

Comparative Analysis of the Effects of Different Disinfection Methods on the Mechanical Properties of Valplast and Acrylic Resin Denture Base Materials

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ABSTRACT

Background and objective: Dental prostheses should be disinfected effectively without damaging the denture base.

Aim: This in vitro study evaluates the effect of three commonly used chemical disinfectants, 4% chlorhexidine, 2% glutaraldehyde, and 5.25% sodium hypochlorite, on the mechanical properties of two widely used denture base materials: Heat-cured acrylic resin and Valplast.

Methods: A total of 160 rectangular specimens were fabricated and equally divided into two main material groups (80 specimens of Heat-cured acrylic resin and 80 specimens of Valplast). Each group was further subdivided into four subgroups (n=20) according to the disinfectant applied, including a control group with distilled water. Disinfection protocols involved immersing each specimen in distilled water for 3 minutes, followed by a 10-minute exposure to the designated disinfectant, and concluding with a 3-minute washing in distilled water. Flexural strength and flexural modulus were assessed using a universal testing machine based on the three-point bending test according to ISO 178:2019 standards.

Results: Statistical analysis was conducted using one-way ANOVA, Dunnett's post hoc, and an independent t-test at a significance level of $P \leq 0.05$. The flexural strength test indicated that, for both main groups, the control group exhibited the highest mean values, while specimens immersed in 5.25% sodium hypochlorite recorded the lowest mean values and showed no significant differences between Heat-cured acrylic resin and Valplast materials under corresponding treatment conditions.

Conclusion: These findings suggest that disinfection protocols do not impact the mechanical properties of denture base materials, and Valplast consistently exhibited lower values in both parameters compared to Heat-cured acrylic resin.

Keywords: Heat-cured acrylic resin, Valplast, Flexural strength, Flexural modulus, chemical disinfectant

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INTRODUCTION

Heat-cured acrylic resin is one of the most extensively used materials in prosthetic dentistry due to its favorable aesthetic, mechanical, and handling properties. Since its introduction, Heat-cured acrylic resin has been widely applied in the fabrication of denture bases, artificial teeth, and impression trays, earning its status as a material of choice in removable prosthodontics.¹ In recent decades, advancements in prosthetic materials have introduced thermoplastic polymers, leading to a noticeable shift in clinical practices. Thermoplastic denture base materials, such as polyamides (e.g., Valplast), have gained popularity for their flexibility, biocompatibility, and absence of residual monomers. These materials undergo a purely physical transformation during processing, softened by heat and then injected into molds without undergoing chemical alteration. This innovation has opened new possibilities in denture fabrication, offering improved patient comfort and aesthetics. However, the long-term performance of these materials relies heavily on standardized and reproducible processing protocols to maintain their mechanical integrity.² Dental professionals, particularly those involved in prosthodontics, face a heightened risk of microbial cross-contamination. Inadequate infection control practices can result in the transmission of pathogens between patients, clinicians, dental assistants, and laboratory technicians. Many studies have indicated that there is a risk of cross-infection in clinical and laboratory settings, especially when prosthetic devices and impressions are contaminated.³ As a preventive measure, all dental prostheses must undergo effective disinfection protocols both upon arrival at the dental laboratory and prior to delivery to the patient.⁴ Various chemical disinfectants are commonly employed in dental practice, including glutaraldehyde, sodium hypochlorite, chlorhexidine, phenol, ethanol, and quaternary ammonium compounds.⁵ While these agents are effective against a broad spectrum of microorganisms, their repeated use may alter the mechanical and surface properties of denture base materials. Heat-cured acrylic resin dentures, for example, may exhibit reduced flexural strength, increased surface roughness, or even structural degradation when exposed to aggressive disinfectants.⁶ Given the clinical importance of disinfection and the growing use of thermoplastic materials such as Valplast, it is essential to evaluate how repeated chemical expo-

sure affects the performance of the denture base. Therefore, the present research aims to examine and compare the effects of 4% chlorhexidine, 5.25% sodium hypochlorite, and 2% glutaraldehyde on the flexural strength and flexural modulus of two commonly used denture base materials: Heat-cured acrylic resin and Valplast thermoplastic nylon.

