

Effects of denture cleansers on denture material properties –An observational Case– Control Study.

Efectos de los limpiadores de prótesis dentales sobre las propiedades del material: Un estudio observacional de casos y controles.

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Abstract: Everyday use of denture cleansers to prevent microbial colonization on dentures can affect the properties of the denture base material. Limited literature is available on the effects of denture cleanser on reinforced resins. This study aimed to evaluate and compare the effect of denture cleanser on the flexural and impact strength of conventional and reinforced heat cure acrylic resins. **Materials and Methods:** Rectangular shaped specimens were prepared for flexural and impact strength as per ISO 1567. The denture base resins used included conventional, high impact, nylon fiber reinforced and glass fiber reinforced heat cure acrylic resins. They were further categorized into subgroups A and B depending on immersion in distilled water or denture cleanser (3.8% sodium perborate based). The flexural strength and impact strength of specimens were measured. The study design is a observational case-control study. SPSS version 25 statistical analysis software was used, and the STROBE statement checklist was followed. **Results:** The mean flexural strength was highest for glass fiber reinforced heat cure resin followed by conventional heat cure resin, high impact heat cure resin and nylon reinforced heat cure resin, respectively. The mean impact strength was highest for high impact heat cure resin followed by glass fiber reinforced heat cure resin, conventional heat cure resin, and nylon fiber-reinforced resin respectively. **Conclusion:** All the denture base resins tested exhibited a decrease in flexural and impact strength following use of a denture cleanser.

Keywords: Denture cleanser; denture bases; flexural strength; fiberglass; acrylic resins; mechanical phenomena.

Resumen: El uso diario de limpiadores para prótesis dentales para prevenir la colonización microbiana en las prótesis puede afectar las propiedades del material base de estas. Existe literatura limitada sobre los efectos de los limpiadores de prótesis sobre resinas reforzadas. Este estudio tuvo como objetivo evaluar y comparar el efecto de un limpiador de prótesis sobre la resistencia a la flexión y al impacto de las resinas acrílicas de curado con calor convencionales y reforzadas. **Material y Métodos:** Muestras de forma rectangular se prepararon para testear la resistencia a la flexión y al impacto según ISO 1567. Las resinas de base de prótesis utilizadas fueron resinas acrílicas convencionales, de alto impacto, y de curado térmico reforzadas con fibra de vidrio o nylon. Posteriormente se clasificaron en los subgrupos A y B según la inmersión en agua destilada o limpiador de prótesis (3,8% de perborato de sodio). Se midieron la resistencia a la flexión y la resistencia al impacto de las muestras. El diseño del estudio fue de un estudio observacional de casos y controles. Se utilizó el software de análisis estadístico SPSS versión 25, y se siguió la guía de la declaración STROBE. **Resultado:** La resistencia a la flexión fue más alta para la resina de curado por calor reforzada con fibra de vidrio seguida de la resina de curado por calor convencional, la resina de curado por calor de alto impacto y la resina de curado por calor reforzada con

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nylon, respectivamente. La resistencia al impacto fue más alta para la resina de curado por calor de alto impacto seguida de la resina de curado por calor reforzada con fibra de vidrio, la resina de curado por calor convencional y la resina reforzada con fibra de nylon, respectivamente. **Conclusión:** Todas las resinas de base de prótesis probadas exhibieron una disminución en

la resistencia a la flexión y al impacto después del uso de un limpiador de prótesis.

Palabras Clave: *Limpiadores de dentadura; bases para dentadura; resistencia flexional; fibra de vidrio; fenómenos mecánicos; resinas acrílicas.*

INTRODUCTION.

