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Evaluation of Flexural Strength of Heat Polymerized Acrylic Resin Specimens Repaired with Auto-Polymerized and Heat-Polymerized Acrylic Resin and Subjected to Repetitive Disinfection for Short Duration

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ABSTRACT

Background: Commonly used disinfectants might have significant effect on flexural strength of repaired polymethyl methacrylate denture base resins. This study evaluated the effect of short-term but repeated disinfection on flexural properties of denture base resin.

Material and method: A total of 110 rectangular specimens (65*10*3 mm) of heat polymerized PMMA resin were divided into 11 groups. The specimens of all the groups except control were sectioned and repaired with heat polymerized and auto polymerized resin. The specimens were chemically disinfected for 10 minutes in 1%, 2.5% and 5.25% sodium hypochlorite and 2% glutaraldehyde before and after repair except three groups. These were then subjected to three-point bending test in universal testing machine. The transverse strength was calculated from force required to fracture the specimens and the data was subjected to statistical analysis.

Results: The transverse strength of control group specimens was highest (87.01 +/- 3.76) when compared to repaired group specimens (64.65±4.89 to 52.83±1.45). The transverse strength of specimens repaired with heat-polymerized acrylic resin (58.83±2.79 to 64.65±4.89) was not significantly higher ($p > 0.05$) than those repaired with auto polymerized acrylic resins (59.37±3.48 to 52.83±1.45). The transverse strength of groups repaired and disinfected was not significantly affected by the chemical disinfectant solutions (1%, 2.5% and 5.25% sodium hypochlorite and 2% glutaraldehyde) used in this study ($p > 0.05$).

Conclusions: Within the limitation of the current study neither the type of repair material nor the chemical disinfectants used significantly ($p > 0.05$) affected the transverse strength of repaired heat-polymerized acrylic resin.

Keywords: Complete Denture Hygiene, Oral health, Oral hygiene practices.

INTRODUCTION

Polymethylmethacrylate is the material of choice for removable denture prosthesis fabrication since many years. Although, these are easy to process, reline and rebase, are cost effective and develop good aesthetics but have low strength, are brittle on impact and are only fairly resistant to fatigue

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failure. A denture flexes on an average 5,00,000 times an year[1] and flexural fatigue is the chief cause of fracture of poly methyl methacrylate denture bases in the midline.[2] Disinfecion of prosthesis submitted for repair is mandatory. Council on Dental Therapeutics has accepeted four categories of chemical disinfectants for infection control in dental office and dental laboratory. 5.25% sodium hypochlorite can be used for disinfection of surface of in-service prostheses. 30 minutes of disinfection with fresh 8% formaldehyde solutions is acceptable for instruments. Glutaraldehyde in 2% solution can disinfect within 10 minutes. Iodophor that has 1% iodine can also be used for surface disinfection in dental offices. Robert Rudd and Senia showed that a 5-minute immersion of dentures in undiluted Clorox (5.2% sodium hypochlorite) accomplished sterilization against a variety of microorganisms, including a spore-forming bacteria and C.albicans.[3] Chau, Saunders et al. documented immersion of acrylic resin strips in 5.25% sodium hypochlorite solution for 10 minutes to be effective for disinfection, not only of surface but also the bacteria that penetrated 3mm deep the surface.[4]. The effect of chemical disinfectants on the flexural strength has been a topic of concern since long. C Shen et al. concluded in their study that the autopolymerized resin yielded greater repair flexural strength than the light-cured repair resin. However, the repair flexural strength of auto polymerized resin was influenced by either disinfecting solution whereas that of the light-cured repair resin was not affected.[5] Pavarina et al. (2003) showed that immersion in 3.78% sodium perborate, 4% chlorhexidine gluconate and 1% sodium hypochlorite did not significantly affect the transverse strength of heat cured resin.[6] Rodrigo Nunes Rached, John M. Powers and Altair Antoninha (2004) in their study demonstrated that heat polymerized resin repaired with auto polymerized resin material exhibited transverse strength equal to the conventional heat polymerized resin used for repair.[7] In a study, Iara Augusta and Vanessa Gomes (2004) found that immersion in 1%, 2.5% and 5.25% sodium hypochlorite and alkaline glutaraldehyde for up to 60 minutes did not affect the transverse strength of the heat polymerized resin.[8] Ayman E. Ellakwa and Ali M. El-Sheikh (2006) reported that the transverse strength of repaired heat polymerized acrylic resin reduced significantly as compared to the intact specimen but the disinfectant solutions (glutaraldehyde and sodium hypochlorite in different concentrations for 10 minutes) and the type of repair material (auto polymerized resin or heat polymerized resin) did not affect the transverse strength of the repaired resin.[9] This study has been designed to evaluate the effect of commonly used disinfectants and two types of repair material on the transverse strength of heat polymerized acrylic resin.

