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**“COMPARATIVE EVALUATION OF THE  
EFFECT OF INCORPORATING ZINC-OXIDE  
NANOPARTICLES ON THE SURFACE  
ROUGHNESS AND HARDNESS OF  
PROVISIONAL RESTORATIVE MATERIALS:  
AN IN-VITRO STUDY.”**

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**By**

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## **LIST OF ABBREVIATIONS USED IN THE STUDY**

<b>ABBREVIATIONS</b>	<b>FULL FORMS</b>
FPD's	Fixed partial denture.
FDP's	Fixed dental prosthesis.
PMMA	Polymethyl methacrylate.
BAC	Bis-acryl resin.
DPI	Dental Product of India.
ZnO	Zinc -Oxide.
NP's	Nanoparticles.
mm	Millimeter.
µm	Micrometer.
VHN	Microvickers Hardness Number.
BisGMA	Bisphenol A glycidyl dimethacrylate.
nm	Nanometer.
%	Percentage
VLC	Visible Light Cure
PEMA	Polyethyl methacrylate.
FS	Flexural strength.
IG	Integrity.
PP	Protemp Plus.

LX	Luxatemp.
UF	UniFast
ZrO <sub>2</sub>	Zirconium dioxide.
SEM	Scanning Electron Microscope.
TiO <sub>2</sub>	Titanium Oixde
Sec	Seconds.

## **ABSTRACT**

### **STATEMENT OF PROBLEM:**

Fixed partial dentures have gained widespread acceptance as a preferred treatment approach for patients with partial tooth loss and since these restorations are fabricated indirectly in a dental lab, they typically entail a waiting period of several days or even weeks for their finalization. Provisional restorations protect the integrity of prepared teeth till the delivery of definitive restoration. In clinical scenarios such as full mouth rehabilitation, cases related to temporomandibular joint disorders, or patients exhibiting parafunctional habits, it is essential that provisional restorations possess robust mechanical properties tailored to address these specific clinical challenges. Commonly utilized materials for the construction of provisional restorations include polymethylmethacrylate (PMMA), polyethyl methacrylate, Bis-acryl composite (BAC) resin, and Epimine resins. Surface roughness and hardness stand as crucial attributes of provisional restorative materials. Surface roughness plays a vital role in deterring plaque buildup, and the absence of plaque attachment is a key determinant of success for provisional fixed prostheses, consequently impacting the overall success of definitive prostheses. Whereas, the resistance to indentation, when subjected to forces of mastication, is termed hardness. In recent years, there has been a growing trend with nanomaterials due to their distinctive structure and properties. Zinc, among various metals, has garnered significant attention in the medical field, primarily due to its antibacterial properties. Zinc Oxide Nanoparticles (ZnO NPs) represent a newer, highly regarded candidate, widely employed owing to their exceptional safety and advantageous physicochemical and biomedical characteristics.

Thus, this study was conducted to evaluate the effect of incorporating Zinc Oxide nanoparticles into the provisional materials to improve the Surface roughness and Hardness

**AIM:**

To compare and evaluate the surface roughness and hardness of provisional restorative materials after incorporation of Zinc-Oxide nanoparticles.

**MATERIALS AND METHODS:**

The provisional restorative material samples of 15mm x 2mm were divided into 2 main groups (DPI tooth moulding material and Protemp 4) and they were further subdivided into three groups consisting of 0%, 2% and 4% zinc-oxide nanoparticles which formed 40 samples per group. The samples were fabricated out of putty impression mold which was fabricated by embedding wax specimens of same dimensions. The samples after fabrication underwent finishing and polishing and were subjected to surface roughness and hardness evaluation. The surface roughness was evaluated using digital profilometer and the hardness was evaluated by Micro Vickers hardness tester. The average of the reading made the results, and they were subjected to statistical analysis.

**RESULTS:**

The data from the study was entered into a Microsoft Excel spreadsheet, and the statistical analysis was performed. To explain the data's underlying structure, descriptive statistics were used. Independent t-test was applied for comparison between the two main groups. One way ANOVA and Tukey's Post-Hoc test was used to compare within the main groups.

The descriptive statistics for surface roughness which was measured between group 1(DPI tooth moulding material) and group 2 (Prottemp 4) at 24 hours and 7 days showed lowest mean for surface roughness was found in group 2 samples at 24 hours which was statistically significant ( $p<0.05$ ), and the highest value was seen with group1 samples at 24 hours.

The results for hardness when compared between the groups at 24 hours and 7 days showed that the highest VHN was found with group 2 samples at 7 days interval and the lowest mean was observed with group 1 samples at 24 hours. The results also showed that there was an increase in the hardness of the samples irrespective of the groups with an increase in the storage time ( $p<0.05$ ). The evaluation of hardness through independent t-test, showed a significant increase in the hardness values between group 1 and group 2 after storage in artificial saliva for 7 days.

Among all the samples it was observed that group 1a samples had the highest surface roughness at 24 hours and the lowest values were seen with group 2b at 24 hours. Among all the samples, it was observed that the hardness was highest in group 2 samples without nanoparticle incorporation.

## **CONCLUSIONS**

- Group 1 samples exhibited notably higher surface roughness and lower hardness values in comparison to bis-acryl resins at 24 hours and 7 days.
- Reinforcement of 2% ZnO nanoparticle resulted in reduced surface roughness values compared to both the control and reinforced groups between the two main groups.
- Incorporating 2% ZnO nanoparticles led to a statistically significant decrease in surface roughness values within group 1 samples. Samples without

nanoparticle incorporation within group 2 displayed a statistically significant increase in hardness values compared to the reinforced groups.

- In conclusion, the addition of 2% ZnO nanoparticles effectively reduced surface roughness in provisional resins without substantially altering hardness parameters.

**KEY WORDS:** Provisional restorative materials, surface roughness, hardness, Zinc-oxide nanoparticles, DPI tooth moulding material, Protemp 4, conditioning.

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## **INTRODUCTION**

Fixed partial dentures have gained widespread acceptance as a preferred treatment approach for patients with partial tooth loss. Since these restorations are fabricated indirectly in a dental lab, they typically entail a waiting period of several days or even weeks for their finalization.<sup>1</sup> According to GPT 10, provisional prosthesis is ‘a fixed or removable dental prosthesis, or maxillofacial prosthesis designed to enhance esthetics, stabilization, and/or function for a limited period of time, after which it is to be replaced by a definitive dental or maxillofacial prosthesis; often such prostheses are used to assist in determination of the effectiveness of a specific treatment plan or the form and function of the planned definitive prosthesis’.<sup>2</sup> During rehabilitation, these resins safeguard the periodontal and pulp tissues till the ultimate prosthesis is installed. These temporary restorations should exhibit commendable marginal fit, aesthetic appeal, and the necessary resilience to withstand the demands of mastication. The choice of resin materials for provisional restorations hinges significantly on their strength properties.<sup>3</sup>

In clinical scenarios such as full mouth rehabilitation involving a reduced vertical dimension, the use of long-span bridges, cases related to temporomandibular joint disorders, or patients exhibiting parafunctional habits, it is essential that provisional restorations possess robust mechanical properties tailored to address these specific clinical challenges. Additionally, patients preferring dental implant therapy typically require a healing period of three months or more. In certain situations, where implant placement is combined with adjunctive procedures such as bone or soft tissue augmentation, temporary long-span bridges may be necessary to span across the implant sites for durations ranging from several months to up to a year.<sup>4</sup>

Commonly utilized materials for the construction of provisional restorations include polyethyl methacrylate, polymethylmethacrylate, epimine resins and bis-acryl composite resin. The dental materials used for provisional FPD's need to possess sufficient strength to endure the forces exerted during chewing, especially in patients with parafunctional habits like bruxism or with patients with long-span fixed prosthesis. Polymethylmethacrylate resin is a frequently employed material for provisional restorations, with a primary drawback being its relatively low flexural strength, surface hardness, and surface roughness.<sup>5</sup>

The most recent category of materials represented by BAC resins, share similarities with composite resins employed in dental restorations. These resins are composed of inorganic and organic fillers and exhibit reduced shrinkage and production of heat during polymerization compared to other resins, resulting in superior fit at the margins. They also offer satisfactory aesthetics and greater color stability when contrasted with PMMA or polyethyl methacrylates.<sup>6</sup> The introduction of composite provisional materials, such as Protemp, preceded other options. These possess enhanced strength, radiopacity, excellent color retention, and the added benefit of being repairable using other composite materials. Protemp IV followed the preceding generation of provisional materials, offering increased translucency and significantly improved ease of handling.

The provisional materials currently accessible are functional, aesthetically pleasing, and readily repairable. Practitioners' primary considerations revolve around the ease of handling and the polishing process of these materials<sup>7</sup>. Surface roughness and hardness stand as crucial attributes of provisional restorative materials. Surface roughness plays a vital role in deterring plaque buildup, and the absence of plaque

attachment is a key determinant of success for provisional fixed prostheses, consequently impacting the overall success of definitive prostheses. It has been proved by various studies that dental materials tend to increase the bacterial load and hinder the oral hygiene methods because of increased surface roughness values<sup>8</sup>. Whereas the resistance to indentation, when subjected to forces of mastication, is termed hardness.<sup>9</sup>

A growing trend in recent years with nanomaterials due to their distinctive structure and properties. These materials find extensive application in ceramics, resins, and metals within the dental field, presenting ample opportunities for innovation and improvement in dental materials. The concept of nanotechnology was initially introduced by Richard Feynman in 1959. Presently, nanoparticles are recognized for their significant potential in various medical and biological applications. Inorganic metallic nanoparticles, including metal oxides like iron dioxide, zinc oxide, cerium oxide and titanium oxide, as well as metals such as copper, silver, iron, gold, magnesium, and quantum dots like cadmium selenide and cadmium sulphate, along with aluminum and silicon oxide, are employed, either individually or in nanocomposites, to enhance the dental materials' mechanical and biologic properties of dental materials.<sup>10</sup>

Zinc, among various metals, has garnered significant attention in the medical field, primarily due to its antibacterial properties. Zinc Oxide Nanoparticles (ZnO NPs) represent a newer, highly regarded candidate, widely employed owing to their exceptional safety and advantageous physicochemical characteristics. Moreover, ZnO NPs, owing to its strong biocompatibility, cost-effectiveness, higher stability and

lower toxicity, demonstrate substantial ability for diverse applications in biomedical field.<sup>10</sup>

Thus, this study will evaluate the effect of incorporating Zinc Oxide nanoparticles into the provisional materials to improve the Surface roughness and Hardness.

## **NEED FOR THE STUDY**

One of the prevalent challenges encountered by humans is tooth loss. Traditionally, missing teeth is replaced with removable dentures, complete dentures, fixed partial dentures, and implants. Fixed partial dentures, also known as bridges, are permanent prosthetic devices that replace teeth which are missing by gaining support from adjacent natural teeth / implants.<sup>12</sup>

The role played by provisional restorations is of utmost importance in the field of fixed prosthodontic treatment. The term provisional prosthesis is frequently used interchangeably with the term interim prosthesis. These restorations either removable or fixed, are designed to improve esthetics, stabilization and function, for a temporary time period. These restorations serve a limited duration before being replaced by a permanent prosthesis.<sup>13</sup>

Temporary restorations are employed as an aid in diagnosis in cases where there is a need to correct occlusal planes which are irregular, adjust the vertical dimension of occlusion, or in planning of alterations in the contour and location of the gingiva. Additionally, provisional restorations assist in visualizing and assessing changes related to the colour, size, shape of the definitive restoration.<sup>14</sup> In critical scenarios, provisional restorations play a major role in the overall treatment planning process. It is essential that these provisional restorations retain their structural integrity consistently throughout both the diagnostic as well as the restorative phases of the treatment.<sup>15</sup>

An accurately fabricated provisional FPD must offer a glimpse of the upcoming prosthesis while promoting the well-being of abutments and periodontium.<sup>16</sup>

In terms of their composition, the materials can be classified into four groups: urethane dimethacrylate, polyethyl or butyl methacrylate, polymethyl methacrylate, bisphenol A-glycidyl dimethacrylate composite resin.<sup>17</sup> PMMA resins are cost-effective and offer advantages such as good color stability, accurate marginal fit, and excellent polishability. Nevertheless, they come with certain limitations, such as exothermic heat produced during polymerization, increased polymerization shrinkage, decreased strength, diminished resistance to wear, and the potential for irritation to periodontium and pulp due to the presence of excess free monomers.<sup>18</sup> In recent years, there has been widespread use of Bisacryl composite provisional resins due to their superior characteristics compared to traditional PMMA resins. These advantages include reduced polymerization shrinkage, lower exothermic reaction, improved surface hardness, and ease of manipulation.<sup>19</sup>

Temporary restorations endure the impact of forces during chewing and necessitate distinct mechanical properties which enable them to withstand the repetitive functional forces in the oral environment. Therefore, to anticipate a material's performance, it is crucial to understand their mechanical properties.<sup>20</sup> Dental materials must sustain properties which include their ability to be polished and retain that polish, ensuring a surface quality that avoids undesirable biological interactions and bacterial plaque adherence to restorative materials.<sup>21</sup> Biofilms play a central role in causing carious lesions, gingival and periodontal diseases, and reducing surface roughness of restorative biomaterials can minimize their retention. Experimental findings suggest that maintaining a surface roughness below 0.2  $\mu\text{m}$  for any dental material significantly decreases the likelihood of bacterial adhesion.<sup>22</sup> A smooth surface contributes to clinical durability, optimal aesthetic appearance, improved optical compatibility with that of enamel, surface gloss, and prevents staining and

discolouration of the restoration.<sup>23</sup> The hardness of a material serves as an indicator of its wear resistance, thereby diminishing the risk of perforation and playing a crucial role in preserving the integrity of the materials' structure of restorations over an extended period.<sup>24</sup>