METHODS

This *in vitro* investigation involved the preparation and evaluation of 160 rectangular specimens to examine the effects of different disinfectant solutions on the flexural strength and flexural modulus of two denture base materials: Heat-cured acrylic resin and Valplast thermoplastic resin. The samples were evenly categorized into two main sections based on material type: 80 specimens of Heat-cured acrylic resin and 80 specimens of Valplast. Each material group was further subdivided for two mechanical tests (flexural strength and flexural modulus), with 40 specimens allocated to each test (20 Heat-cured acrylic resin, 20 Valplast), as illustrated in Figure 1.

The specimens underwent a disinfection protocol simulating clinical conditions, where both dental technicians and clinicians typically perform disinfection twice. Each specimen was initially immersed in distilled water for 3 minutes, followed by 10 minutes of exposure to the assigned disinfectant, and then rinsed in distilled water again for 3 minutes.⁷ This cycle was repeated four times to reflect repeated disinfection.⁸

The specimens in both Heat-cured acrylic resin and Valplast groups were divided into four disinfection subgroups (n = 20 each):

1. **Group I (Control):** No exposure to disinfectants, immersed only in distilled water.
2. **Group II:** Disinfection using 5.25% sodium hypochlorite solution.
3. **Group III:** Disinfection using 4% chlorhexidine gluconate.
4. **Group IV:** Disinfection using 2% glutaraldehyde solution.

For Heat-cured acrylic resin specimens, Lucitone 199 (Dentsply International Inc., Charlotte, NC, USA) was used. Wax patterns were fabricated according to standardized dimensions and invested using traditional denture flasking procedures. After curing, specimens were deflasked and finished using green stone burs to obtain a smooth surface, followed by sequential polishing with abrasive

sandpaper to remove minor scratches and then polished to clinical standards.

All samples were preserved in distilled water at $37 \pm 2^\circ\text{C}$ for 50 ± 2 hours before testing to simulate oral conditions. Mechanical testing of flexural strength and modulus was performed using a uni-

versal testing machine with a three-point bending configuration, following ISO 178:2019 standards.⁹ Statistical analysis was conducted by one-way ANOVA and Tukey's post hoc test with a significance threshold set at $P \leq 0.05$.