MATERIALS AND METHODS

This in vitro study was conducted at Dr. R. Ahmed Dental College & Hospital, Kolkata, India and School of Bioscience and Engineering, Jadavpur University, Kolkata, India.

METHOD

A total of 110 rectangular specimens (65*10*3 mm) of heat polymerized PMMA resin (Dental Products of India Pvt. Ltd) were fabricated. The specimens were divided into 11 groups of which 10 were sectioned and repaired. Specimens of eight groups were chemically disinfected. All specimens except control group were sectioned and repaired with heat polymerized and auto polymerized resin and disinfected once again except the groups HP and AP [table A]. The transverse strength of all specimens was determined by the force required to fracture the specimens in three point bending test, using the equation $S = 3PL / 2bd^2$ where 'P' is load at fracture, 'L' is distance between the supports, 'b' is the width of the specimen and'd' is the thickness of the specimen.

[A] Preparation of mould and polymethylmethacrylate resin specimens

Machine cut master dies of length 65mm, width 10mm and thickness 3mm made of stainless steel (Fig.1) were used to fabricate dental stone moulds through flasking.

Fig 1: Master Dies of 65mm * 10mm *3mm dimension

Separating media (heat cure cold mould seal, Dental Products of India Pvt. Ltd.) was applied to the moulds and allowed to dry. The polymer and monomer of heat polymerized PMMA resin were mixed in a ratio of 3:1 and kneaded thoroughly at dough stage followed by packing. Flash material was removed by trial closure. The flasks were bench pressed to achieve metal-to-metal contact. These were then cured at room temperature for 45 minutes followed by curing cycle of 74 degree Celsius for eight hours in a curing unit succeeded by bench cooling.

A total of 110 specimens were fabricated and measured using vernier caliper with an accuracy of 0.01mm. The specimens were divided into 11 groups [Table A] . Group C specimens were left intact to serve as control. The specimens of groups HP1 through HP2G and groups AP1 through AP2G were immersed in chemical disinfectants- 1%, 2.5% and 5.25% sodium hypochlorite and 2% glutaraldehyde, respectively, each for 10 minutes.

Table A: Group details

Group C	Control (neither disinfected nor repaired)
Group HP	Repaired with Heat Polymerized Acrylic Resin (Not Disinfected)
Group HP1	Repaired with Heat Polymerized Acrylic Resin (1% Hypochlorite)
Group HP2.5	Repaired With Heat Polymerized Acrylic Resin (2.5% Hypochlorite)
Group HP5.25	Repaired With Heat Polymerized Acrylic Resin (5.25% Hypochlorite)
Group HP2G	Repaired With Heat Polymerized Acrylic Resin (2% Glutaraldehyde)
Group AP	Repaired With Auto Polymerized Acrylic Resin (Not Disinfected)
Group AP1	Repaired With Auto Polymerized Acrylic Resin (1% Hypochlorite)
Group AP2.5	Repaired With Auto Polymerized Acrylic Resin (2.5% Hypochlorite)
Group AP5.25	Repaired With Auto Polymerized Acrylic Resin (5.25% Hypochlorite)
Group AP2G	Repaired With Auto Polymerized Acrylic Resin (2% Glutaraldehyde)

All the specimens were thoroughly washed under running water and dried with absorbent paper. The specimens of all groups except C were sectioned in the middle using double sided diamond disc to create a 10 mm gap (Fig.2).

Fig 2: Sectioning of specimen

These were then cleaned and repositioned in the same dental stone mould in such a way that a 10mm gap existed between the two sections of the specimens (Fig.3).

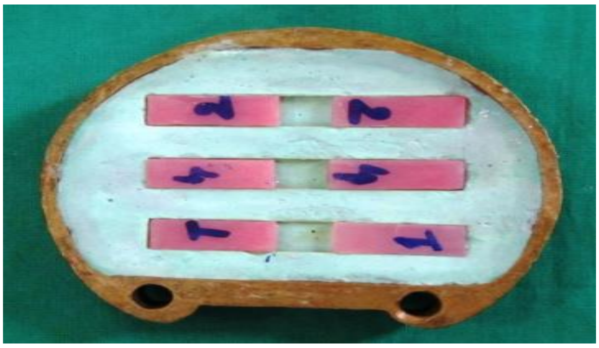

Fig 3: Repositioning of cut specimens in dental stone moulds.