Technological advancements have led to the adoption of various techniques and materials aimed at enhancing the characteristics of PMMA.<sup>25</sup> These methods involve incorporating different fibres, like polyethylene, glass fibres and carbon fibres, along with various nanoparticles.<sup>26</sup> Additionally, the modification of these particles is achieved through pre-impregnation with silane coupling agents or resin monomers.<sup>27</sup>

Nanoparticles are minute solid particles within a range of 1 to 100 nm, employed to enhance the dental materials' mechanical properties<sup>28</sup>. Strengthening dental polymers involves the incorporation of various nanoparticles, including zinc, titanium, and aluminum.<sup>29</sup> Zinc, an indispensable trace element, is present in various bodily tissues, including hard tissues of tooth, muscle, skin, bone. The reason for which nanoparticles have a widespread use in dentistry is attributed to their distinctive morphological, magnetic, electrical, mechanical, photochemical and catalytic properties which are readily customized. Alterations can be made by adjusting the size, incorporating additional compounds through doping, or modifying the synthesis conditions. It is noted that as the particle size decreases, the desirable characteristics tend to improve. ZnO nanoparticles have proven to increase the mechanical properties as well as having excellent antimicrobial effect upon incorporation into dental materials without having any cytotoxic effects<sup>30</sup>. Kati et al conducted a study in which he found that ZnO NP's with 1% and 2% concentration, incorporated in self-cure acrylic resins showed improvement in the flexural strength significantly.<sup>31</sup>

Prior research has focused on assessing the impact of incorporating various nanoparticles to augment the mechanical characteristics of provisional resins. However, there exists a gap in comparative investigations regarding the Zinc oxide nanoparticle incorporation to enhance the surface characteristics of provisional restorative resins. Hence, the current study was conducted to address this gap, specifically comparing two self-cure provisional materials, DPI tooth moulding material, and Protemp 4, the evaluation focusing on surface roughness and hardness after incorporating 2% and 4 % Zinc oxide nanoparticles into the provisional resins at both 24 hours and 7 days of conditioning.

## **HYPOTHESIS**

### **NULL HYPOTHESIS:**

- There is no change in the hardness and surface roughness of the provisional restorative material after incorporation of zinc oxide nanoparticles.

### **RESEARCH HYPOTHESIS:**

- There is change in the surface roughness and hardness of the provisional restorative material after of zinc oxide nanoparticle incorporation.

## **AIMS AND OBJECTIVES**

### **STUDY AIM:**

To compare and evaluate the surface roughness and hardness of provisional restorative materials after incorporation of Zinc-Oxide nanoparticles.

### **OBJECTIVES:**

1. Evaluating the surface roughness and hardness of DPI tooth moulding material and Protemp 4 in wet conditions at 24 hours and 7<sup>th</sup> day interval.
2. Comparing the surface roughness of DPI tooth moulding material and Protemp 4 after incorporation of 2% and 4% Zinc-Oxide nanoparticles in wet conditions 24 hours and 7<sup>th</sup> day interval.
3. Comparing the hardness of DPI tooth moulding material and Protemp 4 after incorporation of 2% and 4% Zinc-Oxide nanoparticles in wet conditions 24 hours and 7<sup>th</sup> day interval.
4. Evaluating and comparing the surface roughness and hardness of DPI tooth moulding material and Protemp 4 with increasing concentrations of Zinc-Oxide nanoparticles in wet conditions 24 hours and 7<sup>th</sup> day interval.

## REVIEW OF LITERATURE

1. **Dixon et al (1995)** conducted an in-vitro investigation using Triad VLC provisional restorative resin incorporated with glass fibers as their test group and without fibers for the control group to evaluate the mechanical properties of provisional restorative resins. It was found that there was no significant difference in the modulus of rupture, but a significantly greater mean flexural elastic modulus with fibers.<sup>32</sup>
2. **Diaz and Arnold (1999)** conducted an investigation evaluating the microhardness of five provisional materials. Cylindrical samples of bis-acryl resin composites and methyl methacrylate acrylic resins were fabricated and stored for 14 days. Knoop hardness was measured 24 hours after fabrication and three microhardness measurements were obtained. It was concluded that all the bis-acryl resin composite materials exhibited superior microhardness over traditional methyl methacrylate.<sup>33</sup>
3. **O B Abouelatta et al (2006)** in their in-vitro study evaluated the surface roughness and microhardness of two provisional resins i.e., Protemp II and Trim-PEMA at 24 hours, 1, 2 and 3 weeks after incorporating it in 37<sup>0</sup> deionized distilled water which constituted the test group and the ones without incorporation, stored in distilled water formed the control group. It was found that at 24 h, the surface roughness was recorded with bis-acrylic-Prottemp II as higher than methacrylate materials. No significant differences of microhardness between TrimR -PEMA and bis-acrylic-Prottemp II were recognized at 1, 2 and 3 weeks. The microhardness values increased with the increase of surface roughness and vice versa in both TrimR -PEMA and bis-

acrylic-Protemp II. It was seen that both surface roughness and microhardness were affected by water storage. Bis-acrylic-Protemp II revealed better results in hardness than methacrylate resins, whereas TrimR -PEMA had better surface roughness.<sup>34</sup>

4. **Markus Balkenhol et al (2007)** conducted an investigation which examined the flexural strength and flexural modulus of 4 provisional crown and bridge materials (Trim, Luxatemp AM Plus, Luxatemp AM Plus Solar and Cool Temp Natural) after mixing using different curing mechanisms. The study found that the chemical nature and curing mechanism significantly influenced the mechanical properties, but the curing mechanism disappeared at progressive points in time after mixing. Composite resin-based materials were preferred due to their favorable mechanical properties, while dual-curing provisional materials were recommended for high mechanical strength.<sup>35</sup>
5. **Vaibhav Deorao Kamble et al (2012)** conducted a study to compare the flexural strength of polymethyl methacrylate (PMMA) and bis-acryl composite resin (Protemp IV) reinforced with polyethylene and glass fibers. Results showed that PMMA had significantly lower flexural strength than bis-acryl composite resin. Glass fiber reinforcement produced higher flexural strength for both resins, while polyethylene fibers showed no significant difference. Silane impregnated glass fibers showed the highest flexural strength for bis-acryl composite resin. The study concluded that glass fibers may be an effective method for reinforcing provisional restorative resins, especially when aesthetics are important.<sup>36</sup>
6. **Ronald E. Kerby et al (2013)** conducted an in-vitro evaluation of flexural strength, flexural modulus, work-of-fracture, and Weibull parameters of 6

provisional resins (NuForm, Tuff-Temp, Turbo Temp 2, Protemp Plus, Integrity, Temphase) after storage in distilled water for 1 hour and 24 hours. Results showed that 24-hour flexural strength and flexural modulus values were significantly higher than 1-hour values. The urethane Tuff-Temp showed higher 1-hour FS and FM, while bis-acryl Protemp Plus showed greater flexural strength and work-of-fracture. There was no decrease in the flexural strength and modulus of, Turbo Temp 2, Protemp Plus, NuForm after 24 hours.<sup>37</sup>

7. **T Takamizawa et al (2014)** conducted in-vitro research which aimed to evaluate the flexural properties and erosive wear behavior of provisional resin materials. Three bis-acryl base resins [Protemp Plus (PP), Integrity(IG), Luxatemp Automix Plus(LX)], and a conventional PMMA resin, UniFast III (UF) were evaluated. A resin composite, Z100 Restorative, was used as a benchmark. The materials were subjected to wear challenges of 25,000, 50,000, 100,000, and 200,000 cycles in a wear simulator. The results showed that all three bis-acryl base provisional resins (PP, IG, and LX) demonstrated significantly higher values than the PMMA resin (UF) in flexural strength and elastic modulus. Z1 demonstrated significantly higher flexural strength and elastic modulus than the other materials tested. The findings provided valuable information on the flexural properties and relative wear behavior of provisional resins.<sup>38</sup>
8. **May L. Mei et al (2015)** investigated the impact of heat treatment on the physical properties of four resin-based restorative materials: Duralay, Trim II, Luxatemp, and Protemp 4. The materials were tested at 23, 37, or 60°C for flexural strength, surface roughness, color change, and marginal discrepancy.

The study showed that flexural strength remained unchanged at 23°C or 37°C, while surface roughness and marginal discrepancy increased at 60°C.<sup>39</sup>

**9. Egle Mickeviciute et al (2016)** in their study evaluated staining solutions' effects on color stability and roughness of provisional resin materials. Three materials were tested in cola and coffee for 1 and 4 weeks, with 240 specimens used. Results showed coffee had the highest  $\Delta E$  values, while the  $\Delta E$  values were highest for unpolished and polished bis-acryl resin. Time factor influenced color stability, with the highest Ra values in cola.<sup>40</sup>

**10. Ankita Singh et al (2016)** conducted an investigation to evaluate and compare the flexural strength of six temporary crown and bridge materials available commercially. The materials tested included three poly methyl methacrylate-based materials (DPI, SC10 and Trulon) and three bis-acrylic-based composite resins (Protemp, Cooltemp, Luxatemp). After 72 specimens were fractured and repaired, it was seen that the flexural strength of the repaired samples decreased. The study found that the strength of the bis-acrylic composite resins decreased significantly after repair, while the strength of the poly methyl methacrylate-based materials remained similar at 24 hours and 8 days.<sup>41</sup>

**11. Marianthi Topouzi et al (2017)** conducted a study to evaluate the fracture toughness of the PMMA provisional materials reinforced with neat silica nanoparticles and triethoxyvinylsilane-modified silica nanoparticles for fixed interim restorations. Composite PMMA-Silica nanoparticle powders were mixed with PMMA liquid, and compact bar-shaped specimens were fabricated. Fracture toughness was remarkably higher than control, with a tendency to decrease with filler concentration. Dynamic mechanical properties

were affected, with increased silica nanoparticle content increasing storage modulus and shifting Glass Transition Temperature at higher temperatures.<sup>42</sup>

**12. Elzbieta Celej-Piszcz et al (2017)** conducted a study to determine the mechanical properties of eight marketed temporary filling materials. Samples were prepared and stored at 370°C for 7 days. The results showed composite temporary materials had significantly better mechanical properties in flexural strength and Vickers micro-hardness testing.<sup>43</sup>

**13. Ívian Verena Maia Tupinambá et al (2018)** in their study evaluated the surface roughness of bis-acrylic and acrylic resins under different polishing methods. Fifty samples were divided into five groups: unpolished, abrasive tips, goat hairbrush, diamond paste, and silicone tips (enhance). The results showed that the lowest roughness values were in Group 4 (goat hairbrush and diamond paste), while the highest values were in Group 5 (enhance). It was also found that bis-acrylic resins exhibited significantly smoother surfaces than the acrylic resins.<sup>44</sup>

**14. Daniela Astudillo-Rubio et al (2018)** conducted a systematic review and meta-analysis aimed to compare the mechanical properties of dimethacrylates and monomethacrylates used in fabricating provisional restorations. The review followed PRISMA guidelines and analyzed 256 articles. After removing duplicates, 24 articles were included in the qualitative synthesis and 7 in the quantitative synthesis (meta-analysis). The results showed that dimethacrylate-based provisional restorations had better mechanical behavior than monomethacrylate-based ones in terms of flexural strength and hardness. However, fracture toughness showed no significant differences.<sup>45</sup>

**15. Vignesh KC et al (2020)** conducted in-vitro research to compare the fracture toughness of pedo shade packable composite resin and Protemp 4 when used inside a strip crown to restore primary incisors. 36 exfoliated non-carious teeth were divided into two groups. The resin was packed into strip crowns, while Protemp 4 was filled and autopolymerized. The study showed that the mean force required to fracture strip crowns was higher with Protemp 4, but there was no significant difference in fracture toughness between the two groups.<sup>46</sup>

**16. Pooja Agroya et al (2020)** conducted an investigation which aimed to compare flexural strength and hardness of four commercially available provisional restorative resins for fabricating interim fixed partial restorations in dental clinics. The study used four resins: DPI self-cure tooth molding powder (PMMA), SNAP (EMA), Protemp 4 temporization material (Bis-acrylic composite), and Revotek LC (urethane dimethacrylate resin). After 8 days of immersion, the results showed that Group C (Protemp) had significantly higher flexural strength and hardness.<sup>47</sup>

**17. Sultan Aati et al (2021)** conducted an in-vitro investigation evaluating the effectiveness of loading functionalized ZrO<sub>2</sub> nanoparticles in 3D printed acrylate ester-based resin for accelerated aging in artificial saliva. The composites were characterized using TEM and Ramanspectroscopy, and their mechanical and physical properties were evaluated. The results showed that the composites were more ductile, with the highest degree of conversion and maximum strength at 3 wt.% addition. Overall properties were significantly enhanced after 3 months of aging.<sup>48</sup>

**18. Laetitia Gantz et al (2021)** in their in-vitro study investigated the surface roughness and morphology of six bis-acryl and two PMMA provisional resins

after subjecting it to two step polishing system. It was seen that Protemp 4 showed the least surface roughness and Unifast Trad showed the highest surface roughness values. On SEM analysis it was found that the increase in the surface roughness values was due to the filler particles and that a positive relation between fillers and roughness was assessed.<sup>49</sup>