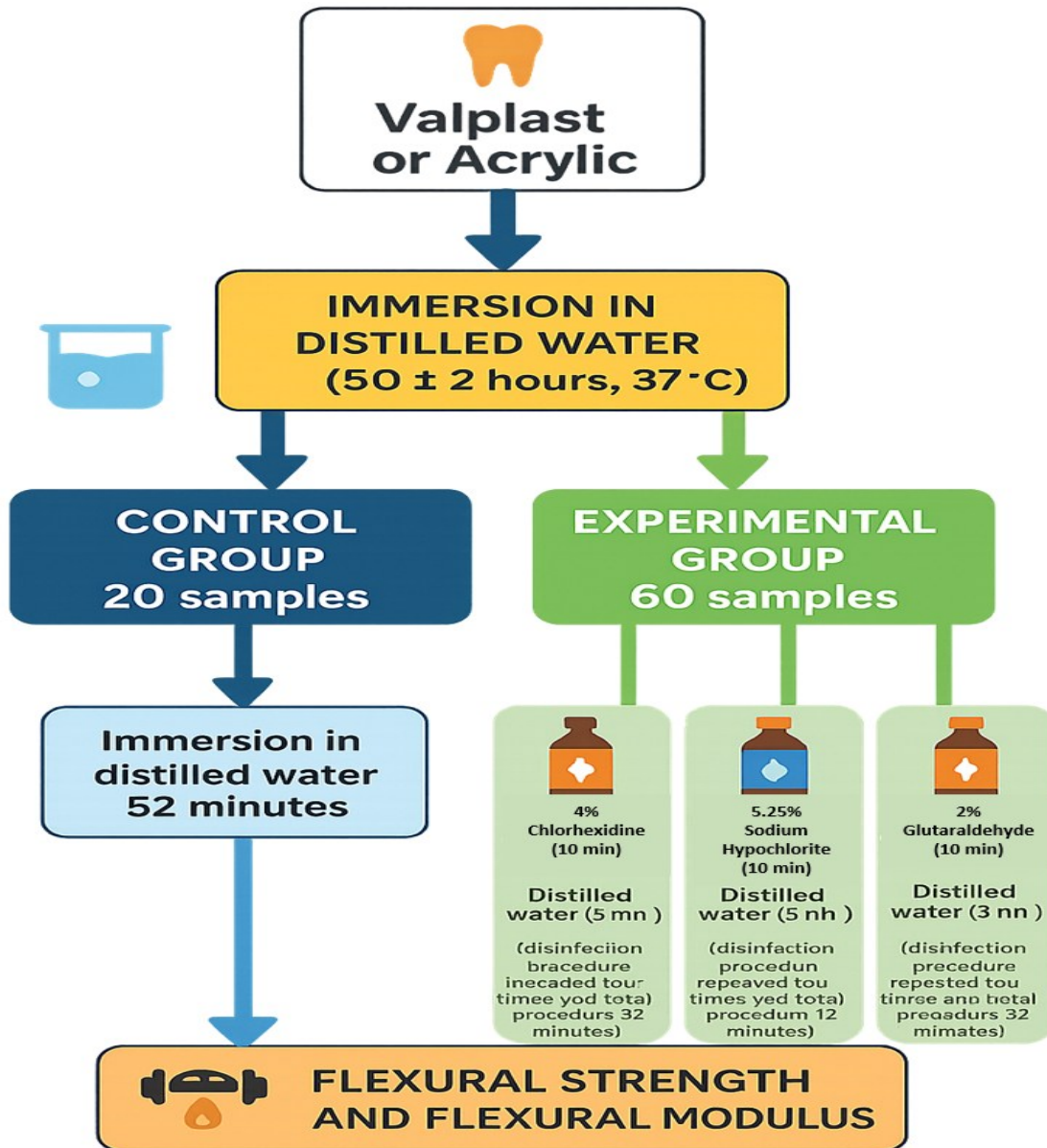


Figure 1. Sample Distributions

For the fabrication of Heat-cured acrylic resin specimens, Lucitone 199 acrylic resin (Dentsply International Inc., Charlotte, NC, USA) was used. Wax specimens were first shaped into standardized rectangular forms and invested in dental stone within conventional metal flasks. The Heat-cured acrylic resin specimens were then processed through standard compression molding techniques.

After curing, the samples were deflasked, trimmed using green stone burs, and polished sequentially with fine-grade sandpaper to remove residual surface irregularities before final polishing.

For Valplast specimens, nylon thermoplastic material was supplied in sealed Valplast cartridges (FDA-approved, ISO-certified, MSDs compliant; USA). A special metallic flask compatible with the

Valplast injection system was used. The wax patterns were invested in dental stone, and injection molding was performed using an electric furnace and nylon injection unit according to the manufacturer's guidelines. Once processed, Valplast specimens were finished and polished strictly following the manufacturer's instructions to ensure consistent surface quality.

Following specimen preparation, all samples (both Heat-cured acrylic resin and Valplast) were immersed in distilled water heated to 37 ± 2 °C for a conditioning period of 50 ± 2 hours to simulate intraoral environmental conditions prior to mechanical testing.¹⁰ Transverse strength testing was conducted to assess the mechanical properties of Heat-cured acrylic resin and Valplast samples after immersion in the disinfectant solutions. A total of 40-disc specimens (n = 20 Heat-cured acrylic resin, and n = 20 Valplast) with the dimensions of (65 X 10 X 3) mm in length X width X depth respectively were prepared for each experimental group to be used for the transverse strength test according to ISO 178:2019 standardization.

Flexural strength and flexural modulus were evaluated using a three-point bending test with a computerized universal testing machine. The tests were carried out with a constant crosshead speed of 0.5 mm/minute and a compression load cell of 500 N (ISO 178:2019 standardization).

Deformation of the Valplast specimens was continued until a U-shaped configuration was obtained; none of the specimens were fractured and remained in one piece. While Heat-cured acrylic resin specimens were fractured into two pieces.

