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Research Paper

Comparative Evaluation of Surface Roughness and Wear Resistance of Heat Cured Acrylic Denture Base Resin Subjected to Long Term Immersion in Different TDS Levels of Water - An *in-vitro* Study

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ABSTRACT

Objective: This in-vitro study aimed to compare the surface roughness and wear resistance of conventional and high-impact heat-cured acrylic denture base resins following long-term immersion in water with varying Total Dissolved Solids (TDS) levels.
Materials and Methods: A total of 160 samples were divided into two groups: Group A (conventional acrylic resin) and Group B (high-impact acrylic resin). Each group was subdivided based on water type: control, hard, soft, and distilled. Surface roughness was measured using a profilometer, and wear resistance was tested with a pin-on-disc apparatus after three months of immersion.
Results: Statistically significant differences were observed between groups and across time points. High-impact resin exhibited lower surface roughness and higher wear resistance than conventional resin across all water types. Hard water resulted in the most significant deterioration in both materials.
Conclusion: Water quality, especially TDS level, affects the longevity and clinical performance of denture base resins. High-impact acrylic resin demonstrated superior properties, suggesting its preferable use in varied water environments.

Keywords: Surface roughness, Wear resistance, acrylic resin, Denture base, Total Dissolved Solids (TDS), Water immersion, High-impact resin.

INTRODUCTION

Acrylic denture bases are widely used in prosthodontics due to their ease of fabrication, aesthetic appeal, and patient comfort. Heat-cured acrylic resins are considered the gold standard among denture base materials owing to their superior mechanical strength, dimensional stability, and durability. [1]

However, over time, issues like wear resistance and surface roughness compromise their performance, affecting esthetics, comfort, and hygiene. Increased surface roughness is particularly concerning, as it promotes plaque accumulation and the growth of pathogens like *Candida albicans*, increasing the risk of oral infections [2]

To address these drawbacks, modifications to PMMA (polymethyl methacrylate) have been explored, such as incorporating filler particles or using rubber-reinforced variants like high-impact PMMA. These changes aim to enhance impact resistance and durability. Despite improvements, PMMA remains prone to abrasion, especially when in contact with hard objects, facilitating microbial colonization.

Environmental factors—particularly long-term water immersion—significantly affect acrylic resin properties. Dentures are regularly exposed to saliva during use and stored in water-based solutions, which leads to water absorption [3]

Water molecules act as plasticizers, penetrating between polymer chains, reducing hardness and mechanical integrity, and potentially altering the optical appearance of the material [4,5]

One crucial but often overlooked factor is the composition of the water itself. Total Dissolved Solids (TDS)—comprising salts, minerals, metals, and organic substances—can vary widely depending on geographical and environmental conditions. High TDS levels, often due to industrial waste and runoff, may adversely affect the structural and surface properties of acrylic resins [6]

This study evaluates the surface roughness and wear resistance of heat-cured acrylic denture base resins after prolonged immersion in water with varying TDS levels.

MATERIALS & METHODS

Study Design:

In vitro experimental study.

Sample Distribution:

A total of 160 samples was fabricated and divided into two groups (n=80 each):

- Group A: Conventional heat-cured PMMA (DPI)
- Group B: High-impact heat-cured PMMA (Acryl-HI)

Each group was further subdivided into four subgroups (n=20 each):

- Subgroup 1: Control (TDS 50–100 ppm)
- Subgroup 2: Hard water (TDS 200–500 ppm)
- Subgroup 3: Soft water (TDS 0–60 ppm)
- Subgroup 4: Distilled water (TDS 0–5 ppm)

Materials Used

- **Acrylic Materials**:
- DPI Heat Cure Acrylic, Acryl-HI High-Impact Acrylic
- **Water Types:** Distilled, Soft, Hard, and Control
- **Armamentarium:** Stainless steel flask (custom, 4 molds – 65×10×2.5 mm), petroleum jelly, trimming burs, carving tools, sandpaper, pumice, digital stopwatch, acrylizer, micromotor, hydraulic press, clamp

Equipment:

1. TDS meter
2. Mitutoyo SURFTEST SJ 410 Profilometer
3. Pin-on-Disc Wear Testing Machine

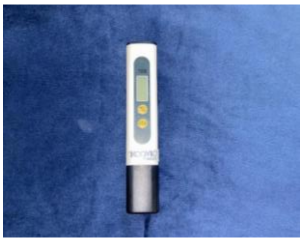
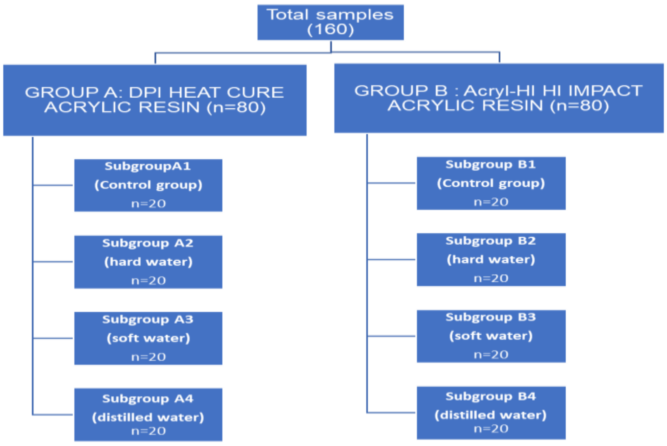


Fig 1: TDS METER

Specimen Preparation: Each specimen was fabricated using a customized stainless-steel flask. Acrylic materials were mixed, packed, and polymerized at 74°C for 2 hours followed by 100°C for 1 hour. Post-polymerization, specimens were finished and polished to standard dimensions (64×10×2.5 mm).

Preparation of water samples:
Subgroup 1: control group with TDS (50-100ppm)
Sub group 2: hard water with TDS (200-500ppm)
Sub group 3: soft water with TDS (0-60ppm)
Sub group 4: distilled water with TDS (0 - 5ppm)

Grouping of Samples:



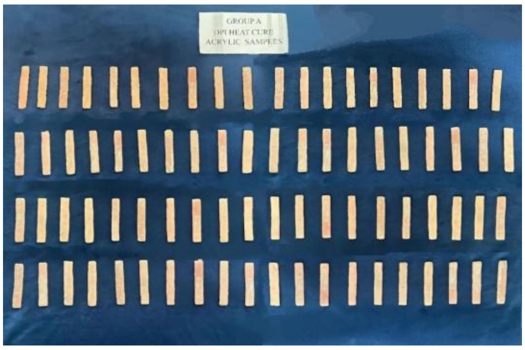


Fig 2: GROUP A DPI HEAT CURE ACRYLIC SAMPLES

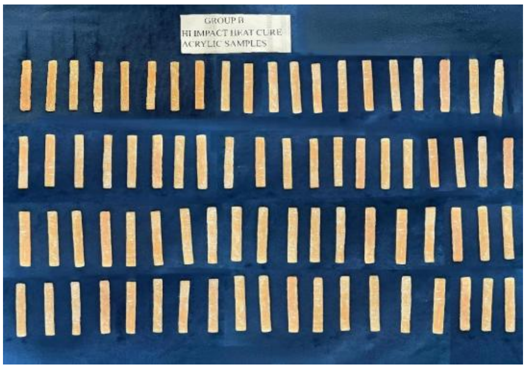


Fig 3: GROUP B ACRYL-HI HI IMPACT ACRYLIC RESIN SAMPLES

Treatment Protocol:
Specimens were immersed in their respective water solution for 3 months.

Surface Roughness Evaluation: Surface roughness was measured using a Mitutoyo SURFTEST SJ 410 profilometer. Three readings were taken per sample, and the mean Ra value (µm) was recorded.

$Ra = 1\ nS\ (Xi - X)$ Ra: average surface roughness X: the mean height Xi: an individual pixel height.

Wear Resistance Testing: Wear resistance was assessed using a Pin-on-Disc machine (ASTM G99 standard). Each test was conducted at 100 rpm under a 10 N load for 1 hour. Volume and percentage weight loss were calculated by measuring pre- and post-test dimensions, and results were plotted against sliding distance.