**19. Rashin Giti et al (2021)** conducted an in-vitro study evaluating the surface roughness, plaque accumulation, and cytotoxicity of provisional restorative materials fabricated using conventional, digital subtractive, and additive methods. The results showed significant differences among the groups. Surface roughness was higher in the conventional group, while the additive group had higher bacterial attachment. The additive group had higher cell viability than the subtractive group, but the conventional group was not significantly different. Surface roughness was highest in the conventionally cured group, but the additive group had the most plaque accumulation and lowest cytotoxicity.<sup>50</sup>

**20. Emad Azmy et al (2022)** conducted an investigation examining the impact of nanoparticles (ZrO<sub>2</sub>, TiO<sub>2</sub>, and SiO<sub>2</sub>) on the flexural strength, impact strength, hardness, and wear resistance of acrylic resin denture base material. The specimens were divided into four groups based on nanofiller concentrations: unmodified, ZrO<sub>2</sub>, TiO<sub>2</sub>, and SiO<sub>2</sub> and two subgroups based on the concentration of nanoparticle incorporation (3% and 7%). The results showed significant increase in flexural and impact strength, hardness, and wear resistance, except for the T7 (7% TiO<sub>2</sub> concentration) and S7(7% SiO<sub>2</sub> concentration). The study also found a significant enhancement in wear resistance, except for the T7 and S7 groups.<sup>51</sup>

**21. C Pushpalatha et al (2022)** conducted a review in which the significance of nanotechnology in modern material science, particularly its application in dentistry has been discussed. It highlights Zinc Oxide Nanoparticles (ZnO NPs) as metal oxide nanoparticles with versatile biomedical applications. These applications encompass various benefits, including enhancement in antimicrobial, regenerative, and mechanical properties. It outlines specific uses of ZnO NPs in dentistry, such as enhancing the antibacterial properties of restorative materials, acting as an anti-sensitivity agent in toothpaste, combating pathogenic oral microflora, coating dental implants, improving the antifungal effects of denture bases, remineralizing dentinal lesions, enhancing the stability of local drug delivery agents, and other diverse applications.<sup>52</sup>

**22. Eda Eslemez Topcu et al (2022)**, in their study evaluated the performance of surface sealants for *Streptococcus mutans* adhesion and surface roughness against chewing forces on interim prosthetic materials. Twelve specimens were fabricated from polymethyl methacrylate and bis-acryl interim crown materials and divided into four groups based on surface treatment. Surface roughness values were measured before and after dynamic loading in a chewing simulator. Results showed that surface sealant application significantly decreased surface roughness compared to conventional polishing, except for Optiglaze or BisCover LV applied Protemp 4 and Palaseal or Biscover LV applied Tempofit. A positive correlation was found between surface roughness values and *Streptococcus mutans*.<sup>53</sup>

**23. Saeed J. Alzahrani et al (2023)** in the systematic review they conducted of 19 studies which examined the mechanical properties of 3D-printed provisional resin materials for crown and fixed dental prosthesis. Results showed higher

hardness, smoother surfaces, less wear volume loss, and higher wear resistance with 3D printed resins when compared to conventional or milled materials. It was concluded that 3D-printed provisional resin materials had a promising option for fabricating provisional crowns and FDPs.<sup>54</sup>

**24. Mostafa Ehsan Al-Douri and Mohammed Mouyad Sadoon (2023)**

conducted in-vitro research to evaluate the impact of incorporating Zinc Oxide (ZnO) nanoparticles to 3D printed denture base resin. Results showed significant increases in flexural strength, with the highest strength at 3% concentration. Shore D hardness remained unaffected by the nanoparticles' additions. However, all concentrations resulted in a significant reduction in surface roughness.<sup>55</sup>

**25. Hafsa Al Idrissi et al (2023)**

conducted a study to evaluate and compare the flexural strength of four commonly used provisional resin materials: cold-polymerized PMMA, heat-polymerized PMMA, auto-polymerized bis-acryl composite, and light-polymerized urethane dimethacrylate resin. The mean values showed that heat-polymerized PMMA had the highest flexural strength, while light-polymerized urethane dimethacrylate resin had the lowest. No significant differences were found in the flexural strengths of cold polymerized PMMA, hot polymerized PMMA, or auto-bis-acryl composite.<sup>56</sup>

**26. Hatice Defne Burduroğlu et al (2023)**

in their in-vitro test examined six provisional restoration materials for mechanical strength, surface roughness, and discoloration tests. The strongest groups were Imident and Protemp 4. Microhardness and surface roughness evaluation showed methacrylate resins were stronger than other groups. As for color stability, polymethyl

methacrylate groups were found to discolor less than other groups. Revotek LC and Protemp 4 showed clinically unacceptable  $\Delta E$  values ( $\Delta E > 3.3$ ).<sup>57</sup>

**27. Priya Gupta et al (2023)** conducted an investigation to evaluate and compare the flexural strength of heat polymerized PMMA provisional restorative resin reinforced with different percentages of silanized zirconium oxide nanoparticles. The study involved sixty heat cured PMMA resin specimens which were divided into four groups. Three point bending tests were conducted on each group, and the mean flexural strength was calculated. The results showed that the maximum strength was obtained by reinforcement with 2.5% silanized zirconium oxide nanoparticles.<sup>58</sup>

## MATERIALS AND METHODS

### DATA SOURCE/ LABORATORY DETAILS:

This particular in-vitro study was carried out in-

- KLE Academy of Higher Education and Research, KLE V. K. Institute of Dental Sciences, Belagavi.
- Department of Prosthodontics and Crown & Bridge – (For fabrication of provisional restorative specimens.)
- KLS Gogte Institute of Technology, Belagavi – (For evaluation of surface roughness and hardness)
- Raghavendra Spectro Metallurgical Laboratory, Bangalore – for evaluation of Hardness.

### SAMPLE SIZE ESTIMATION:

- At 95% confidence and 80% power, the sample size was estimated to be,

$$n = \frac{(z_{1-\alpha/2} + z_{1-\beta})^2 (SD_1^2 + SD_2^2)}{(\bar{x}_1 - \bar{x}_2)^2}$$
$$= 40$$

Were,

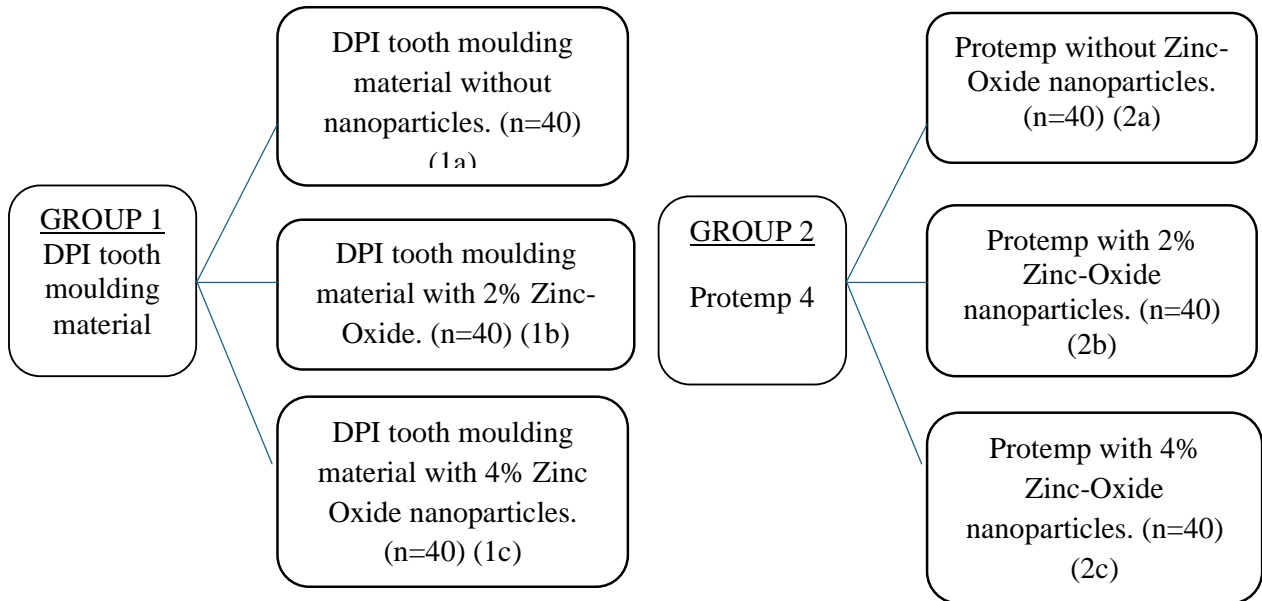
$$Z_{1-\alpha/2} = \alpha\text{-error at } 5\% = 1.960$$

$$Z_{1-\beta} = \text{power of test at } 80\% \text{ (} 20\% \beta \text{ error)} = 1.64$$

$$(SD_1^2 + SD_2^2)^2 = (2.68^2 + 0.82^2)$$

$$(\bar{x}_1 - \bar{x}_2)^2 = (10.92 - 12.16)^2$$

**SAMPLE DISTRIBUTION:**



**INCLUSION CRITERIA:**

- Provisional material specimens of size 15mm x 2mm were included in the study.
- Specimens free of voids.
- Specimens free of surface irregularities.

**EXCLUSION CRITERIA:**

- Specimens with surface defects and deformities.
- Specimens with inaccurate dimensions.
- Specimens with porosity.

**MATERIALS AND METHODOLOGY:**

Materials: (Figure 1)

1. DPI tooth moulding material (self-cure)
2. Protemp 4.
3. Zinc-Oxide nanoparticles.
4. Polyvinyl siloxane impression material.
5. Modelling wax.
6. Artificial saliva.
7. Wet grit sandpaper.

Armamentarium: (Figure 2)

1. Analytic balance.
2. Digital profilometer.
3. Micro Vickers hardness tester.

**METHODOLOGY:**

**DETAILS OF THE PROCEDURES CONDUCTED DURING RESEARCH:**

Fabrication of DPI tooth moulding (self-cure) material samples:

According to ADA specification number 27, wax blocks of 15mm x 2mm were fabricated to give 40 samples in each group. A mold of polyvinyl siloxane impression material was obtained by embedding these wax blocks into it. DPI tooth moulding material was incorporated into the mold by mixing a 3:1 ratio of polymer powder and monomer liquid (control group). Nanoparticles of size 30-50nm were weighed and incorporated into the polymer. Then a 3:1 ratio of polymer powder and monomer liquid were incorporated into the mold and was allowed to set (reinforced group). The retrieved samples were finished and polished using wet grit sandpaper and conditioned in artificial saliva for 7 days. (Figure 3)

Fabrication of Protemp 4 samples:

According to ADA specification number 27, wax blocks of 15mm x 2mm were fabricated to give 40 samples in each group. A mold of polyvinyl siloxane impression material was obtained by embedding these wax blocks into it. Protemp 4 was incorporated into the mold directly using autopolymerizing gun and tip (control group). Nanoparticles of size 30-50 nm were weighed and incorporated into the base and catalyst paste and mixed uniformly using a spatula and incorporated into the mold and were allowed to set (reinforced group). The retrieved samples were finished and polished using wet grit sandpaper and conditioned in artificial saliva for 7 days. (Figure 4)

Evaluation of surface roughness:

The retrieved samples were subjected to surface roughness evaluation. It was carried out using a Profilometer. The samples were kept perpendicular, and the readings were measured by passing the stylus over the length of the specimens. Each disc was measured for three readings consecutively and the average of them formed the results. These results were subjected to statistical analysis. (Figure 6)

Evaluation of hardness:

The retrieved samples were subjected to evaluation of hardness. It was carried out using Micro Vickers hardness tester. Here, a load of 50g was applied onto the surface of the samples and an indentation was made using a diamond indenter for 10 seconds. Each disc was measured for three readings consecutively and the average of “them would form the results of the study”. These results were subjected to statistical analysis. (Figure 7)

**FABRICATION OF DPI TOOTH MOULDING MATERIAL SAMPLES:**

According to ADA specification number 27, for each group, wax block with 15mm x 2mm dimension were made to give 40 samples in each group.

A mold of polyvinyl siloxane impression material was obtained by embedding the wax blocks in it.

DPI tooth moulding material was poured into the mold with a spatula by mixing 3:1 ratio of polymer powder and monomer liquid, in a silicone mixing cup. (Control group)

Zinc Oxide nanoparticle powder of 30-50 nm size was weighed and incorporated at different concentrations into the polymer powder. Then 3:1 ratio of polymer powder and monomer liquid were mixed and incorporated into the mold. (Reinforced group)

DPI tooth moulding samples retrieved, were finished and polished using wet grit sandpaper. The polished samples were conditioned in artificial saliva for 7 days.

**FABRICATION OF PROTEMP 4 SAMPLES:**

According to ADA specification number 27, for each group, wax block with 15mm x 2mm dimension were made to give 40 samples in each group.



A mold of polyvinyl siloxane impression material was obtained by embedding the wax blocks in it.



Protemp 4 base and catalyst paste were directly dispensed into the mold using auto polymerizing gun and tip. (Control group).

