8	82.3
A6: bis-acrylic	86.1	84	77.4	93.4	94.5	87
A7: light cure	53.4	57.2	54.3	48.3	52.5	53.1
A8: heat cure + fiber	99.4	102	93.4	102.9	106.8	100.9

Table 4 Cuboidal specimens—deflection (mm)

Group name	Sample 1	Sample 2	Sample 3	Sample 4	Sample 5	Mean
A1: control	4.5	4.4	4.2	4.5	4.6	4.4
A2: heat cure repair	2.7	1.8	2.5	2.5	3	2.5
A3: self cure repair	2.8	2.7	2.3	1.8	2.1	2.3
A4: self cure + wire	2.5	2.4	2.5	3.1	1.9	2.5
A5: self cure + mesh	3	3.8	3.3	2.7	2.7	3.1
A6: bis-acrylic	3.8	3.4	3	2.8	3.2	3.2
A7: light cure	2.1	1.4	1.9	3.3	1.7	2.1
A8: heat cure + fiber	3.9	3.8	3.6	3.9	4.2	3.9

Table 5 Cuboidal specimens—fracture toughness (N mm)

Group name	Sample 1	Sample 2	Sample 3	Sample 4	Sample 5	Mean
A1: control	715.9	726.9	729.5	752.2	768.9	738.7
A2: heat cure repair	222.5	145.9	197	212.2	256.7	206.9
A3: self cure repair	191	208.8	159.5	101.4	132.8	158.7
A4: self cure + wire	190.1	186.4	201.6	235.3	129.4	188.6
A5: self cure + mesh	267.6	303.2	275.4	248.5	255.8	270.1
A6: bis-acrylic	349	304.6	247.6	279	322.7	300.6
A7: light cure	119.6	85.9	110	170.1	95.2	116.2
A8: heat cure + fiber	413.6	413.4	358.7	428.2	478.6	418.5

Table 6 Cuboidal specimens—modulus of elasticity (N/mm^2)

Group name	Sample 1	Sample 2	Sample 3	Sample 4	Sample 5	Mean
A1: control	5524.3	5866.5	6465.8	5803.8	5524.8	5837
A2: heat cure repair	4768.5	7035.6	4925	5306.2	4455.7	5298.2
A3: self cure repair	4480	4476.3	4711.3	4891.5	4706.1	4653
A4: self cure + wire	4753.1	5055.3	5040.6	3825.6	5600.3	4855
A5: self cure + mesh	4645.8	3281.2	3951.2	5327	5336.5	4508.3
A6: bis-acrylic	3776..7	4117.6	4299.5	5560.8	4924.3	4535.8
A7: light cure	4237.3	6847.1	4761.5	2440.8	5147	4686.7
A8: heat cure + fiber	4248.8	4473.7	4325.1	4399	4239.2	4337.2

Table 7 Mandibular denture specimens fracture load (N)

Group name	Sample 1	Sample 2	Sample 3	Sample 4	Sample 5	Mean
B1: control	413.1	407.3	388.6	401.2	395.4	401.1
B2: heat cure repair	163.7	169.6	177.6	169.3	171.4	170.3
B3: self cure repair	136.8	134.8	138.7	142.9	136.9	138
B4: self cure + wire	202.1	195.7	201.8	215.7	199.6	203
B5: self cure + mesh	245.1	209.8	234.5	255.8	246.7	238.4
B6: bis-acrylic	303.8	319.5	348.7	322.6	305.4	320
B7: light cure	123.8	132.6	115.3	132.7	126.5	126.2
B8: heat cure + fiber	344.1	313.9	332.1	327.7	334.8	330.5