Heat polymerized PMMA resin was used to repair specimens of group HP through HP2G and auto polymerized PMMA resin (DPI cold cure) was used as repair resin for group AP through AP2G. The repair materials were added in a free flowing stage so that they filled the space between the specimens (Fig.4).

Fig 4: Addition of free-flowing repair material

Berge M had found that the repair performed with the low-viscosity self cured resin resulted in higher bending strength values than when using repair material with the higher initial viscosity.[10] The joint space was slightly overfilled to allow for polymerization shrinkage and finishing. After repair, the specimens in groups were once again disinfected for 10 minutes except for groups C, HP and AP (Fig.5)

Fig 5: Disinfection of repaired specimens. [C] Flexural strength test:

ANSI/ADA Specification no. 12 (ISO 1567) includes the transverse strength test as a measure of comparison for denture base resins. This test is a collective measure of tensile, compressive and shear stresses. Beyli M.S. et al. in a study found that the cause of fracture of acrylic resin dentures is a flexural fatigue from cyclic deformation of the base during function.[11] Craig and Powers mentioned that the transverse strength test is especially useful in comparing denture base materials as the prosthesis is exposed to such stresses during mastication. Sharp changes in contours, pinholes, deep scratches and residual processing stress are the contributing factors for stress intensification.[12]

The flexural strength or modulus of rupture is measured with a bar supported at each end under a static load. [13] The specimens were placed on universal testing machine (INSTRON) one at a time (Fig.6).

Fig 6: Transverse strength test in universal testing machine

The distance between the two supporting wedges was kept 50 mm and the cross-head moved at speed of 5mm per minute. The specimens were connected to the load measuring cell, which recorded the force applied to the specimen. The force required to fracture the specimen was recorded and the transverse strength was calculated using the equation $S = 3PL / 2bd^2$ where 'P' is load at fracture, 'L' is distance between the supports, 'b' is the width of the specimen and'd' is the thickness of the specimen. The data was analyzed statistically to measure the statistical significance.

Table I: Fracture Load And Flexural Strength For Control Group C

Serial No.	Group C	
	Flexural Strength (S)	Fracture Load (P)
1	89.25	107.10
2	94.06	112.87
3	74.83	89.80
4	74.41	89.29
5	88.41	106.09
6	74.33	89.20
7	91.47	109.76
8	95.61	114.74
9	110.62	132.75
10	77.08	92.49

Table II- Fracture Load and Flexural Strength for Specimens Repaired with Heat Polymerized Acrylic resin

Serial No.	HP		HP1		HP2.5		HP5.25		HP2G	
	S	P	S	P	S	P	S	P	S	P
1	89.66	107.60	46.09	55.31	70.25	84.30	76.22	91.47	61.90	74.28
2	74.92	89.90	91.44	109.73	64.77	77.73	62.12	74.54	49.76	59.71
3	64.92	77.91	48.27	57.93	46.23	55.48	39.48	47.38	80.10	96.12
4	70.73	84.87	68.29	81.94	59.41	71.29	53.60	64.32	64.85	77.82
5	60.24	72.29	63.73	76.48	63.31	75.97	64.66	77.59	82.71	99.25
6	47.85	57.42	46.91	56.30	43.80	52.56	79.30	95.16	81.64	97.97
7	46.10	55.32	47.95	57.55	66.66	79.99	43.40	52.08	70.69	84.83
8	40.41	48.49	65.73	78.88	54.04	64.85	81.90	98.28	58.93	70.72
9	45.71	54.85	62.32	74.78	64.85	77.82	41.08	49.30	62.99	75.59
10	79.90	95.88	63.98	76.78	55.03	66.04	73.58	88.30	32.97	39.56

Table III: Fracture Load And Flexural Strength For Specimens Repaired With Auto- Polymerized Acrylic Resin.