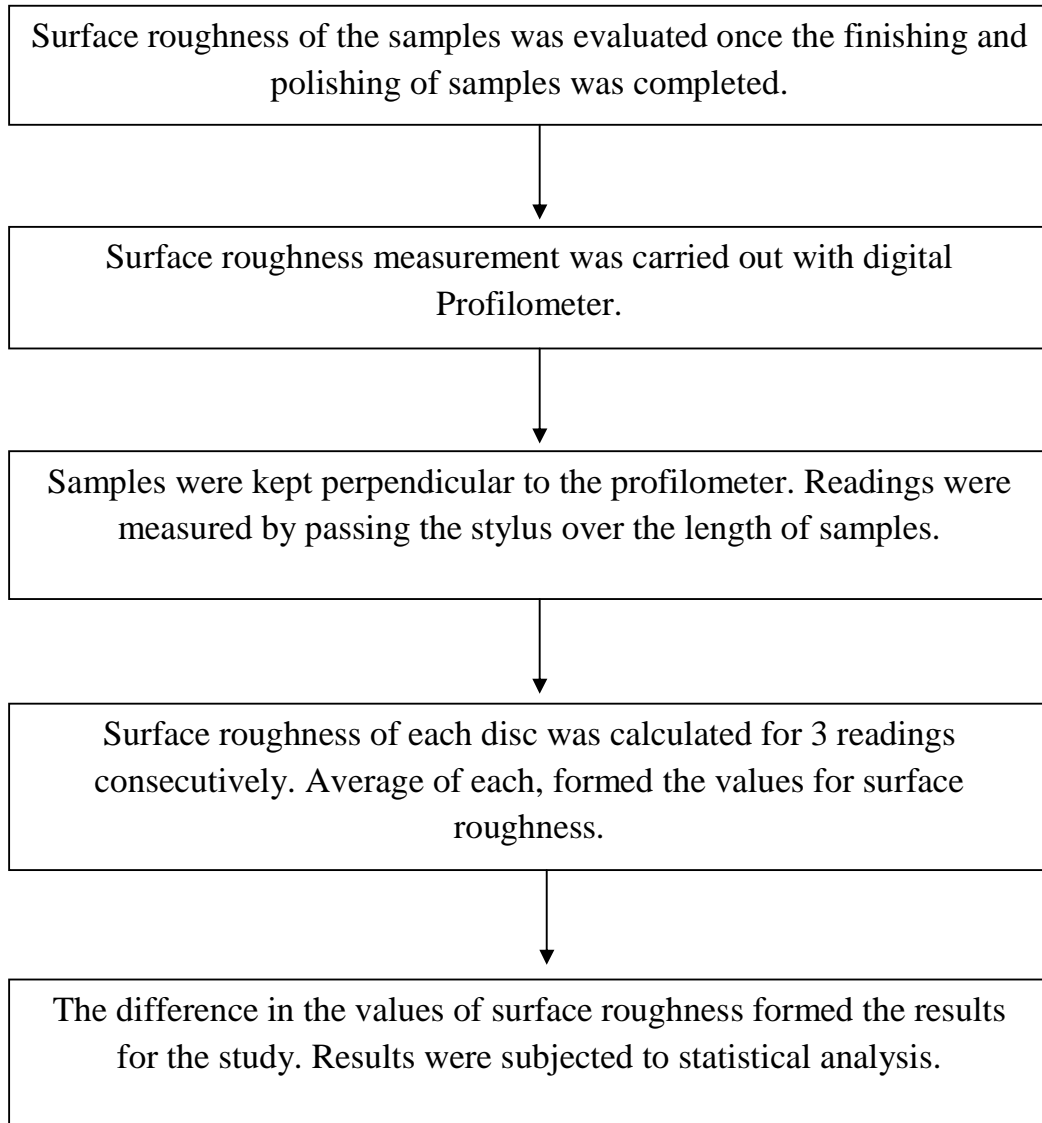


Zinc Oxide nanoparticle powder of size 30-50 nm was weighed and incorporated at different concentrations into the base and catalyst paste and spatulated uniformly and incorporated into the moulds using a spatula. The specimens were allowed to set. (Reinforced group).

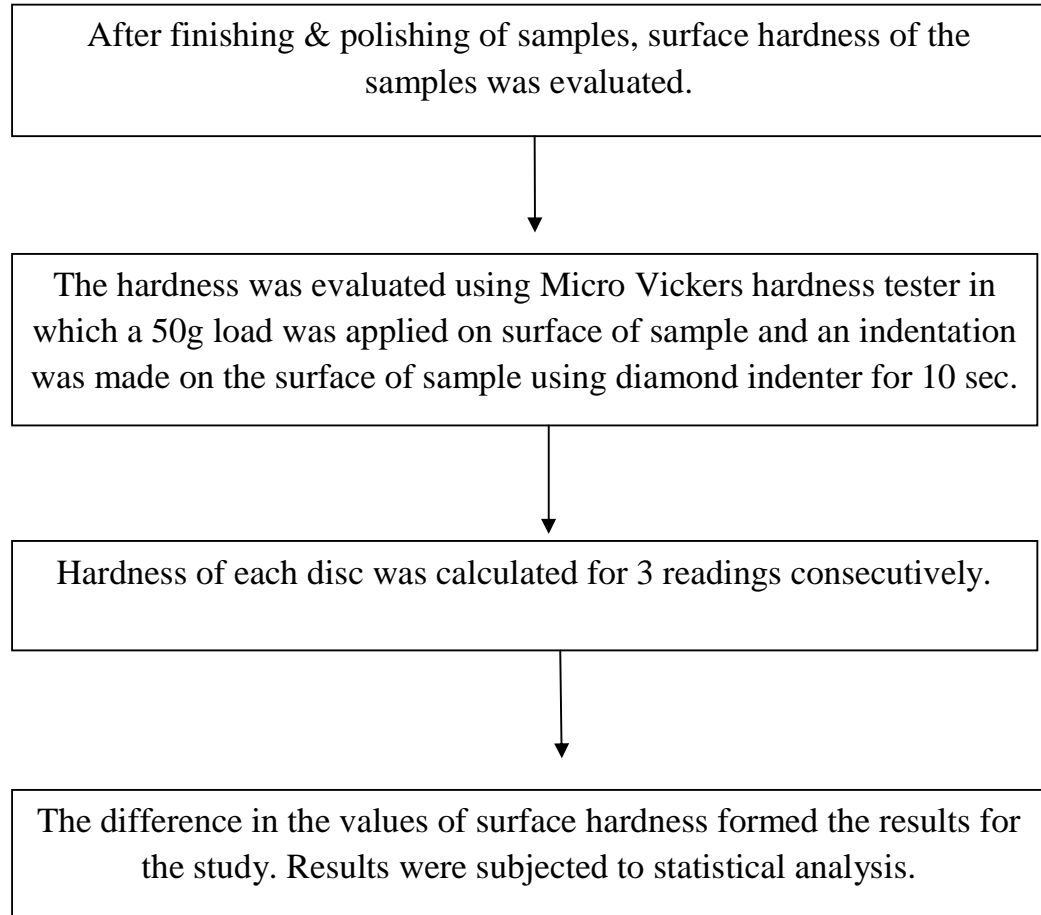


Protemp 4 samples retrieved, were finished and polished using wet grit sandpaper. The polished samples were conditioned in artificial saliva for 7 days.

**SURFACE ROUGHNESS ASSESSMENT:**



**ASSESSMENT OF HARDNESS**



**FLOW CHART ON METHODOLOGY:**

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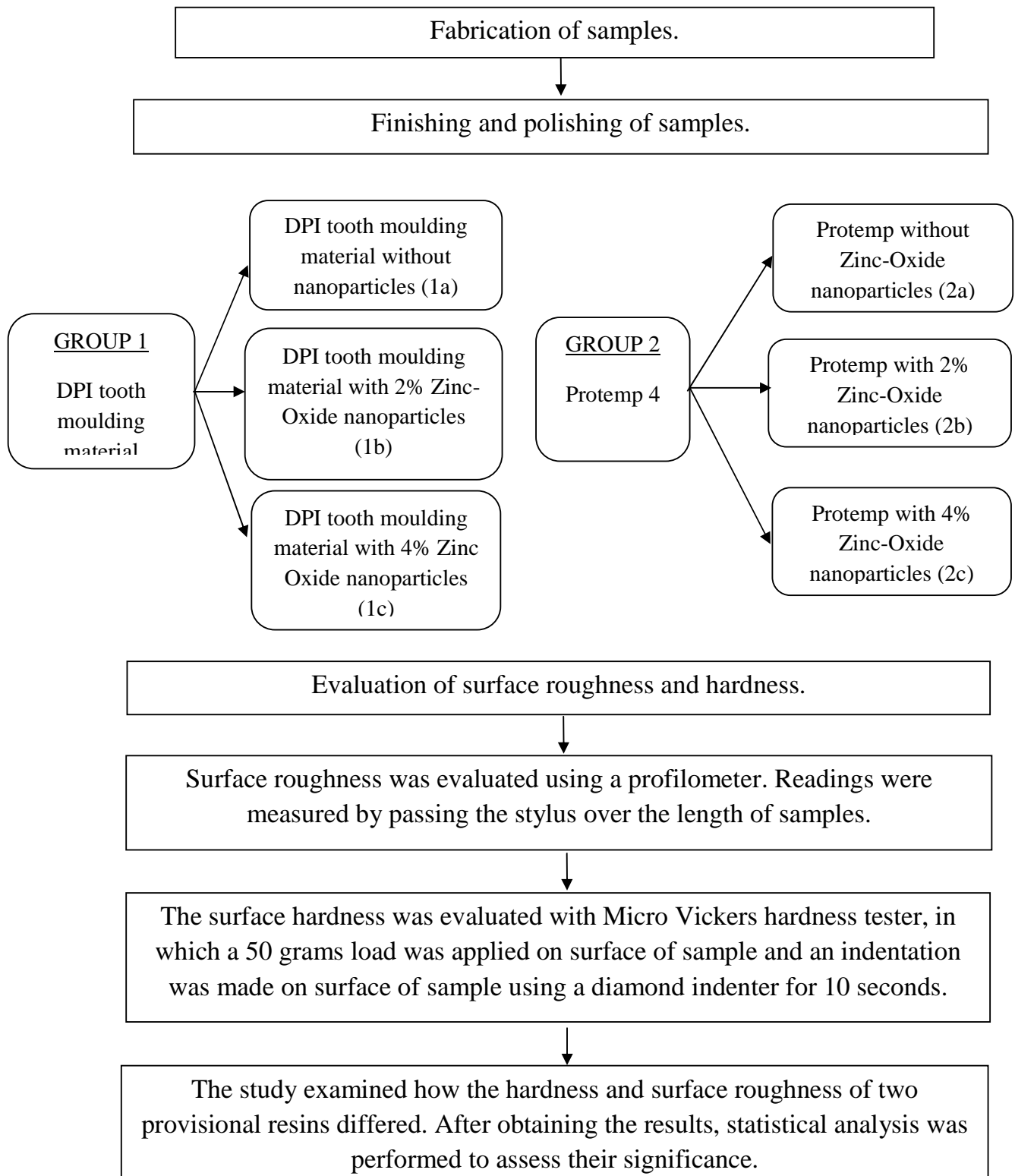


FIGURE 1: MATERIALS AND METHODS



DPI tooth moulding material (self-cure)



Prottemp 4.



Zinc-oxide nanoparticles.



Polyvinylsiloxane impression material



Artificial saliva.

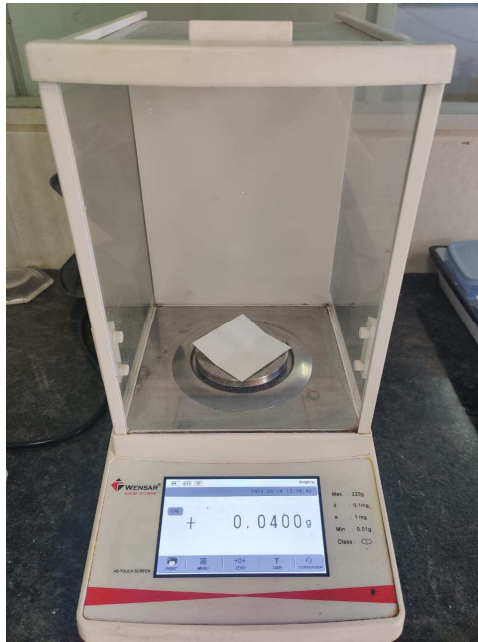


Modelling wax.



Wet grit sandpaper.

FIGURE 2: ARMAMENTARIUM



Analytical balance.

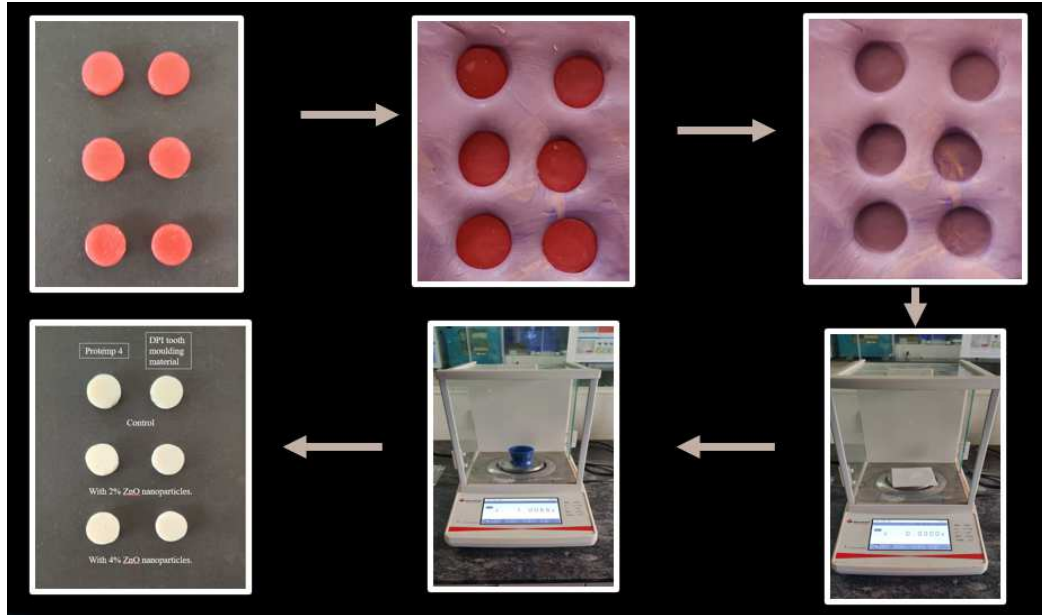


Digital profilometer.