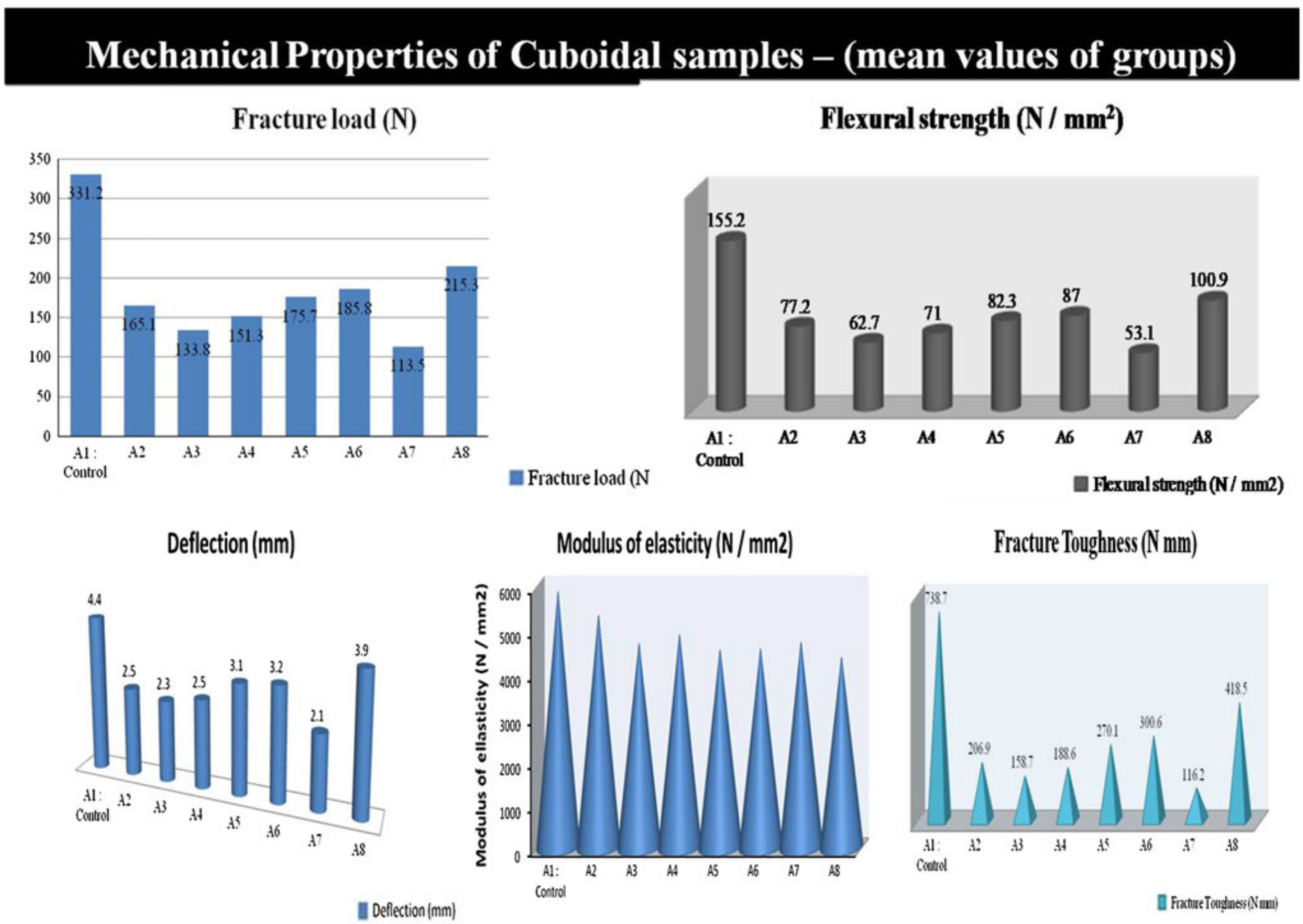

Fig. 5 Mechanical properties of cuboidal samples—(mean values of groups)

reinforcement material should be based on properties pertaining to the shortcomings of PMMA resins. Considering the drawbacks which includes mechanical failures and dimensional instability, this study was done to analyze the fracture load, flexural strength, fracture toughness, deflection, modulus of elasticity, linear and curvilinear dimensional disparity before and after reinforcement.