Serial No.	AP		AP1		AP2.5		AP5.25		AP2G	
	S	P	S	P	S	P	S	P	S	P
1	53.09	63.71	50.95	61.14	60.76	72.91	45.28	54.33	53.99	64.78
2	63.58	76.29	40.02	48.03	63.58	76.30	45.80	54.96	72.86	87.44
3	45.42	54.50	50.95	61.14	52.25	62.70	54.79	65.75	55.38	66.46
4	63.28	75.93	47.32	56.79	55.26	66.31	58.24	69.89	45.31	54.37
5	80.11	96.13	57.21	68.65	45.61	54.73	58.46	70.15	53.99	64.79
6	69.23	83.07	59.21	71.05	50.38	60.46	53.63	64.36	45.97	55.16
7	52.43	62.92	44.89	53.87	60.62	72.74	56.23	67.48	52.21	62.65
8	67.36	80.84	70.05	84.06	54.37	65.25	53.14	63.76	48.93	58.71
9	49.52	59.42	72.23	86.68	46.63	55.96	52.74	63.29	53.98	64.77
10	49.78	59.73	48.16	57.79	60.87	73.04	50.05	60.06	68.75	82.50

Table IV: Results of Two Way ANOVA.

Source of Variation	DF	SS	SS	Source of Variation
Repair Material (Adjusted)	1	964.67	964.59	Repair Material (Unadjusted)
Disinfectant (Unadjusted)	4	248.75	248.83	Disinfectant (Adjusted)
Repair material X	4	177.60	177.60	Repair material X

Disinfectant				Disinfectant
Between Cells	9	1391.03	1391.03	Between Cells
Within Cells (Error)	90	12938.41	12938.41	Within Cells (Error)
Total	99	14329.44	14329.44	Total

DF- Degrees of Freedom

The test statistic for the hypothesis of no interaction was $F_{4,90} = 0.3088; p>0.05$ which was insignificant. Thus, the results of Two Way ANOVA are as follows:

TABLE V: Results of Two Way ANOVA

Source of Variation	DF	SS	MS	F-Value	p-value
Repair Material	1	964.67	964.67	6.71	<0.01*
Disinfectant	4	248.75	62.18	0.43	>0.05
Repair material X Disinfectant	4	177.60	44.40	0.31	>0.05

* Significant at the level of p<0.01

Thus there was statistically significant difference between the repair materials

($F_{1,90} = 6.71; p<0.01$).

Since the interaction between Repair Material and Disinfectant is insignificant ($F_{4,90} = 0.31; p>0.05$) One Way ANOVA for groups was applied

TABLE VI: one way ANOVA table for Groups

Source	D. F.	Sums of squares	Mean sum of squares	'F'	'p'
Between Groups	10	8829.31	882.93	6.14	<0.01
Residual	99	14213.06	143.56	-	
Total	109	23042.37	-	-	

ANOVA showed that there was significant difference between groups ($F_{10, 99} = 6.14; p<0.01$).

TABLE VII: Mean Transverse Strengths (Mpa) and Standard Errors (s.e.) For Intact and Repaired Materials

Group	Repair Material	Disinfectant Solutions	Mean ± s.e.
Group-C	--	--	87.01±3.76
Group-HP	Heat-polymerized	--	62.04±5.29
Group-HP1	Heat-polymerized	1% sodium hypochlorite	60.47±4.43
Group-HP2.5	Heat-polymerized	2.5% sodium hypochlorite	58.83±2.79
Group-HP5.25	Heat-polymerized	5.25% sodium hypochlorite	61.53±5.16
Group-HP2G	Heat-polymerized	2% glutaraldehyde	64.65±4.89
Group-AP	Autopolymerized	--	59.37±3.48
Group-AP1	Autopolymerized	1% sodium hypochlorite	54.09±3.33
Group-AP2.5	Autopolymerized	2.5% sodium hypochlorite	55.03±2.00
Group-AP5.25	Autopolymerized	5.25% sodium hypochlorite	52.83±1.45

Group-AP2G	Autopolymerized	2% glutaraldehyde	55.13±2.85

TABLE VIII: Differences Of Means Of Groups

Group	C	HP	HP1	HP2.5	HP5.25	HP2G	AP	AP1	AP2.5	AP5.25
HP	24.97*	-	-	-	-	-	-	-	-	-
HP1	26.54*	1.57	-	-	-	-	-	-	-	-
HP2.5	28.18*	3.21	1.64	-	-	-	-	-	-	-
HP5.25	25.48*	0.51	1.06	2.70	-	-	-	-	-	-
HP2G	22.36*	2.61	4.18	5.82	3.12	-	-	-	-	-
AP	27.64*	2.67	1.1	0.54	2.16	5.28	-	-	-	-
AP1	32.92*	7.95	6.38	4.74	7.44	10.56	5.28	-	-	-
AP2.5	31.98*	7.01	5.44	3.80	6.50	9.62	4.34	0.94	-	-
AP5.25	34.18*	9.21	7.64	6.00	8.70	11.82	6.54	1.26	2.20	-
AP2G	31.88*	6.91	5.34	3.70	6.40	9.52	4.24	1.04	0.10	2.30

* Significant at the level of $p<0.01$

TABLE IX: Comparison of significance level.