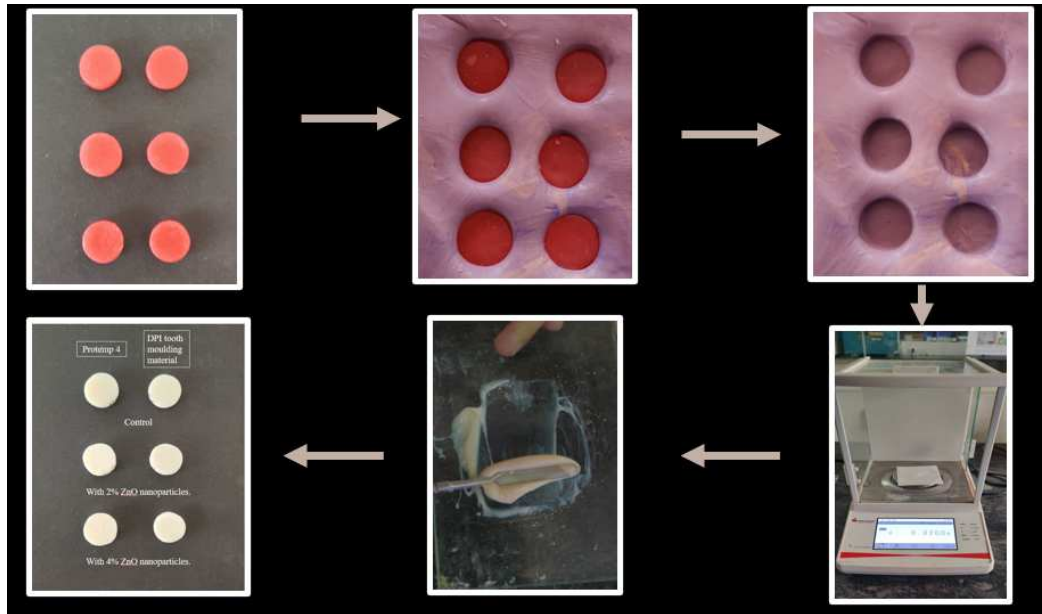
Micro Vickers hardness tester.

**FIGURE 3: FABRICATION OF DPI TOOTH MOULDING SELF-CURE SAMPLES.**



Wax blocks of 15mm x 2mm thickness were fabricated and the thickness was measured using a wax gauge. Then these were incorporated into a mixture of polyvinylsiloxane impression material to form moulds for fabrication provisional acrylic samples. Then the wax blocks were removed. The polymer and monomer were blended together and then poured into molds. A glass slab was employed to exert pressure, ensuring consistency across all samples. After setting, the samples were retrieved and underwent finishing and polishing procedures. For the test groups, the nanoparticles were weighed in the analytic balance and incorporated into the polymer powder to give 2% and 4% incorporated ZnO nanoparticle samples.

FIGURE 4: FABRICATION OF PROTEMP 4 SAMPLES.



Wax blocks of 15mm x 2mm diameter were fabricated and the thickness was measured using a wax gauge. Then these were incorporated into a mixture of polyvinylsiloxane impression material to form moulds for fabrication of Protemp 4 samples. Then the wax blocks were retrieved. The base and catalyst paste were dispensed onto a glass slab, mixed thoroughly, and then transferred into the molds. Pressure was applied using a glass slab to ensure consistency across all samples. After setting, the samples were retrieved and underwent finishing and polishing procedures. For the test groups, the nanoparticles were weighed in the analytic balance and incorporated into the base catalyst paste to give 2% and 4% incorporated ZnO nanoparticle samples.

FIGURE 5: TOTAL SAMPLES FABRICATED.

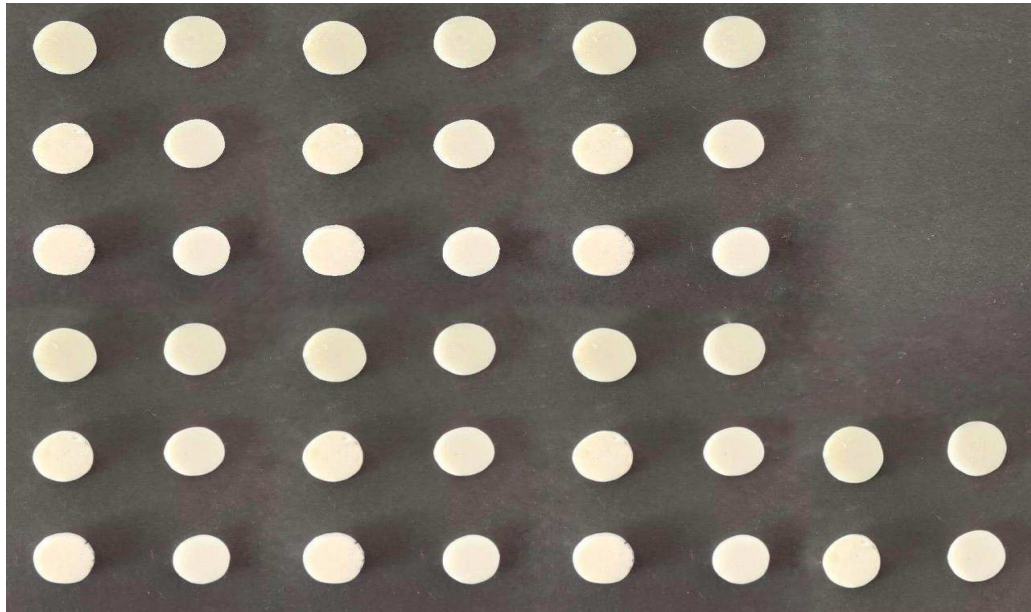
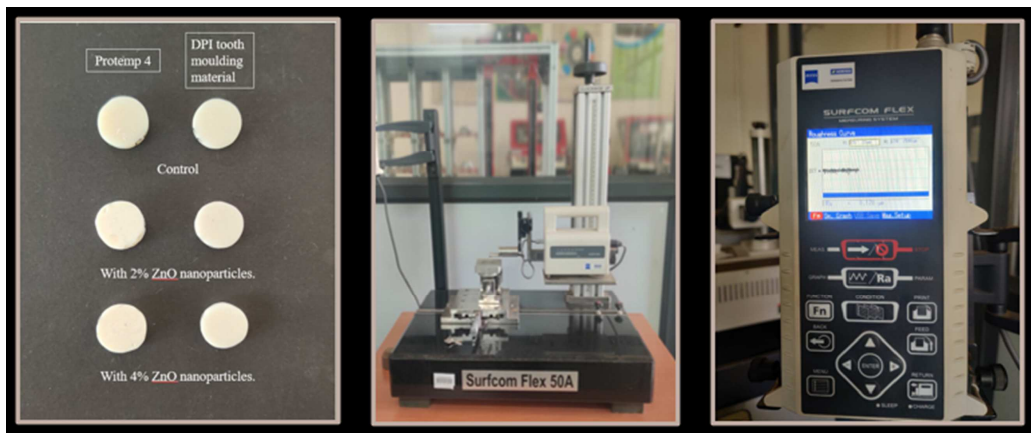


FIGURE 6: EVALUATION OF SURFACE ROUGHNESS.

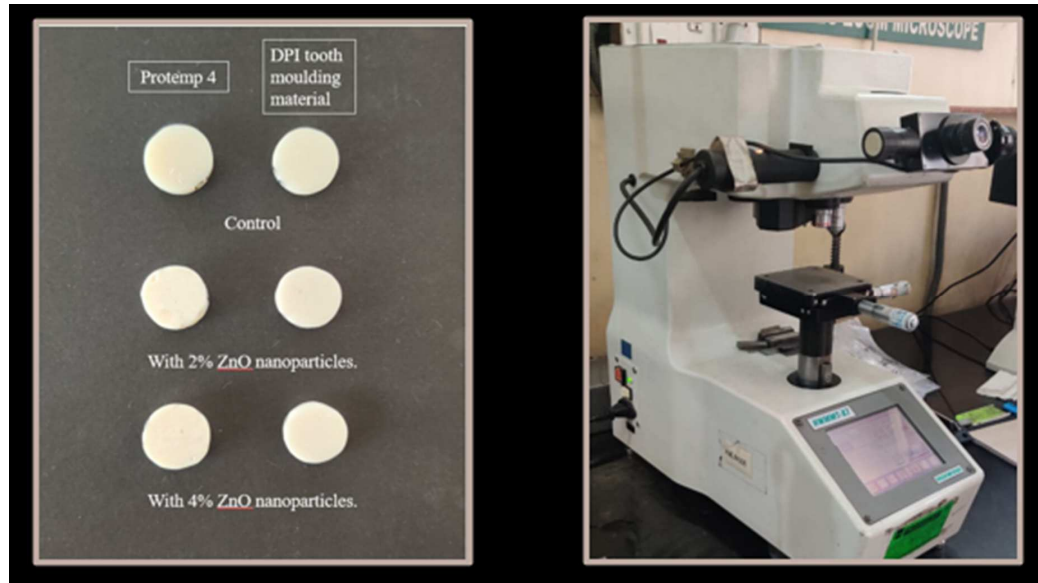


After finishing & polishing of samples, surface roughness of the samples was evaluated.

Surface roughness measurement was carried out with digital profilometer.

Surface roughness of each disc was calculated for 3 readings consecutively. Average of each of them, gave the value of surface roughness.

**FIGURE 7: EVALUATION OF HARDNESS.**



After finishing & polishing of samples, hardness of the samples was evaluated.

Surface hardness was evaluated using a Micro Vickers hardness tester, where a 50g load was applied to the sample surface. A diamond indenter was then used to make an indentation on the sample surface for a duration of 10 seconds.

## **RESULTS**

The goal was to evaluate and compare the outcome of incorporation of ZnO nanoparticles into provisional materials to enhance their physical properties such as surface roughness and hardness, after conditioning at 24 hours and 7<sup>th</sup> day interval.

### **STATISTICAL ANALYSIS**

The study data was entered into a Microsoft Excel spreadsheet, and statistical analysis was conducted. Descriptive statistics were utilized to elucidate the underlying structure of the data.

Independent t-test was applied for comparison between the two main groups.

One way ANOVA and Tukey's Post-Hoc test was used for comparing within the main groups.

The results will be described under the following headings:

1. Descriptive statistics of group 1 and group 2 samples.
2. Comparison of surface roughness and hardness between the groups.
3. Comparison of surface roughness and hardness within the groups.

#### **1. DESCRIPTIVE STATISTICS OF GROUP 1 AND GROUP 2 SAMPLES:**

##### **SURFACE ROUGHNESS:**

The descriptive statistics for surface roughness which was measured between group 1 and group 2 at different time interval (Table 1 & 2 respectively) showed lowest mean for surface roughness was found in group 2 samples at 24 hours which

was statistically significant ( $p < 0.05$ ), and the highest values were seen with group 1 samples at 24 hours. Additionally, it was observed that the surface roughness values decreased as the storage time increased for samples in group 1. (Figure 8)

**Table 1: Descriptive statistics for surface roughness at 24 hours and 7<sup>th</sup> day interval between the two groups respectively.**

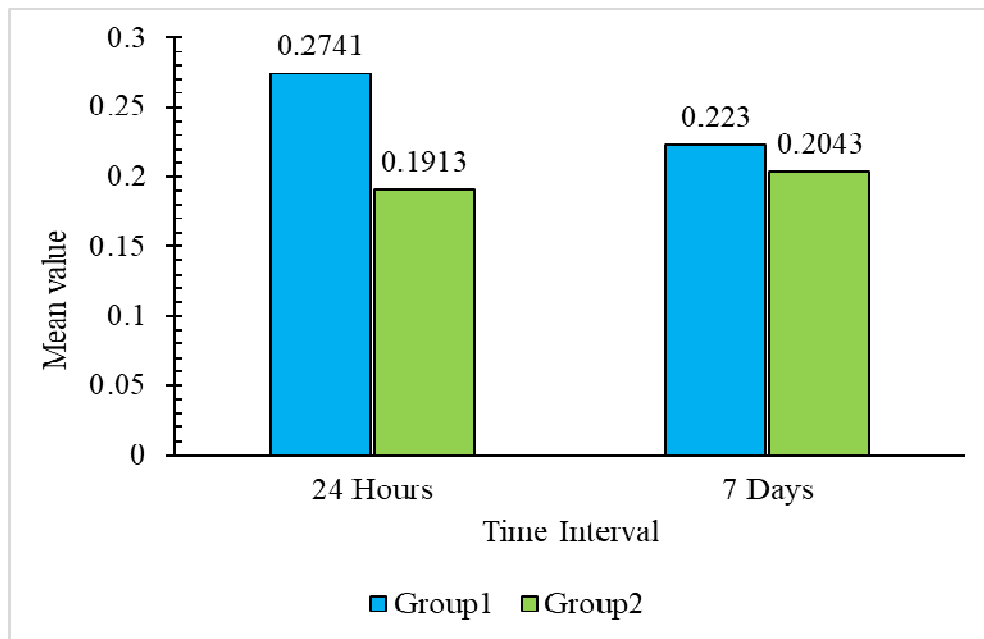
Descriptive data for surface roughness at 24 hours.				Descriptive data for surface roughness at 7 days			
Groups	N	Mean	Std. Deviation	Groups	N	Mean	Std. Deviation
1	120	0.2741	0.19555	1	120	0.223	0.0865
2	120	0.1913	0.07871	2	120	0.2043	0.10749

**Table 2: Comparison of group 1 and 2 at 24 hours and 7 days (respectively) using independent t-test for surface roughness.**

Independent Samples Test						
	t-test for Equality of Means					
	t-value	df	p-value	Mean Difference	95% C.I.	
					Lower	Upper
Average of 1 and 2 group for 24 hours.	4.3	238	<0.05	0.08275	0.04484	0.12066

Independent Samples Test						
	t-test for Equality of Means					
	t-value	df	p-value	Mean Difference	95% C.I.	
					Lower	Upper
Average of 1 and 2 group for 7 Surface	1.489	238	0.138	0.01875	-0.00606	0.04356

**FIGURE 8:** Descriptive statistics for surface roughness of group 1 and group 2 samples at 24 hours and 7<sup>th</sup> day interval.