Seven different repair and reinforcement materials were evaluated through the study for above mentioned properties and they were compared with a control group of unrepaired specimens. Cuboidal shaped specimens were made in accordance with ISO 178 to evaluate the mechanical properties mentioned above. Analyzing the mechanical properties with cuboidal specimens provides data which cannot be fully attributed to the clinical scenario because of the shape variation of mandibular complete dentures. The shape, thickness and form of the specimen tested have a significant influence on the results even under stringent

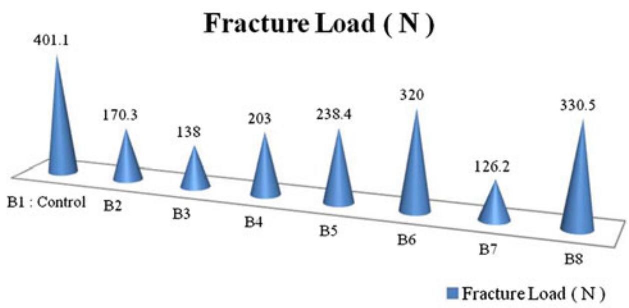

Fig. 6 Fracture load of denture samples—(mean values of groups)

testing conditions. Data with clinical significance can be attained by testing the specimens that are similar to the ones used in the clinical situation [31]. Hence in this study, specimens of mandibular complete dentures were made to test the dimensional steadiness of various reinforcement materials so that clinically pertinent data was obtained. Additionally fracture load of the repaired dentures was also analyzed to ascertain any difference in interpretations of data between cuboidal specimens and denture specimens with regard to mechanical properties.

Preparing a round edge profile of the sectioned specimens before repair was considered in this study as it has been affirmed to be superior to other types of edge profiles [32]. From the evaluation of the mechanical properties, heat cure PMMA resin with polyethylene fibers can be stated as the better repair material as it demonstrated the best fracture load, flexural strength, fracture toughness, deflection and bonding to older resin material.

Auto-polymerizing PMMA resin demonstrated poor mechanical properties in this study. It can be suggested that reinforcement of chrome-cobalt alloy mesh or orthodontic wires must be done when auto-polymerizing PMMA is utilized for repair of dentures. Light cure PEUDA resin temporary material showed poor mechanical as well as dimensional stability characteristics; hence it is not recommended as a repair material based on this study. The poor mechanical properties of light cure resin has been affirmed to be due to lack of cohesion/adhesion between light cure resin and heat cure PMMA resin based on a study [33]. The finding of the current study is in accord with the investigation by Mahroo et al. [34] which shows that light cure resin has poor mechanical properties than self cure resin. These judgments are in direct contradiction to the findings of other studies which demonstrate that visible light cure resin has good mechanical properties [35–37].

Mandibular complete denture specimens were made to verify the relevance of the mechanical properties evaluated using cuboidal specimens to that of the clinical scenario. The results confirmed the relevance as heat cure with polyethylene fiber reinforcement demonstrated highest fracture load, nearest to that of unrepaired dentures in both cuboidal and denture specimens.

The repaired specimens fractured at the junction between older material and reinforcement material—Fig. 8, except for the heat cure resin with polyethylene repair specimens. This emphasizes the finding based on a study that the bond strength between heat cure denture base material and the repair resin is poor [38]. The polyethylene fiber reinforced heat cure resin sample fractured at the reinforcement material matrix which denotes better bonding of this material to older resin—Fig. 9. Nevertheless, a standard investigative analysis of the tensile bond strength of the reinforcement materials is required to confirm this finding.

On comparison of the mean fracture load values of repaired denture specimens with the mean unilateral occlusal bite force, it was observed that mean fracture load values of denture specimens repaired with heat cure PMMA, self cure PMMA and light cure PEUDA resins were marginally lower than the mean unilateral occlusal bite force [189 ± 78 N (42.5 ± 17.5 lb)] [39]. All the denture specimens repaired with additional reinforcement materials demonstrated higher mean fracture load values. This observation persuades to claim that dentures repaired with the reinforcement materials can resist fracture under average functional forces.