The popularity of polymethyl methacrylate (PMMA) as a denture base material is attributed to its ease of processing, low cost, lightweight, excellent aesthetic properties, low water sorption, and solubility; as well as the ability to be repaired easily.^{1,2-4} However, low thermal conductivity, inferior mechanical strength, brittleness, high coefficient of thermal expansion and relatively low modulus of elasticity makes it more prone to failure during the clinical service.^{1,3,5,6} Various modifications of PMMA also have been tested to improve the existing material including a chemical modification to produce graft copolymer high impact resins and mechanical reinforcement through the inclusion of glass fibers, sapphire whiskers, aramid fibers, carbon fibers, stainless steel mesh, nylon, or (more recently) ultra-high-modulus polyethylene fibers.⁷ Denture cleanser material used for maintaining denture hygiene must show minimal adverse effects on the denture material, as the majority cause changes in color, flexural strength as well increase surface roughness. The lack of denture hygiene can cause accumulation of materials and oral infections. Therefore, denture disinfection has been recommended as a necessary procedure for preventing cross-contamination and for the maintenance of a healthy oral mucosa. Daily use of denture cleansers can affect the physical and mechanical properties of denture base materials.⁸ Many research studies have been conducted on the effect of denture cleansers on the conventional heat cure denture base resin. But there is limited literature on the effect of denture cleansers on fiber-reinforced denture base resin.

Thus, the present study was taken up to evaluate and compare the effect of sodium perborate denture cleanser on the flexural and impact strength of different heat cure acrylic resins. It was conducted with the objective of evaluating and comparing the effect of the denture cleanser on the flexural and impact strength of conventional heat cure acrylic resin, high impact heat cure acrylic resin, nylon fiber reinforced heat cure acrylic resin, and glass fiber reinforced heat cure acrylic resin.

MATERIALS AND METHODS.

Four different acrylic denture base materials were used for the study of the effect of denture cleanser on acrylic denture base material. Group I- conventional heat cure resin (Trevalon, Dentsply Sirona, PA, U.S.A.), Group II- high impact acrylic resin (Lucitone 199, Dentsply Sirona, PA, U.S.A.), Group III- 2% nylon fiber (Unidirectional, M.P.Sai Enterprise, Mumbai, India) reinforced heat cure acrylic resin, and Group IV- 2% glass fiber (Unidirectional, M.P.Sai Enterprise, Mumbai, India) reinforced heat cure acrylic resin. The study design is an observational case-control study. SPSS version 25 statistical analysis software was used. STROBE statement checklist was followed during the preparation of the manuscript.

Custom-made metal blanks were fabricated to prepare molds for preparing specimens of denture base resins by a compression molding technique. For testing flexural strength the size of the blanks was: 64mm length, 10mm width, 3.3mm height, per ISO 1567:1999; the international organization for standardization. For testing impact strength the size of the blanks was: 50mm length, 6mm width, 4mm height per ISO 1567:1999.

Metal blanks were invested in dental flasks using dental stone type III (Kalabhai Karson, Mumbai, India). The mixing time, working time and setting time were followed as recommended by the manufacturer. The metal blanks were removed once the stone was set entirely. The molding space thus obtained was used for the preparation of the test specimens. Separating medium (Samit Products, New Delhi, India) was applied to the dental stone mold with the help of a camel hair brush and dried. The powder-liquid ratio used was 2:1 by volume and mixing time was per manufacturer's instructions. When the mix reached the dough stage, it was kneaded and packed into the mold space, and final closure was done under bench press. The flasks were allowed to undergo short time polymerization in a water bath at 72°C for 1.5 hours, followed by 30 minutes boiling in 100°C water in an acrylic. After completion of the curing cycle, the flasks were bench cooled until they reached

room temperature. The specimens were recovered, and the flash was trimmed.

For Group III, 2% nylon fiber reinforced heat cure acrylic resin was used. Nylon fibers and polymer were weighed in electronic balance to give the appropriate reinforcement. Nylon fibers 2% by weight and 5mm in length were soaked in a monomer for 10 minutes in a Petri dish for better bonding of these fibers with the PMMA resin matrix. The fibers were removed from the monomer, and excess liquid was allowed to dry. The monomer treated nylon fibers were mixed thoroughly with a polymer to disperse the fibers.