**HARDNESS:**

The results for hardness when compared between the groups at different time intervals (Table 3&4 respectively) showed that the highest VHN was found with group 2 samples at 7 days interval and the lowest mean was observed with group 1 samples at 24 hours. The results also showed that there was an increase in the hardness of the samples irrespective of the groups with an increase in the storage time ( $p<0.05$ ). (Figure 9)

**Table 3: Descriptive statistics for hardness between the two groups at 24 hours. And 7 days respectively.**

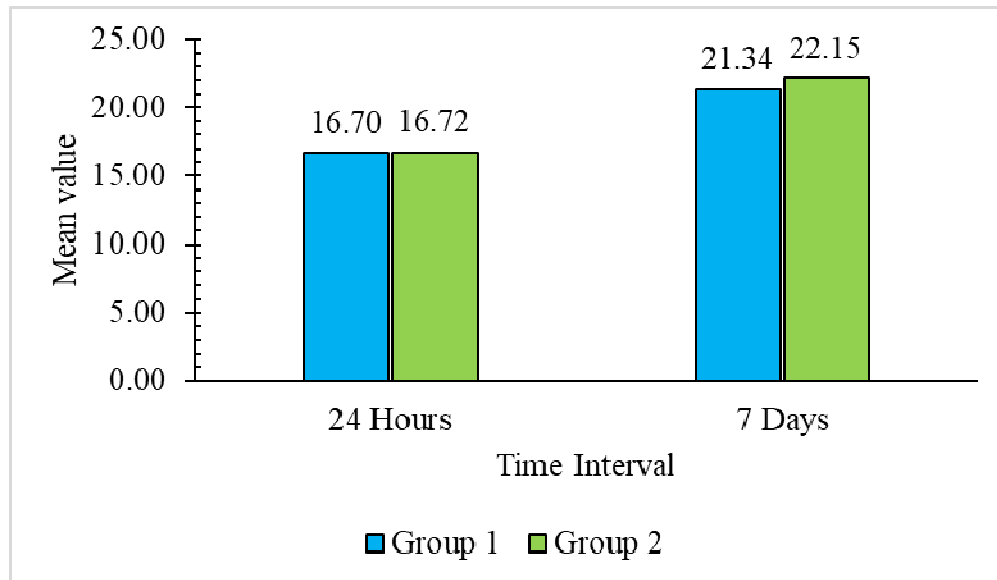
Descriptive data for hardness at 24 hours				Descriptive data for hardness at 7 days			
Groups	N	Mean	Std. Deviation	Groups	N	Mean	Std. Deviation
1	120	16.70	1.14	1	120	21.3358	1.2643
2	120	16.72	0.90	2	120	22.1458	0.95371

**Table 4: Comparison of group 1 and 2 at 24 hours and 7 days (respectively) using independent t-test for hardness.**

Independent Samples Test						
	t-test for Equality of Means					
	t-value	df	p-value	Mean Difference	95% C.I.	
					Lower	Upper
Average of 1 and 2 group for 24 Hardness	-0.17	238	0.866	-0.0225	-0.28396	0.23896

Independent Samples Test						
	t-test for Equality of Means					
	t-value	df	p-value	Mean Difference	95% C.I.	
					Lower	Upper
Average of 1 and 2 group for 7 Hardness	-5.603	238	<0.05	-0.81	-1.0948	-0.5252

**FIGURE 9:** Descriptive statistics of group 1 and group 2 samples at 24 hours and 7 days for hardness.



**2. COMPARING SURFACE ROUGHNESS AND HARDNESS BETWEEN THE GROUPS:**

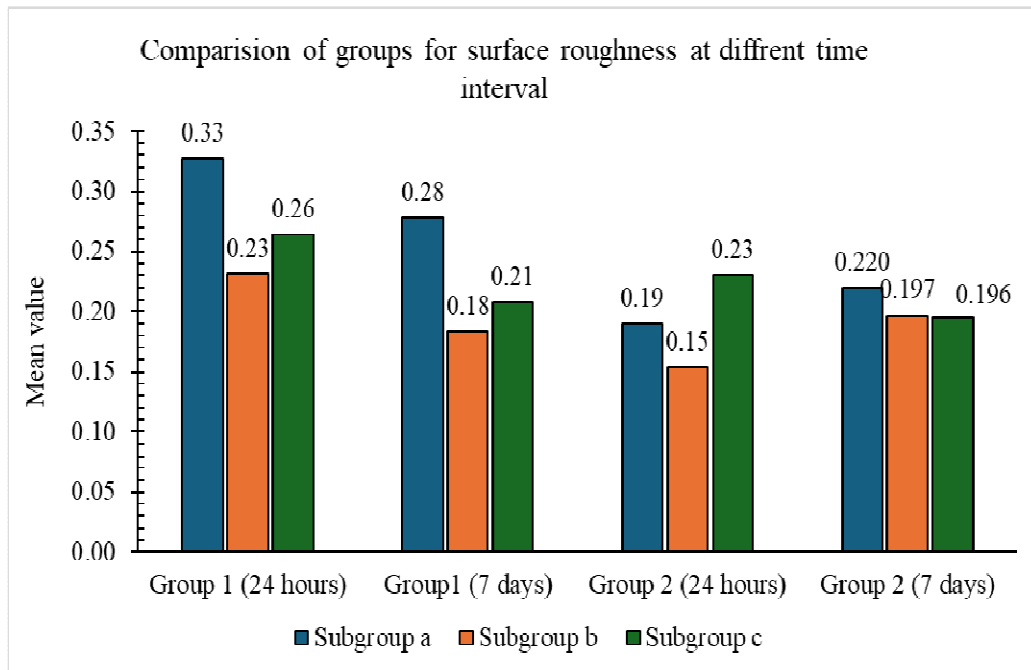
**SURFACE ROUGHNESS:**

The results for the surface roughness comparison at 24 hours and 7 days for group 1a and 2a (Table 5) showed that the lowest surface roughness value was observed with group 2a samples at 24 hours and the highest value was seen with group 1a at 24 hours. When group 1b and 2b were compared, the lowest values were seen with group 2b at 24 hours and highest value was seen with group 1b at 24 hours. When group 1c was compared with 2c, the results showed that group 2c after 7 days of storage had the lowest mean surface roughness values and group 1c at 24 hours had highest surface roughness values. Among all the samples it was observed that group 1a samples had highest surface roughness at 24 hours and the lowest values were seen with group 2b at 24 hours. (Figure 10)

**Table 5: Comparison of surface roughness of group 1 and group 2 samples after incorporation of 2% and 4% zinc-oxide nanoparticles at 24 hours and 7 days.**

Surface roughness in $\mu\text{m}$	Group 1 (24 hours)	Group1 (7 days)	Group 2 (24 hours)	Group 2 (7 days)
Subgroup a	0.33	0.28	0.19	0.220
Subgroup b	0.23	0.18	0.15	0.197
Subgroup c	0.26	0.21	0.23	0.196

**FIGURE 10:** Comparison of group 1 and group 2 for surface roughness at different time intervals after conditioning.



**HARDNESS:**

The results for the comparison of hardness of group 1a and 2a samples at 24 hours and 7 days (Table 6) showed that after 7 days of storage of samples in artificial saliva, the hardness of both the groups increased over the time. When group 1a and 2a were assessed for hardness, the results showed that the highest mean hardness value was observed with group 2a samples after 7 days of storage and the lowest value was seen with group 1a at 24 hours. When the subgroups 1b and 2b were compared the lowest hardness values were observed with group 2b at 24 hours and the highest value was seen with group 1b and 2b at 7 days. When group 1c and 2c were compared, the results depicted lowest mean values with 1c at 24 hours and the highest was seen with 1c and 2c at 7 days. It was also observed that there was a statistically significant increase ( $p < 0.05$ ) in the hardness values as the storage time increased. Among all the samples the highest hardness values were observed with group 2a at 7 days, but no statistically significant observation between the two groups were seen (Figure 11). The evaluation of hardness through independent t-test, showed a significant increase in the hardness values between group 1 and group 2 after storage in artificial saliva for 7 days. (Figure 12 & 13)

**Table 6:** Comparison of hardness of group 1 and group 2 samples after incorporation of 2% and 4% zinc-oxide nanoparticles at 24 hours and 7 days.

Normal	Group 1 (24 hours)	Group1 (7 days)	Group 2 (24 hours)	Group 2 (7 days)
Subgroup a	16.55	20.26	17.12	22.69
Subgroup b	17.19	21.92	16.04	21.92
Subgroup c	16.35	21.84	17.00	21.84

**FIGURE 11:** Comparison of group 1 and group 2 for hardness at different time intervals after conditioning.

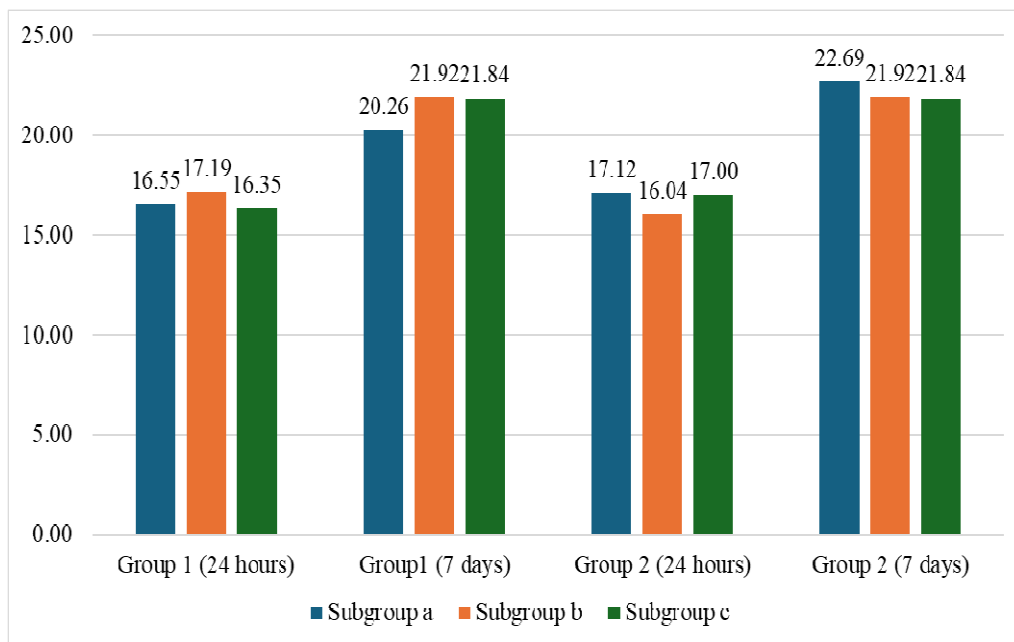


FIGURE 12: Comparison of hardness of group 1 samples at 24 hours and 7 days.