The polymerization chemistry of bis-acrylic resin results in minimal dimensional variance during polymerization. The concentration of reacting carbon–carbon double bond in bis-acrylic monomer is lower than in the equivalent amount of methyl methacrylate. It can be affirmed that polymerization takes place at a slower pace and polymerization shrinkage is also considerably lesser than PMMA. The inter-ionic space between the two terminal reactive double bonds is greater in bis-acrylic than in methyl methacrylate which thereby results in effective dilution of the pace of the polymerization reaction and also reduces the shrinkage. These fundamental differences in chemistry and differences in the method of polymerization of the resins make bis-acrylic resin superior in dimensional stability during and after polymerization.

It is inferred from the study that repair joints of heat-polymerized PMMA resins with polyethylene fibers demonstrate better mechanical properties than other common repair materials—Figs. 4 and 5. Bis-acrylic resins show better dimensional stability property among the commonly used repair materials—Fig. 6. It was also deduced from the study that the difference between dimensional stability properties of bis-acrylic and heat-polymerized PMMA resins with polyethylene fibers is very negligible and the clinical implication of this difference is uncertain. Based on this logical assertion, good mechanical properties can be

Table 8 Linear dimensional change in samples before and after repair (mm)

Sample	Before repair	After repair	Disparity
(i) Group C2: heat cure repair			
1	15.17	15.11	0.06
2	18.28	18.35	0.07
3	15.82	15.80	0.02
4	14.97	14.88	0.09
5	16.12	16.28	0.16
			Mean = 0.08
(ii) Group C3: self cure repair			
1	14.92	14.95	0.03
2	15.16	15.14	0.02
3	15.17	15.13	0.04
4	16.02	16.09	0.07
5	15.12	15.09	0.03
			Mean = 0.04
(iii) Group C4: self cure + wire			
1	16.15	16.05	0.1
2	15.97	15.96	0.01
3	15.88	15.84	0.04
4	16.01	15.98	0.03
5	15.14	15. 23	0.09
			Mean = 0.05
(iv) Group C5: self cure + mesh			
1	15.55	15.47	0.08
2	16.05	15.98	0.07
3	16.13	16.11	0.02
4	15.67	15.64	0.03
5	16.08	16.01	0.07
			Mean = 0.05
(v) Group C6: bis-acrylic			
1	15.58	15.57	0.01
2	16.22	16.19	0.03
3	15.96	15.95	0.01
4	16.02	16.00	0.02
5	15.57	15.55	0.02
			Mean = 0.02
(vi) Group C7: light cure			
1	15.51	15.66	0.15
2	16.14	16.07	0.07
3	16.13	15.99	0.14
4	15.59	15.50	0.09
5	15.72	15.63	0.09
			Mean = 0.11
(vii) Group C8: heat cure + fiber			
1	15.77	15.72	0.05
2	15.63	15.58	0.05
3	16.31	16.27	0.04
4	14.87	14.94	0.07
5	15.44	15.36	0.08
			Mean = 0.06

Table 9 Curvilinear dimensional change in samples (% change after repair)

Group name	Sample 1	Sample 2	Sample 3	Sample 4	Sample 5	Mean
C2: heat cure repair	0.09	0.04	0.05	0.04	0.1	0.06
C3: self cure repair	0.02	0.04	0.02	0.03	0.04	0.03
C4: self cure + wire	0.03	0.07	0.04	0.1	0.02	0.05
C5: self cure + mesh	0.04	0.06	0.06	0.05	0.08	0.06
C6: bis-acrylic	0.02	0.01	0.02	0.02	0.03	0.02
C7: light cure	0.1	0.09	0.04	0.08	0.08	0.08
C8: heat cure + fiber	0.06	0.05	0.08	0.04	0.05	0.06

affirmed as the more vital requisite for choosing a denture repair material.

An ideal reinforcement material which accomplishes the intended task of fortifying the dentures and the one which surmounts the mechanical and physical shortcomings of PMMA resins is yet to originate. Although no such idealistic option for reinforcement material can be affirmed, it can be stated based on this study that heat cure PMMA resins with polyethylene fibers is the best among the currently available options as it satisfies at least the most critical norms if not all of the requirement criteria for a reinforcement material.