For Group IV, 2% glass fiber heat cure denture base resin was used. Glass fibers and polymer were weighed in electronic balance to give the appropriate reinforcement. Glass fibers 2% by weight and 5mm in length were soaked in silane coupling agent for 5 minutes in a Petri dish for better bonding of these fibers to the PMMA resin matrix. They were air dried for 1 hour and then placed in a hot air oven for 6hrs at 115°C. The silane treated fibers were mixed thoroughly with a polymer to disperse the fibers.

Following polymerization, all specimens were finished with No. 400, 600, 800, 1000 silicone carbide grinding papers. Specimens were polished using a slurry of water and pumice with a brush wheel. Samples were stored in distilled water at room temperature until all samples were fabricated.

Immersion of test specimens in distilled water and denture cleanser solution

Twenty specimens of each group for flexural strength and impact strength testing were divided into two subgroups of ten samples as follows:

Subgroup A: specimens immersed in distilled water

Subgroup B: specimens immersed in denture cleanser (Clinsodent)

The denture cleanser solution used was 3.8% sodium perborate based, prepared in distilled water. All the samples were stored in distilled water for 24 hrs initially. Ten samples for subgroup B were immersed in sodium perborate denture cleanser for 10 minutes at room temperature.

After 10 minutes specimens were thoroughly washed and stored in water at room temperature. This procedure was repeated for 180 cycles to mimic 180 days immersion. During this period samples of subgroup A were immersed in distilled water.

Flexural strength of the denture base resin was tested in Universal Testing Machine as per ISO 1567:1988.

Impact strength of the denture base resin was tested in Izod/Charpy impact tester as per ISO 1567:1999.

Measurement of Flexural strength and Impact strength

i: Flexural strength measurement: The flexural strength was calculated with the following equation:

$$S=3PL/2bd^2$$

Where, S is a flexural strength,

P is peak load applied,

L is the distance between support, *i.e.*, 64mm

b is sample width, *i.e.*, 10mm

d is specimen thickness, *i.e.*, 3.3mm

ii: Impact strength measurement: The impact strength was calculated by the formula:

$$aCA = EC/(hb_A)$$

where, EC is the corrected absorbed energy,

h is the width of the specimen,

b_A is the remaining thickness as the notch base

The mean and standard deviation of flexural and impact strength of specimens in each group was calculated. Statistical analysis for the derived data was done by two-way analysis of variance (ANOVA) followed by post-hoc LSD test. The level of significance was set at a probability level of $p \leq 0.05$.

RESULTS.

Table 1 shows the mean values of the flexural and impact strength of different denture base resins immersed in distilled water and denture cleanser. Tables 2-9 shows statistical analyses for flexural strength and impact strength of varying denture base resins immersed in distilled water and denture cleanser.

Statistically, a significant difference was found when comparing conventional heat cure denture base resin, high impact denture base resin, 2% nylon reinforced denture base resin, and 2% glass fiber reinforced denture base resin. Flexural strength result obtained in this study were in consensus with the study done previously,^{7,12,19,20} where the flexural strength of PMMA increased after the incorporation of glass fibers than conventional heat cure resin. The inclusion of glass fibers beyond 5% showed a decrease in flexural strength and nylon reinforcement had slightly higher flexural strength than conventional heat cure rein.²⁰ In the present study, the flexural strength of 2% nylon reinforced group was less than conventional heat cure resin.

The mean impact strength was highest for high impact heat cure resin followed by glass fiber reinforced heat

cure resin, conventional heat cure resin, and nylon fiber-reinforced resin respectively. Statistically, a significant difference was found while comparing high impact denture base resin with the other three groups. While conventional heat cure denture base resin, 2% nylon reinforced denture base resin and 2% glass fiber reinforced denture base resin had no significant difference among them.

Impact strength result obtained in this study were in consensus with the study done previously,^{12,13,21,22} found glass fibers reinforced acrylic resin was better than

conventional heat cure acrylic resin.