Flexural Strength and Flexural Modulus Calculation

The mechanical testing of specimens was conducted using a universal testing machine via the three-point bending method, in accordance with ISO 178:2019. Both flexural strength (FS) and flexural modulus (FM) were calculated using standard formulas derived from the load-deflection data obtained during testing.

A. Flexural Strength (FS)

The flexural strength (in megapascals, MPa) was calculated using the following formula:

Where:

$$FS = \frac{3FL}{2bd^2}$$

- F = Maximum load applied at the midpoint (in

newtons, N)

- L = Span length between supports (50 mm)
- b = Width of the specimen (10 mm)
- d = Thickness of the specimen (3 mm)

$$FM = \frac{FL^3}{4ybd^3}$$

B. Flexural Modulus (FM)

The flexural modulus (in gigapascals, GPa) was calculated from the slope of the linear portion of the load-deflection curve using the following formula:

Where:

F = Load at a specific point within the linear region (N)

L = Span length between supports (50 mm)

b = Width of the specimen (10 mm)

d = Thickness of the specimen (3 mm)

y = Deflection corresponding to load F (in mm)

All measurements were recorded and computed with high precision to ensure consistency across groups.

Statistical Analysis

All statistical analyses were performed using the Statistical Package for the Social Sciences (SPSS), version 26.0. The following statistical methods were applied to evaluate the significance of differences among groups:

- One-way Analysis of Variance (ANOVA): Employed to assess whether there were statistically significant differences among the four disinfection groups for each denture base material.
- Dunnett's Post Hoc Test: Applied for multiple comparisons to determine statistical differences between each experimental group and the control group.
- Independent Samples t-test: Used to compare the differences in mechanical properties between the two denture base materials (Heat-cured acrylic resin vs. Valplast) under similar disinfection conditions.

A significance value of $p \leq 0.05$ was adopted for all tests.

Data were assessed to confirm compliance with the assumptions required for parametric analysis and were found to be suitable for the applied tests, and approval from the research scientific & ethics committee of Kurdistan Higher Council of Medical Specialties with reference number (52) on 10 Jan 2024.

RESULTS

Flexural Strength

The results of the flexural strength test indicated that, for both Heat-cured acrylic resin and Valplast specimens, the control group exhibited the highest mean values, while specimens immersed in 5.25% sodium hypochlorite recorded the lowest mean values.

Flexural Modulus

- For Heat-cured acrylic resin specimens, the control group again demonstrated the highest mean flexural modulus, with the sodium hypochlorite group showing the lowest.
- For Valplast specimens, the control group had the highest mean flexural modulus, while the minimum value was observed in the group treated with 2% glutaraldehyde.

Statistical Significance

The one-way ANOVA results showed no statistically significant differences between the four disinfection groups for either Heat-cured acrylic resin or Valplast specimens ($p > 0.05$). The magnitude

of differences between groups was small, indicating limited clinical relevance despite the lack of statistical significance. Similarly, Dunnett’s test presented no significant differences between the experimental groups and the control group. Furthermore, the independent t-test showed no significant differences between Heat-cured acrylic resin and Valplast materials under corresponding treatment conditions. Detailed numerical results, including mean values and standard deviations, are presented in Tables 1–4.

3.1 Flexural Strength Heat-cured acrylic resin

Table 1 presents the mean and standard deviation of flexural strength values for Heat-cured acrylic resin specimens subjected to different disinfectant solutions. The control group exhibited the highest flexural strength (2826.08 ± 113.43 MPa), while the sodium hypochlorite group recorded the lowest (2702.04 ± 78.09 MPa). However, Dunnett’s post hoc analysis showed no statistically significant differences ($p > 0.05$) between the control and any disinfected group.