CD	Value
At 5% level of significance (CD_5)	12.66
At 1% level of significance (CD_1)	14.87

As per the CD the mean value of Group-C was significantly higher than that of the other groups ($p<0.01$). But there was no significant difference between the means of other groups ($p>0.05$).

DISCUSSION

The current work was undertaken to evaluate the transverse strength of repaired heat-polymerized acrylic resin specimens and to evaluate the effect of four types of commonly used chemical disinfectant solutions (1%, 2.5% and 5.25% sodium hypochlorite and 2% glutaraldehyde). The study had been designed to simulate the clinical milieu of denture fracture, their disinfection, followed by repair and disinfection, once again, before insertion in the patient's mouth.

On analyzing the results in table VII, it was found that the mean transverse strength of the Group C (intact heat polymerized acrylic resin) specimens was significantly higher ($p < 0.05$), than other groups. Although the transverse strength for specimens repaired with heat polymerized acrylic resin was higher than those repaired with auto polymerized acrylic resin, it had no statistical significance ($p>.05$) at 5% and 1% level of significance; as shown in table VIII and IX. In the present study, the repair strength with heat-polymerized acrylic resin ranged from 67.6% to 74.3% of the original material and that of auto polymerizing acrylic resin was found to be 60.7% to 68.2% of the original material.

This is consistent with findings of Ayman E. Ellakwa and Ali M El-Sheikh (2006) who demonstrated that the repair strength of heat-polymerized resin ranges from 69% to 73% of the original material and the repair strength of autopolymerizing resin ranges from 61% to 67% of the original material.[10]. This is also consistent with the studies done by Berge and Leong and Grant who have shown that the repair strength of autopolymerizing acrylic resins was approximately 60% to 65% of the original material.[11,14] The results of the present study are also consistent with those of Rached et al evaluated the transverse repair strength of a conventional heat-polymerized and a microwave-polymerized acrylic resin that were repaired with these same resins and with an autopolymerizing acrylic resin. They found that autopolymerizing resin had a repair strength similar to those found for the conventional heat- and microwave-polymerized materials.[15] Differences in material composition and experimental protocols of this study may explain the difference in findings from various studies.

The effect of disinfectants on transverse strength of repaired specimens was also analysed. There was no statistically significant difference as per the critical difference determined by applying TUKEY test to the mean values of transverse strength. The mean value of group-C was significantly higher than that of the other groups ($p<0.01$) but there was no significant difference between the means of other groups ($p>0.05$) i.e. neither the presence of various disinfectants nor the two repair materials brought about significant difference transverse strength of specimen of the repaired ten groups. The repaired specimens treated with/without disinfectant solutions showed similar ($p > 0.05$) transverse strength values. No differences ($p > 0.05$) were detected among the repaired specimens either with heat-polymerized or autopolymerized acrylic resins. The intact specimens showed transverse strength values (86.9 ± 11.8) significantly higher ($p < 0.05$) than the values of the repaired specimens.

The absence of any significant change in flexural strength of repaired specimens after immersion in the disinfectants could be attributable to the fact that the disinfectants didn't contain chemicals such as alcohol and phenol that cause dissolution or crazing. Furthermore, the heat-polymerized resin evaluated contained cross-linking agent, which has been used widely in the manufacture of acrylic denture teeth to increase their resistance to solvents and surface stresses.

As the flexural strength of the acrylic resin remained unaffected, it seems that all immersion solutions evaluated in this study could be safely used for tested time period. However, a denture base, during its service life, may be exposed several times to disinfecting solutions due to repeated fractures. Therefore, the effects of long-term immersion in the disinfectant solution on the transverse strength of the denture base materials need furtther evaluation. Further studies can also be carried out to determine the effect of these solutions on the surface characteristics of the materials used in present day.

CONCLUSIONS

Within the limitation of the current study neither the type of repair material nor the chemical disinfectants used significantly ($p > 0.05$) affected the transverse strength of repaired heat-polymerized acrylic resin.

CONFLICTS OF INTEREST

The authors declare they have no potential conflict of interests regarding this article.

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