Conclusion

Within the limitations of experimental design, protocol and testing conditions of this study, the following can be concluded:

- Un-repaired cuboidal and denture specimens had superior mechanical properties of fracture load, flexural strength, fracture toughness, deflection and modulus of elasticity than the repaired specimens.
- In the repair groups of cuboidal and denture specimens, heat cure PMMA with polyethylene fibers had the best mechanical properties.
- Visible light cure PEUDA resin temporary material demonstrated the poorest mechanical properties among all the reinforcement materials evaluated.
- The mechanical properties of self cure PMMA specimens improved with the reinforcements as the reinforcements held the fractured segments together though fracture/deformation occurred at a lower load level.
- For all the repaired specimens, fracture occurred at the interface between old and repair material. Except for the fiber reinforced heat cure PMMA resin specimens

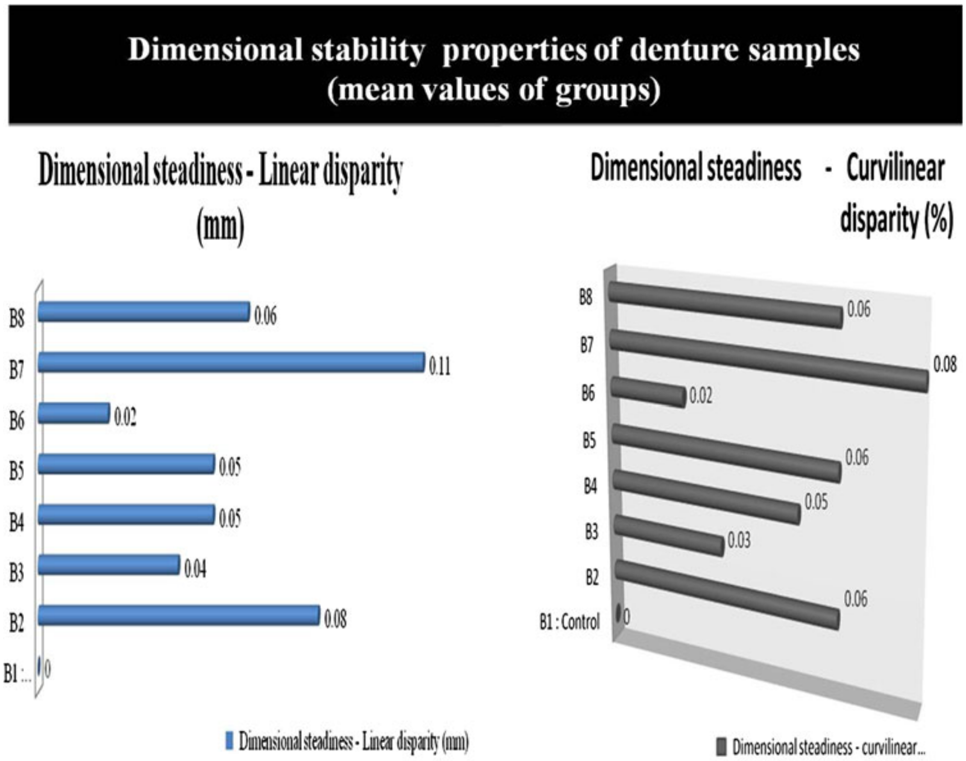

Fig. 7 Dimensional stability properties of denture samples—(mean values of groups)

Fig. 8 Evaluation of the fracture site—fracture at junction between older material and reinforcement material

Fig. 9 Evaluation of fracture site—polyethylene fiber reinforced sample (Group A8)—fracture at the reinforcement material matrix (denotes better bonding of reinforcement material to older resin)

which demonstrated fracture line in the reinforcement material matrix.

- The linear and curvilinear dimensions of specimens repaired with bis-acrylic exhibited the least dimensional disparity.
- There is no discernible difference between the results obtained with cuboidal specimens and denture specimens with regard to fracture load and fracture site evaluation.
- The mean fracture load values of the denture specimens repaired with three basic repair materials heat cure PMMA, self cure PMMA and light cure PEUDA resins were marginally lower than the mean unilateral occlusal bite force that can be anticipated. All the denture specimens repaired with other reinforcement materials demonstrated higher mean fracture load values.

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