STATISTICAL ANALYSIS

All statistical analyses were performed using SPSS Statistics Version 26.0. Descriptive statistics, including mean and standard deviation (SD), were calculated for each group. To determine the significance of differences over time and between materials, **paired t-tests** were used for within-group comparisons (baseline vs. 3 months), and **independent t-tests** were applied for between-group comparisons. A *P*-value ≤ 0.05 was considered statistically significant.

RESULTS

COMPARISON OF SURFACE ROUGHNESS AFTER 3 MONTHS BETWEEN CONVENTIONAL HEAT CURE AND HIGH IMPACT

Table 1 and graph 1 shows the comparison of surface roughness between conventional heat-cure and high-impact acrylic resins after 3 months in various water types.

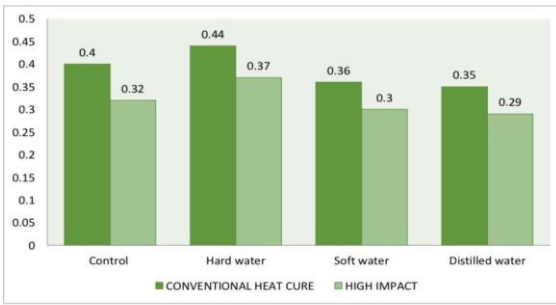
In all groups, conventional resin exhibited significantly higher surface roughness than high-impact resin ($P < 0.001$). Mean values were higher in the conventional group across Control (0.40 ± 0.045 vs. 0.32 ± 0.014), Hard Water (0.44 ± 0.042 vs. 0.37 ± 0.023), Soft Water (0.36 ± 0.037 vs. 0.30 ± 0.017), and Distilled Water (0.35 ± 0.040 vs. 0.29 ± 0.014)

Table 1

	CONVENTIONAL HEAT CURE		HIGH IMPACT		P-VALUE
	MEAN	SD	MEAN	SD	
Control	0.40	0.045	0.32	0.014	<0.001
Hard water	0.44	0.042	0.37	0.023	<0.001
Soft water	0.36	0.037	0.30	0.017	<0.001
Distilled water	0.35	0.040	0.29	0.014	<0.001

Independent t test; P≤0.05 is statistically significant

Graph 1



COMPARISON OF WEAR RESISTANCE AFTER 3 MONTHS BETWEEN CONVENTIONAL HEAT CURE AND HIGH IMPACT

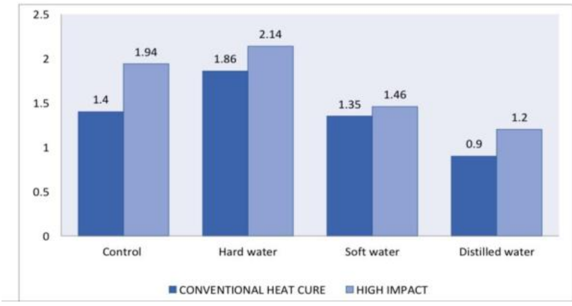
Table2 and Graph2 compare the wear resistance of conventional heat-cure and high-impact acrylic resins after 3 months of immersion in different water types. High-impact resin showed significantly greater wear resistance than conventional resin in all groups ($P < 0.001$). Mean values were higher for high-impact resin in the Control

(1.94 ± 0.312 vs. 1.40 ± 0.488), Hard Water (2.14 ± 0.073 vs. 1.86 ± 0.278), Soft Water (1.46 ± 0.111 vs. 1.35 ± 0.142), and Distilled Water (1.20 ± 0.381 vs. 0.90 ± 0.306) groups.

Table 2

	CONVENTIONAL HEAT CURE		HIGH IMPACT		P-VALUE
	MEAN	SD	MEAN	SD	
Control	1.40	0.488	1.94	0.312	<0.001
Hard water	1.86	0.278	2.14	0.073	<0.001
Soft water	1.35	0.142	1.46	0.111	<0.001
Distilled water	0.90	0.306	1.20	0.381	<0.001

Independent t test; P≤0.05 is statistically significant



Graph 2

DISCUSSION

Edentulism remains a significant global health concern due to its detrimental effects on oral function, nutrition, appearance, and overall quality of life. Denture prostheses play a crucial role in restoring function and aesthetics, and the choice of denture base material significantly influences long-term success.