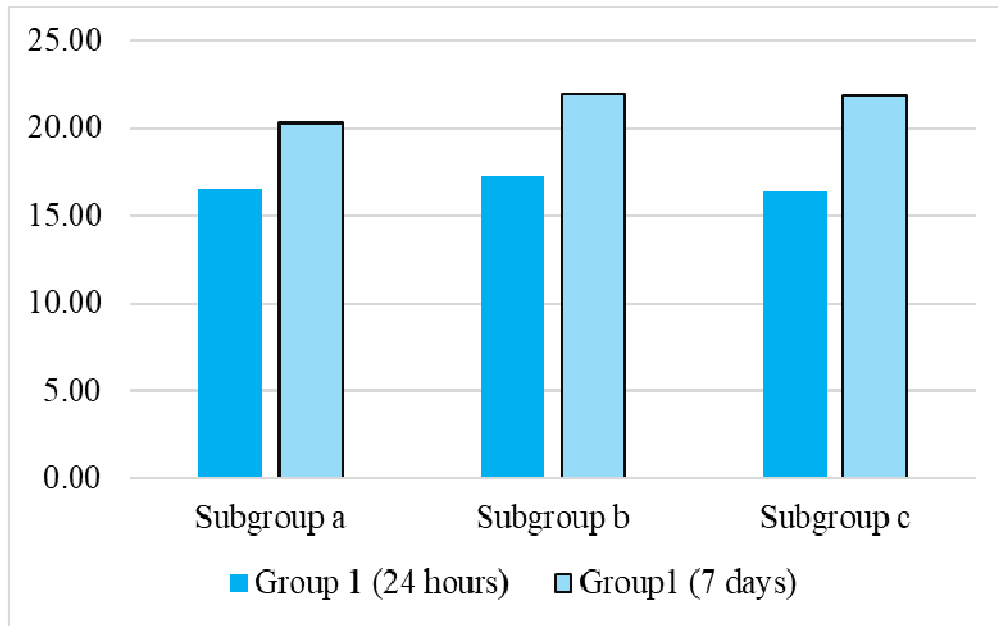
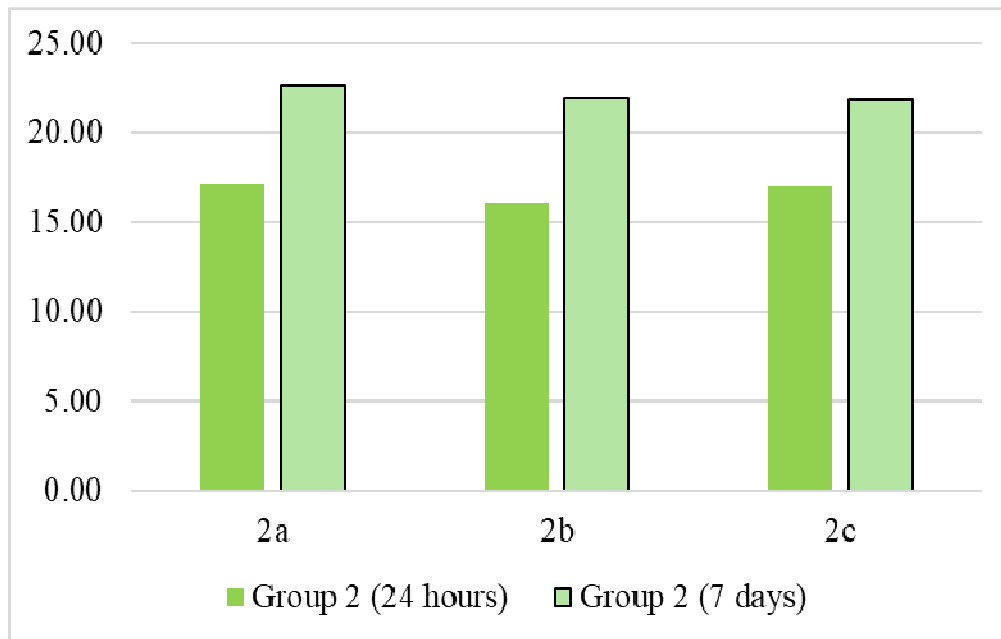


FIGURE 13: Comparison of hardness of group 1 and 2 samples at 24 hours and 7 days.



### **3. COMPARISON OF SURFACE ROUGHNESS AND HARDNESS WITHIN THE GROUP AT 24 HOURS AND 7 DAYS:**

#### **SURFACE ROUGHNESS:**

Evaluation with One Way ANOVA demonstrated a statistically significant decrease ( $p < 0.05$ ) in the values for surface roughness (table 7 & 8) for group 1b samples at 7 days and group 2b samples at 24 hours. Tukey's Post-Hoc test showed that group 1a samples showed a statistically significant increase in the values for surface roughness at 7 days and that for group 2 at 24 hours, group 2c showed statistically significant increase ( $p < 0.05$ ) in the values for surface roughness when compared to group 2a and 2b. (Table 9 & 10) (Figure 14 & 15)

**Table 7: Describing statistically significant results for group 1 at 7 days for surface roughness assessed through One Way ANOVA test.**

ANOVA					
Average of group 1 at 7 days.					
	Sum of Squares	df	Mean Square	F	p-value
Between Groups	0.195	2	0.097	16.397	<0.05
Within Groups	0.695	117	0.006		
Total	0.89	119			

**Table 8: Describing statistically significant difference between the subgroups within group 2 at 24 hours for surface roughness when tested through One Way ANOVA test.**

ANOVA					
Average of group 2 at 24 hours.					
	Sum of Squares	df	Mean Square	F	p-value
Between Groups	0.118	2	0.059	11.135	<0.05
Within Groups	0.619	117	0.005		
Total	0.737	119			

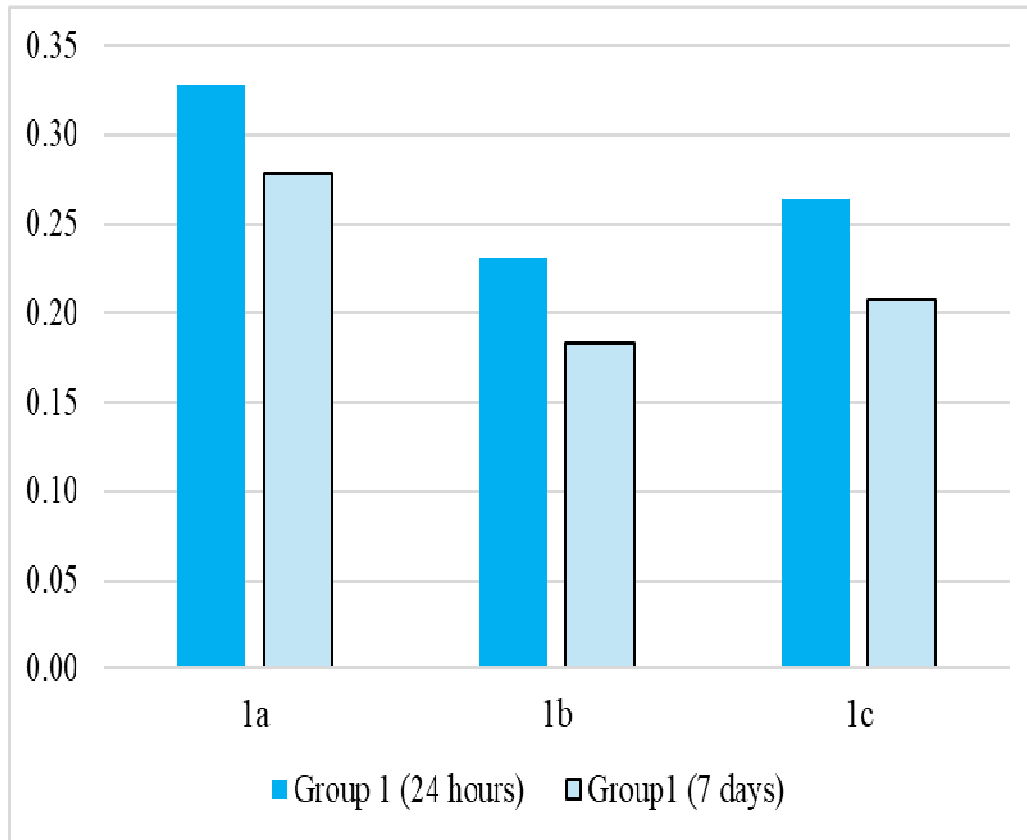
**Table 9:** Tukey's post-hoc test revealed statistically significant differences within group 1 samples specifically at the 7-day mark for surface roughness.

Post-Hoc Test					
(I) Subgroup naming	(J) Subgroup naming	Mean Difference (I-J)	p-value	95% C.I	
				Lower Bound	Upper Bound
a	b	.09500*	<0.05	0.0541	0.1359
	c	.07075*	<0.05	0.0298	0.1117
b	a	-.09500*	<0.05	-0.1359	-0.0541
	c	-0.02425	0.341	-0.0652	0.0167
c	a	-.07075*	<0.05	-0.1117	-0.0298
	b	0.02425	0.341	-0.0167	0.0652
* The mean difference is significant at the 0.05 level.					

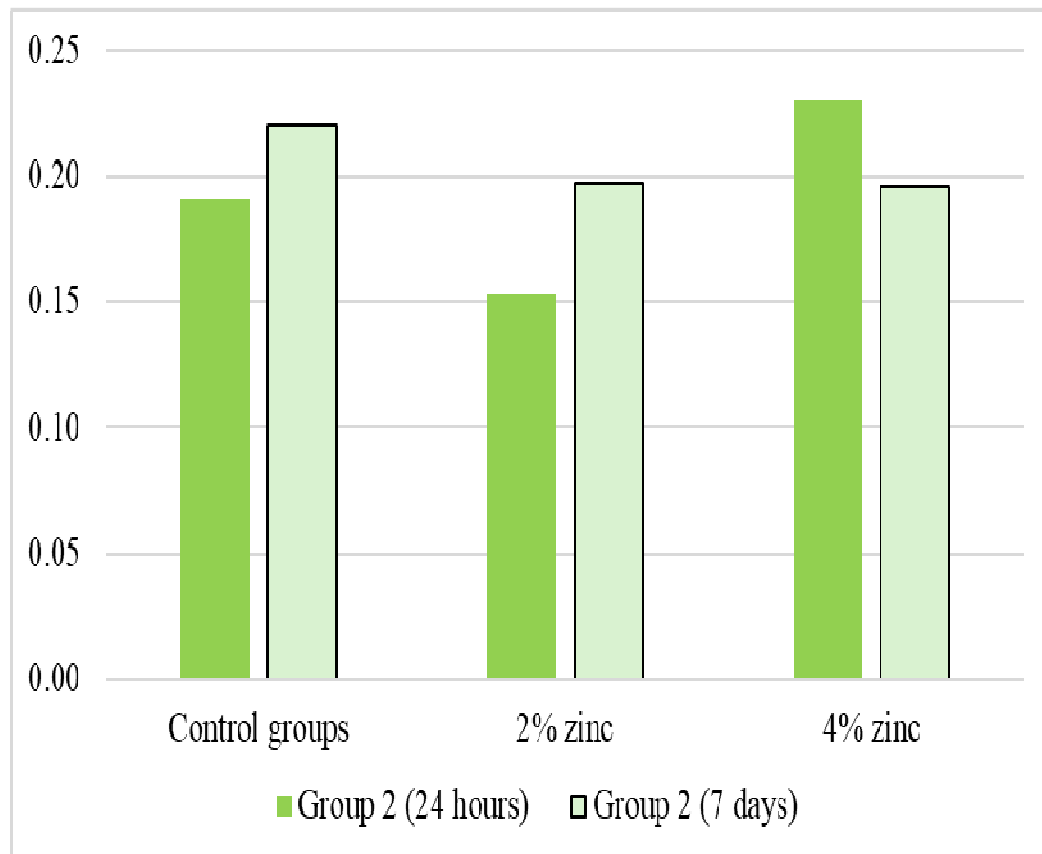
**Table 10:** Tukey’s Post-Hoc test showing statistically significant differences within group 2 samples at 24 hours for surface roughness.

Post-Hoc Test					
(I) Subgroup naming	(J) Subgroup naming	Mean Difference (I-J)	Sig.	95% C.I	
				Lower Bound	Upper Bound
a	b	0.03675	0.066	-0.0019	0.0754
	c	-.04000*	0.041	-0.0786	-0.0014
b	a	-0.03675	0.066	-0.0754	0.0019
	c	-.07675*	0	-0.1154	-0.0381
c	a	.04000*	0.041	0.0014	0.0786
	b	.07675*	0	0.0381	0.1154
* The mean difference is significant at the 0.05 level.					

**FIGURE 14:** Comparison of surface roughness of group 1 within the group at different time intervals.



**FIGURE 15:** Comparison of surface roughness of group 2 within the group at different time intervals.



**HARDNESS:**

The results assessed using One Way ANOVA for hardness within group 1 samples (Table11) revealed a statistically significant increase ( $p=0.002$ ) in the hardness value for 1b when compared to 1a and 1c samples at 24 hours. When the samples were tested at 7<sup>th</sup> day interval, (Table12) a statistically significant decrease was seen ( $p<0.05$ ) in the hardness with group 1a when compared to 1b and 1c samples. When group 2 was assessed at 24 hours for hardness (Table 13), there was a statistically significant ( $p<0.05$ ) increase in the values for 2a samples when compared to the other and when they were assessed at 7th day (Table 14), a significant increase ( $p<0.05$ ) in hardness was seen with group 2a samples when compared to the others.

Tukey's post-hoc test indicated a statistically significant ( $p < 0.05$ ) increase in the hardness of group 1b compared to group 1a and 1c at the 24-hour mark. (Table 15). When the samples were tested at 7 days for hardness (Table16), a statistically significant ( $p<0.05$ ) decrease was observed in the hardness values for group 1a when group 1b and 1c were compared. When group 2 samples were compared (Table 17), there was a statistically significant ( $p<0.05$ ) decrease in the hardness values for group 2b samples when compared with 2a and 2c. When group 2 samples were compared at 7 days for hardness (Table 18), the results depicted a statistically significant ( $p<0.05$ ) increase in hardness of group 2a samples when compared with group 2b and 2c.

Figures 16 and 17 describe the hardness values within group 1 and 2 respectively as a summary.