Table 1. Flexural Strength (Heat-Cured Acrylic Resin Material)

| Groups | Mean±SD (MPa) | P-Value Dunnett test | Signal |
|---------------------------|------------------|----------------------|--------|
| Control | 2826.08 ± 113.43 | - | - |
| 5.25% Sodium hypochlorite | 2702.04 ± 78.09 | 0.056 C-S | NS |
| 4% Chlorhexidine | 2776.94 ± 56.51 | 0.632 C-CHX | NS |
| 2% Glutaraldehyde | 2814.64 ± 42.42 | 0.991 C-G | NS |

3.2 Flexural Strength Valplast

As shown in Table 2, Valplast specimens in the control group showed the highest mean flexural strength (1846.08 ± 70.74 MPa), while the glutar-

aldehyde group had the lowest (1753.72 ± 80.83 MPa). Again, all differences were statistically non-significant ($p > 0.05$).

Table 2. Flexural Strength (Valplast Material)

| Groups | Mean±SD (MPa) | P-Value Dunnett test | Signal |
|---------------------------|------------------|----------------------|--------|
| Control | 1846.08 ± 70.74 | - | - |
| 5.25% Sodium hypochlorite | 1760.64 ± 101.37 | 0.268 C-S | NS |
| 4% Chlorhexidine | 1773.34 ± 70.44 | 0.385 C-CHX | NS |
| 2% Glutaraldehyde | 1753.72 ± 80.83 | 0.216 C-G | NS |

3.3 Flexural Modulus Heat-cured acrylic resin

As outlined in Table 3, the control group exhibited the maximum flexural modulus (71.38 ± 0.82 MPa), while the sodium hypochlorite group had

the lowest (68.96 ± 2.19 MPa). However, no significant differences were observed across groups ($p > 0.05$).

Table 3. Flexural Modulus (Heat-cured acrylic resin Material)

| Groups | Mean±SD (MPa) | P-Value Dunnett test | Signal |
|---------------------------|-------------------|----------------------|--------|
| Control | 71.38 ± 0.82 | - | - |
| 5.25% Sodium hypochlorite | 68.96 ± 2.19 | 0.115 C-S | NS |
| 4% Chlorhexidine | 70.54 ± 56.51 | 0.798 C-CHX | NS |
| 2% Glutaraldehyde | 70.28 ± 42.42 | 0.649 C-G | NS |

3.4 Flexural Modulus Valplast

Table 4 shows the flexural modulus results for Valplast. The control group had the highest value

(56.40 ± 0.796 MPa), while the glutaraldehyde group had the lowest (55.44 ± 0.585 MPa). No statistically significant differences were observed.

Table 4. Flexural Modulus (Valplast Material)

| Groups | Mean±SD (MPa) | P-Value Dunnett test | Signal |
|---------------------------|-------------------|----------------------|--------|
| Control | 56.40 ± 0.796 | - | - |
| 5.25% Sodium hypochlorite | 55.66 ± 0.965 | 0.400 C-S | NS |
| 4% Chlorhexidine | 56.32 ± 0.988 | 0.998 C-CHX | NS |
| 2% Glutaraldehyde | 55.44 ± 0.585 | 0.215 C-G | NS |

3.5 Comparative Analysis Heat-cured acrylic resin vs. Valplast

Independent t-test analysis revealed highly signify Table 5. Comparison of Flexural Strength Heat-cured acrylic resin vs. Valplast cant differences (p

< 0.001) in both flexural strength and modulus between Heat-cured acrylic resin and Valplast across all treatment groups, as summarized in Table 5-6. All values were rechecked for accuracy, and the reported variability reflects the material behavior.

Table 5. Comparison of Flexural Strength Heat-Cured Acrylic Resin vs. Valplast

| Disinfectant Solution | Material | Mean ± SD (MPa) | t-value | P-Value | Significance |
|---------------------------|----------|----------------------|---------|---------|--------------|
| Control | Valplast | 1846.08 ± 70.74 | 16.392 | 0.000 | HS |
| | Acrylic | 2826.08 ± 113.43 | | | |
| 5.25% Sodium Hypochlorite | Valplast | 1760.64 ± 101.37 | 16.448 | 0.000 | HS |
| | Acrylic | 2702.04 ± 78.09 | | | |
| 4% Chlorhexidine | Valplast | 1773.34 ± 70.44 | 24.848 | 0.000 | HS |
| | Acrylic | 2776.94 ± 56.51 | | | |
| 2% Glutaraldehyde | Valplast | 1753.72 ± 80.83 | 25.985 | 0.000 | HS |
| | Acrylic | 2814.64 ± 42.42 | | | |