Polymethyl methacrylate (PMMA) is the most widely used denture base resin due to its ease of fabrication, cost-effectiveness, aesthetic appeal, and repairability. However, its inherent limitations—such as polymerization shrinkage, water absorption, low fracture resistance, and susceptibility to microbial colonization—can compromise its long-term durability.[1]

In an effort to improve mechanical properties, high-impact PMMA was developed through the incorporation of rubber-phase polymers like butadiene styrene. While this modification enhances impact resistance, it may slightly compromise flexural strength and increase surface irregularities, potentially affecting wear performance over time.[7]

Water sorption in acrylic resins, influenced by the polarity of the polymer, leads to dimensional instability, softening of the material, and deterioration of surface and structural properties. Increased surface roughness promotes microbial adhesion and biofilm formation, which can cause local infections like denture stomatitis and systemic risks in vulnerable individuals. [8]

Given that denture users often store prostheses in water, the composition of storage media—including its Total Dissolved Solids (TDS) level—can play a crucial role in material degradation.

In the present in-vitro study, 160 acrylic resin samples were fabricated and divided into two groups: Group A (conventional heat-cured PMMA) and Group B (high-impact PMMA). Each was subdivided into four based on water type: control (normal drinking water), hard water, soft (RO) water, and distilled water. After 3 months' immersion, surface roughness and wear resistance were measured using a profilometer and a pin-on-disc test.

Normal drinking water (TDS 82 ppm) was used as the control, reflecting typical patient exposure during daily oral activities.

Hard water (TDS 342 ppm), classified as moderately hard, contains elevated calcium and magnesium, potentially affecting resin surfaces through mineral interaction.

Reverse osmosis (RO) water (TDS 17 ppm) represents soft water with minimal mineral content, useful for assessing effects of low-ion environments on material stability.

Distilled water (TDS ~1 ppm) served as a nearly demineralized medium to evaluate resin behaviour in ultra-pure conditions with minimal ionic interference.

Previous studies have shown that water quality affects the physical properties of denture base resins.

Saini et al. [9] found heat-cure resins absorb more water than self-cure, while Devlin and Kaushik [10] linked hot water immersion to reduced surface hardness.

Gautam et al. reported increased roughness with abrasive toothpastes, and Chandu et al. showed significant surface hardness loss in hot water. [11]

Jagini et al. [4] found that prolonged water immersion decreased flexural strength, particularly in distilled water.

Unlike Tayde et al., [12] who found minimal surface changes due to regular cleaning and daily water changes, the present study observed greater degradation, likely due to longer immersion and less frequent maintenance.

Results showed

- **Surface Roughness:**

Both groups showed increased roughness over time.

- Highest in Group A: Hard Water (0.44 ± 0.042)
- Lowest in Group B: Distilled Water (0.29 ± 0.014)

Group B consistently exhibited lower roughness, indicating greater resistance to surface degradation.

- **Wear Resistance:**

Both groups showed decreased wear resistance.

- Highest wear: Group B – Hard Water (2.22 ± 0.085 to 2.14 ± 0.073)
- Lowest wear: Group A – Distilled Water (0.93 ± 0.307 to 0.90 ± 0.306)

Group B showed better overall resistance despite higher baseline wear, due to slower degradation.

Findings align with studies by Ganguly, Jayaprakash, Ayoub, Ramkumar, and Galav, which emphasize the degrading effects of minerals and chlorine in water. [13-17]

Hard water caused the most deterioration, likely due to mineral deposits and chemical interactions. Even distilled water led to some degradation over time.

CONCLUSION

Water quality significantly affects the surface and mechanical properties of denture base resins. Hard water had the most adverse effect, while distilled and RO water helped preserve material integrity. High-impact PMMA performed better than conventional resin across all conditions.

LIMITATIONS

- Minor inconsistencies in sample preparation and internal porosity
- Lack of simulated oral forces
- 3-month duration may not reflect long-term effects

Declaration by Authors

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Conflict of Interest: No conflicts of interest declared.

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