In this study, it was observed that denture cleanser decreased the flexural strength of denture base resin in comparison with water immersion (except in conventional denture base resin). The flexural strength of conventional heat cure resin increases after immersion in denture cleanser.²³ In the present study, it was observed that denture cleanser decrease the impact strength of denture base resin in comparison with water immersion. Similar studies obtained similar results.^{14,24}

Table 1. Mean flexural and impact strength of different denture base resins immersed in distilled water and denture cleanser.

Group	Flexural Strength (MPa) Mean ±S.D.		Impact Strength (KJ/m ²) Mean±S.D.	
	Subgroup A	Subgroup B	Subgroup A	Subgroup B
I	118.02±3.67	123.95±4.29	10.00±2.15	8.62±1.86
II	104.67±2.65	102.95±3.89	10.83±1.96	10.62±2.27
III	90.98±4.14	93.09±5.15	8.96±1.42	8.14±1.25
IV	147.48±4.40	136.23±4.41	10.37±1.90	8.75±1.24

Table 2. Mean table for statistical analysis for flexural strength of different denture base resins immersed in distilled water and denture cleanser.

Group	Flexural Strength (MPa) Mean ±S.D.		Mean Flexural Strength of subgroup (A+B) for each Group(MPa)
	Subgroup A	Subgroup B	
Group I	118.02±3.67	123.95±4.29	120.98±4.93
Group II	104.67±2.65	102.95±3.89	103.81±3.36
Group III	90.98±4.14	93.09±5.15	92.03±4.68
Group IV	147.48±4.40	136.23±4.41	141.85±7.19
Mean Flexural Strength of Group (I+ II+ III +IV) for each subgroup	115.29±21.48	114.05±17.72	114.67±19.57

Table 3. Two way analysis of variance for flexural strength of different denture base resins immersed in distilled water and denture cleanser.

SOURCE	df	SS	MS	SE	F	Critical Difference	p-value
Group	3	28183.7	9394.58	0.923	550.953**	2.603	<0.05
Immersion	1	30.3811	30.3811	0.6529	1.782	1.841	>0.05
Group & Immersion	3	815.308	271.769	1.306	15.938**	3.681	<0.05
Within	72	1227.71	17.0515				

p-value: Level of significance $p \leq 0.05$. df: degrees of freedom;

Table 4. Post-Hoc LSD test for flexural strength between different group of denture base resins.

Group	Difference Between Means	p-value
I versus II	17.17	<0.05
I versus III	28.95	<0.05
I versus IV	20.87	<0.05
II versus III	11.78	<0.05
II versus IV	38.04	<0.05
III versus IV	49.82	<0.05

p-value: Level of significance $p \leq 0.05$. When least significant difference is > 2.603 , then p is significant.

Table 5. Post-Hoc LSD test for flexural strength between different subgroups of denture base resins immersed in distilled water and denture cleanser.

Group	Difference Between Means	p-value
IA versus IB	5.93	<0.05
IIA versus IIB	1.72	>0.05
IIIA versus IIIB	2.11	>0.05
IVA versus IVB	11.25	<0.05

p-value: Level of significance $p \leq 0.05$. When least significant difference is > 3.681 , then p is significant.

Table 6. Mean table for statistical analysis for impact strength of different denture base resins immersed in distilled water and denture cleanser.

Group	Impact Strength (KJ/m ²) Mean±S.D.		Mean Impact Strength of subgroup (A+B) for each Group(KJ/m ²)
	Subgroup A	Subgroup B	
Group I	10.00±2.15	8.62±1.86	9.31±2.08
Group II	10.83±1.96	10.62±2.27	10.73±2.07
Group III	8.96±1.42	8.14±1.25	8.55±1.37
Group IV	10.37±1.90	8.75±1.24	9.56±1.77
Mean Impact Strength of Group (I+ II+ III +IV) for each subgroup	10.04±1.94	9.03±1.90	9.54±1.97

Table 7. Two way analysis of variance for impact strength of different base resins denture immersed in distilled water and denture cleanser.