Table 6. Comparison of Flexural Modulus Heat-Cured Acrylic Resin vs. Valplast

| Disinfectant Solution | Material | Mean ± SD (MPa) | t-test Value | P-Value | Significance |
|---------------------------|----------|---------------------------------|--------------|---------|--------------|
| Control | Valplast | 56.40 ± 0.796 | 29.133 | 0.000 | HS |
| | Acrylic | 71.38 ± 0.82 | | | |
| 5.25% Sodium Hypochlorite | Valplast | 55.66 ± 0.965 | 12.396 | 0.000 | HS |
| | Acrylic | 68.96 ± 2.19 | | | |
| 4% Chlorhexidine | Valplast | 56.34 ± 0.988 | 20.356 | 0.000 | HS |
| | Acrylic | 70.54 ± 1.20 | | | |
| 2% Glutaraldehyde | Valplast | 55.44 ± 0.586 | 25.985 | 0.000 | HS |
| | Acrylic | 70.28 ± 42.42 (double-check SD) | | | |

DISCUSSION

Flexural strength is a critical mechanical property that reflects the ability of a material to resist fracture under bending stress.^{11,12} In the present study, comparative analysis between Heat-cured acrylic resin and Valplast denture base materials demonstrated a significantly lower flexural strength in Valplast specimens. This difference is likely associated with the hydrophilic nature of Valplast,¹³ which promotes water absorption and compromises the integrity of the polymer network, potentially weakening its mechanical properties.

In contrast, Heat-cured acrylic resin is characterized by a cross-linked polymer structure that limits water penetration and preserves mechanical integrity. These results are in alignment with earlier research,¹⁴ which reported that nylon-based materials exhibit inferior flexural strength when compared to conventionally processed Heat-cured acrylic resin. The flexural modulus results further emphasize this material difference.

Heat-cured acrylic resin specimens fractured under the three-point bending test, while Valplast specimens showed high elasticity and bent into U-shaped curves without failure. The higher variability observed in Valplast may be attributed to its elastic deformation behavior under load. This finding indicates that Valplast exhibits greater flexibility, resulting in a lower modulus of elasticity, a characteristic that may offer comfort advantages

but limits structural support.¹⁵

The lower modulus values of Valplast also indicate greater susceptibility to long-term deformation under masticatory forces. Importantly, the effect of chemical disinfectants on the mechanical performance of both materials was also investigated.

Immersion in 5.25% sodium hypochlorite, 4% chlorhexidine, and 2% glutaraldehyde for 40 minutes did not result in statistically significant deterioration in flexural strength or modulus. These findings support previous studies¹⁶ indicating that short-term immersion in such disinfectants under controlled conditions is generally safe. However, other studies^{17,18} have reported adverse effects, but these discrepancies may be variations in disinfectant concentration, exposure duration, or elevated immersion temperatures. Our controlled temperature approach (room temperature or as per manufacturer instructions) likely contributed to the negligible effects on mechanical properties.

These findings hold significant clinical implications, particularly given the frequent disinfection of removable prostheses in clinical and laboratory settings. Ensuring that disinfection does not compromise denture integrity is essential for maintaining prosthetic performance and patient safety.¹⁹

This study evaluated short-term disinfection; long-term immersion and cumulative clinical cycles were not investigated and warrant further research.

As an in vitro study, these findings should be interpreted with caution when extrapolating to clinical conditions.

CONCLUSION

This study concludes that both Heat-cured acrylic resin and Valplast denture base materials maintain their mechanical integrity after disinfection with 4% chlorhexidine gluconate, 5.25% sodium hypochlorite, and 2% glutaraldehyde solutions for up to 40 minutes. No statistically significant changes were observed in flexural strength or flexural modulus under these conditions. However, Valplast consistently exhibited lower values in both parameters compared to Heat-cured acrylic resin, suggesting that while it is more flexible, it may not be as suitable for cases requiring higher structural rigidity.

Conflict of Interest

The author declare no conflicts of interest.

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