SOURCE	df	SS	MS	SE	F	Critical Difference	p-value
Group	3	48.9997	16.3332	0.402	5.059	1.133	<0.05
Immersion	1	20.281	20.281	0.2841	6.281	0.801	<0.05
Group & Immersion	3	5.97333	1.99111	0.5682	0.617	1.602	<0.05
Within	72	232.472	3.22878				

p-value: Level of significance $p \leq 0.05$. df: degrees of freedom.

Table 8. Two way analysis of variance for impact strength of different base resins denture immersed in distilled water and denture cleanser.

Group	Difference Between Means	p-value
I versus II	1.42	<0.05
I versus III	0.76	>0.05
I versus IV	0.25	>0.05
II versus III	2.18	<0.05
II versus IV	1.17	<0.05
III versus IV	1.01	>0.05

p-value: Level of significance $p \leq 0.05$. When least significant difference is > 2.603 , then p is significant.

Table 9. Post-Hoc LSD test for impact strength between different subgroups of denture base resins immersed in distilled water and denture cleanser.

Group	Difference Between Means	p-value
IA versus IB	1.38	>0.05
IIA versus IIB	0.21	>0.05
IIIA versus IIIB	0.82	>0.05
IVA versus IVB	1.62	<0.05

p-value: Level of significance $p \leq 0.05$. When least significant difference is > 2.603 , then p is significant.

DISCUSSION.

The flexural strength results obtained in this study were in consensus with previous studies^{7,12,19,20} where the flexural strength of PMMA increased after the incorporation of glass fibers compared to conventional heat cure resin.

The inclusion of glass fibers beyond 5% has resulted a decrease in flexural strength and nylon reinforcement had slightly higher flexural strength than conventional heat cure resin.²⁰ In the present study, the flexural strength of the 2% nylon reinforced group was less compared with conventional heat cure resin.

The mean impact strength was highest for high impact heat cure resin followed by glass fiber reinforced heat cure resin, conventional heat cure resin, and nylon fiber-reinforced resin respectively. Statistically, a significant difference was found while comparing high impact denture base resin with the other three groups. However, there was no significant differences among conventional heat cure denture base resin, 2% nylon reinforced denture base resin and 2% glass fiber reinforced denture base resin.

The impact strength results obtained in this study were also in consensus previous work,^{12,13,21,22} which found glass fibers reinforced acrylic resin was better than conventional heat cure acrylic resin.

In this study, it was observed that denture cleanser decreased the flexural strength of denture base resin in comparison with water immersion, except the flexural strength of conventional heat cure resin, which increases after immersion in denture cleanser.²³

In the present study, it was observed that denture cleanser decreases the impact strength of denture base resin in comparison with water immersion. Other studies obtained similar results.^{14,24}

The most widely used denture base material in dentistry due to its aesthetics, ease in production, processability, and reparability is polymethylmethacrylate (PMMA).

It has been the most commonly used material since the 1930s to fabricate a denture base.⁹ Several types of fibers including carbon fiber, glass fibers, aramid fibers, nylon fibers, and ultra-high-modulus polyethylene fibers have been employed to reinforce PMMA resin.

In patients who use complete and partial removable

dentures, hygiene of dentures and maintaining the health of oral mucosa are of great importance.¹⁰ Denture base materials can get colonized by microorganisms. The contaminated prosthesis can provide a source of cross-contamination between patient and dental personnel. Therefore, denture disinfection should be adequate for the inactivation of microorganisms without adverse effect on denture materials.¹¹

Denture cleansers are used to provide adequate denture plaque control, prevent halitosis, remove discoloration caused by foods and drinks, and eliminate *Candida albicans*, *Candida glabrata* and any other microorganisms, to dissolve calculus and prevent denture-induced stomatitis.¹⁰

Nylon and glass fibers were used for reinforcement at 2% by weight. Fiber incorporation beyond 3% by weight produces dry, friable dough and provides no further beneficial effect on strength.¹² Therefore in this study, 2% fiber reinforcement was used for both glass and nylon.

Sodium perborate was used at 3.8% by weight^{14,15,16} and 10 minutes of immersion daily is needed for sodium hypochlorite and sodium perborate denture cleanser solutions to disinfect the denture completely. Following immersion for 10 minutes in a denture cleanser, specimens were stored in water to prevent them from drying. The specimens were prepared per ISO 1567:1999, of 64x10x3.3mm dimension for flexural strength and ISO 1567:1988 of 50x6x4mm dimension for impact strength.^{17,18}

Flexural strength of the denture base resin was tested in Universal Testing Machine as per ISO 1567:1988. Impact strength of the denture base resin was tested in Izod/Charpy impact tester as per ISO 1567:1999.

High impact denture base has remarkable strength as a result of incorporating rubber molecules into acrylic infrastructure, effectively creating an internal shock absorber. The inclusion of rubber in the high impact resin improves the impact strength. This explains the reason for high impact resin for high impact strength. The addition of synthetic fibers to the monomer-polymer mixture strengthens the resultant acrylic resin.

The result of the present study showed that silanized glass fibers could be due to proper impregnation of fibers with resin polymer. The other factors that are related to the strength of the fiber composite are the type of fibers, the percentage of fibers in a polymer matrix, the orientation of the fibers, fiber form (chopped, continuous,

unidirectional, bidirectional) and the adhesion of the fibers to polymer.¹⁸

Sodium perborate is an alkaline peroxide type denture cleanser. When dissolved in water, sodium perborate decomposes to form an alkaline peroxide solution. This peroxide solution subsequently releases oxygen and loosens debris mechanically.

Therefore, the use of these denture cleansers may cause hydrolysis and decomposition of the polymerized acrylic resin itself.²⁵ That may be the reason for the decrease in flexural and impact strength for specimens immersed in denture cleanser.

It has also been observed that 0.5% NaOCl can be used like any regular denture cleanser without any correlational changes in flexural strength or color change properties of the denture material.²⁶ While immersion of denture material in 1% NaOCl compromises the flexural strength as well as color properties,²⁷ it is really important to consider the concentration of any denture cleansing agent.

There was a decrease in flexural and impact strength after immersion in a denture cleanser of nylon fiber reinforced resin. That may due to the degree of fiber impregnation is critical for the success of reinforcement. Improper impregnation decreases the tensile strength and elastic modulus of fiber composite because of the voids between fibers, increased water sorption, and decreased the degree of conversion.

This study has the limitation of testing the material was *in vitro*, not with the involvement of human subjects. It is important to test it clinically with human participants by means of clinical trials.²⁸ This research is an attempt to bridge the gap in translation research. Research results observed in controlled *in vitro* settings might not be observed in the real-world due to the heterogeneity of patients' oral environments.²⁹ Hence future studies might want to take into consideration case study reports or original research focusing on similar areas.

Informing patients who receive dentures, about such change in properties of their denture material, might allow easy transition of research results into real-world testing. Storytelling as a communication strategy used for raising health literacy³⁰ regarding type of denture used, might create a positive impact in research subjects enrollment in future studies.

From a dental perspective, until dentists are not aware about these effects, they are unable to educate the patient during patient counselling sessions. Hence

the dental school curriculum should include such topics or relevant research inventions in the course curriculum, to raise their knowledge as well as attitude and belief.³¹

CONCLUSION.

All denture base resins tested exhibited a decrease in flexural and impact strength after exposure to denture cleanser. Chemical structure, immersion time, the temperature of solution and mechanism of action of denture cleansers are the factors which affect the flexural and impact strength of the denture base resin immersed cleansers.

Proper use of denture cleanser as prescribed by the manufacturer should be strictly followed by the patients. Hence the current study evaluates the effects on denture material of different mediums, such as water and a denture cleanser.

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