**Table 11:** Describing statistically significant results for group 1 at 24 hours for hardness within the group.

ANOVA					
Average of 1st group for 24 H					
	Sum of Squares	df	Mean Square	F	p-value
Between Groups	15.333	2	7.667	6.437	0.002
Within Groups	139.343	117	1.191		
Total	154.677	119			

**Table 12:** Describing statistically significant results for group 1 at 7 days for hardness within the group.

ANOVA					
Average of 1st group for 7 D					
	Sum of Squares	df	Mean Square	F	p-value
Between Groups	70.212	2	35.106	34.227	<0.05
Within Groups	120.004	117	1.026		
Total	190.216	119			

**Table 13:** Describing statistically significant results for group 2 at 24 hours for hardness within the group.

ANOVA					
Average of 2nd group for 24 H					
	Sum of Squares	df	Mean Square	F	p-value
Between Groups	28.248	2	14.124	24.081	<0.05
Within Groups	68.625	117	0.587		
Total	96.873	119			

**TABLE 14:** Describing statistically significant results for group 2 at 7 days for hardness within the group.

ANOVA					
Average of 2nd group for 7 D					
	Sum of Squares	df	Mean Square	F	p-value
Between Groups	17.562	2	8.781	11.33	<0.05
Within Groups	90.676	117	0.775		
Total	108.238	119			

**Table 15:** Describing Tukey’s Post-Hoc test results showing statistically significant results within group 1 for hardness at 24 hours.

Post-Hoc Test					
(I) Subgroup naming	(J) Subgroup naming	Mean Difference	p- value	Confidence Interval of 95%	
				Lower Bound	Upper Bound
1	2	-.64000*	0.027	-1.2193	-0.0607
	3	0.1975	0.698	-0.3818	0.7768
2	1	.64000*	0.027	0.0607	1.2193
	3	.83750*	0.002	0.2582	1.4168
3	1	-0.1975	0.698	-0.7768	0.3818
	2	-.83750*	0.002	-1.4168	-0.2582
* The mean difference is significant at the 0.05 level.					

**Table 16:** Tukey’s Post-Hoc test results showing statistically significant results within group 1 for hardness at 7 days.

Post-Hoc Test					
(I) Subgroup naming	(J) Subgroup naming	Mean Difference	p-value	95% confidence interval.	
				Lower Bound	Upper Bound
1	2	-1.66000*	<0.05	-2.1976	-1.1224
	3	-1.58250*	<0.05	-2.1201	-1.0449
2	1	1.66000*	<0.05	1.1224	2.1976
	3	0.0775	0.938	-0.4601	0.6151
3	1	1.58250*	<0.05	1.0449	2.1201
	2	-0.0775	0.938	-0.6151	0.4601
* The mean difference is significant at the 0.05 level.					

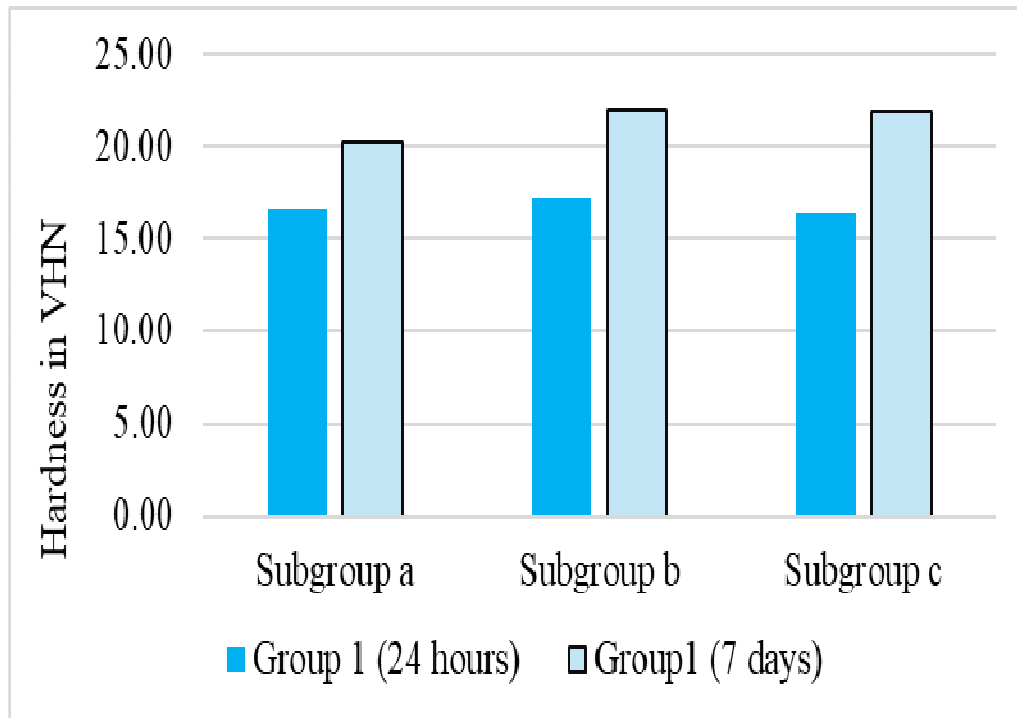
**Table 17:** Describing Tukey’s Post-Hoc test results showing statistically significant results within group 2 for hardness at 24 hours.

Post-Hoc Test					
(I) Subgroup naming	(J) Subgroup naming	Mean Difference	p-value	95% Confidence interval	
				Lower Bound	Upper Bound
1	2	1.08500*	<0.05	0.6785	1.4915
	3	0.1225	0.755	-0.284	0.529
2	1	-1.08500*	<0.05	-1.4915	-0.6785
	3	-.96250*	<0.05	-1.369	-0.556
3	1	-0.1225	0.755	-0.529	0.284
	2	.96250*	<0.05	0.556	1.369
* The mean difference is significant at the 0.05 level.					

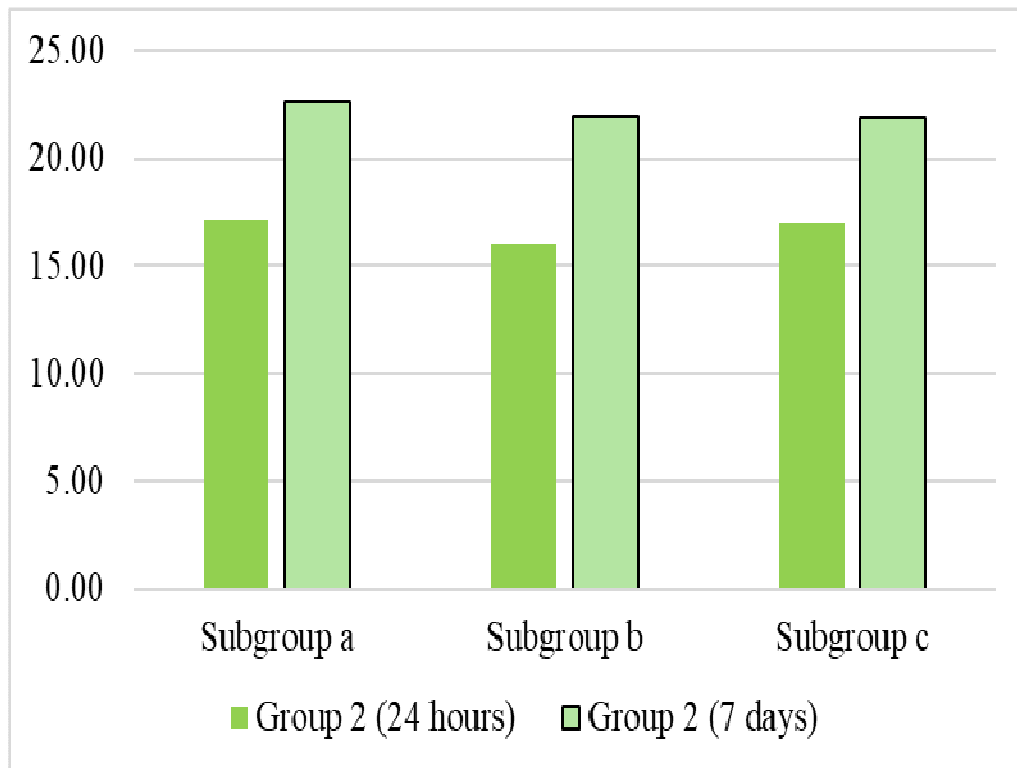
**Table 18:** Describing Tukey’s Post-Hoc test results showing statistically significant results within group 2 for hardness at 7 days.

Post-Hoc Test					
(I) Subgroup naming	(J) Subgroup naming	Mean Difference	p-value	95% Confidence interval	
				Lower Bound	Upper Bound
1	2	.77000*	<0.05	0.3027	1.2373
	3	.84750*	<0.05	0.3802	1.3148
2	1	-.77000*	<0.05	-1.2373	-0.3027
	3	0.0775	0.918	-0.3898	0.5448
3	1	-.84750*	<0.05	-1.3148	-0.3802
	2	-0.0775	0.918	-0.5448	0.3898
* The mean difference is significant at the 0.05 level.					

**FIGURE 16:** Comparison of hardness within group 1 at different time intervals of 24 hours and 7 days.



**FIGURE 17:** Comparison of hardness within group 2 at different time intervals of 24 hours and 7 days.



## **DISCUSSION**

Provisional restorations like crowns and bridges are extensively employed in fixed partial denture (FPD) procedures. They serve as a thermal barrier, shielding the prepared tooth structure, occlusal stability maintenance, and influencing the aesthetic, functional, and therapeutic outcomes of the treatment before the placement of permanent dental prostheses.<sup>59</sup>

For clinical situations necessitating prolonged provisionalization, such as dental implant therapy or extensive occlusal reconstruction such as full mouth rehabilitation cases, it is essential that provisional restorative materials possess strong physical and mechanical characteristics. This is important to prevent failures under extended functional loading conditions.<sup>60</sup> Hardness, density, and strength which are properties of dental materials, determine the durability of the restorations. These restorations are fabricated either through indirect technique or intraorally. Opting for the indirect technique offers notable benefits, such as enhanced marginal integrity and protection against pulpal injury resulting from the exothermic polymerization of acrylic resin.<sup>61</sup>

Currently, two primary material groups, distinguished by their chemical composition, are in use for temporary restorations: methacrylate resins (typically hand-mixed from liquid and powder components) and composite resin-based materials. Methacrylate resins require a chemical initiator to commence the setting process, while materials based on composites are provided in systems that are either dual-curing or self-curing.<sup>62</sup>

In clinical settings, various functional loads act upon the FPD's. Studies on stress analysis have demonstrated that these forces are compressive at the points where the load is applied and involve shear and tensile stresses at points where resistance to the load occurs.<sup>63</sup> Temporary (FDPs) should be durable to withstand wear, thus aiding in maintaining the alignment of prepared teeth and meeting the patient's aesthetic preferences. Density of a material is evaluated by testing microhardness, suggesting that denser materials may exhibit greater wear resistance and surface deterioration. Resins lacking fillers, such as PMMA, are susceptible to wear, yet their filler-free composition and mono-functional molecular nature contribute to color stability.<sup>64</sup>

To enhance periodontal health, it is essential for provisional crowns to feature excellent fit along the margins, appropriate contours, and a smooth topography of surface. Prior to cementation, provisional crowns undergo polishing to form a surface which is comfortable for the patient and helps prevent bacterial plaque accumulation.<sup>65</sup>

These materials' increased surface roughness and poorer fitting surfaces make them more prone to bacterial colonization than definitive prostheses.<sup>66</sup> Several methods involving multiple steps have been outlined for finishing and polishing such materials. One suggested approach involves using slurry of fine pumice on a wheel onto the material surface, and another method by a second muslin wheel which is coated with polishing compound to enhance the luster further. Alternative techniques include employing various, points, polishing pastes, disks and rubber wheels.<sup>67</sup>

In recent years, various provisional restorative resins have emerged, including bis-acrylic composite resin, Polyethyl methacrylate, visible light-cured urethane dimethacrylate, Polymethyl methacrylates.<sup>68</sup> Self cured PMMA resins traditionally have been utilized for the provisional restoration fabrication either by indirect or direct methods. However, light activated polymethylmethacrylate and composite resins have become increasingly popular alternatives in recent years. Despite advancements in enhancing the provisional materials' physical properties, none have been deemed ideal thus far.<sup>69</sup> Autopolymerizing PMMA resins exhibit various shortcomings. Earlier research has noted issues such as polymerization shrinkage and marginal discrepancies. The risk of pulpal damage due to the heat generated during polymerization has been extensively documented, along with the periodontium's sensitivity to the fit and contour of these restorations.<sup>70</sup> Indeed, unlike Polymethyl methacrylate (PMMA), bis-acryl resins contain monomers of divinyl methacrylate along with filler particles. This composition contributes to their unique properties and performance characteristics compared to PMMA. Consequently, there is a potential reduction in polymerization shrinkage and exothermic release, while also enhancing color stability compared to PMMA. Bis-acryl resins moreover are accessible commercially for utilization with auto mix syringes, which may escalate costs, but offer ease of handling and diminish air entrapment. These resins can be employed for virtually all categories of interim restorations.<sup>71</sup>

It has been established that the strength of acrylic provisional resins relies on their resistance to crack propagation, ultimately dictating the strength and usability of fixed partial dentures.<sup>72</sup> Various reinforcement methods are recommended to enhance the characteristics of acrylic resins. To strengthen acrylic resin materials, different methods through strategies like chemical modification involving grafted copolymers

and increased cross-linkage, or by incorporating diverse inorganic and organic fibers have been implemented. For reinforcement, different materials encompass, glass, metal, sapphire, Kevlar, polyester, rigid polyethylene and carbon graphite.<sup>73</sup>

Nanotechnology involves the science and engineering of functional systems at a nanoscale, which is one-billionth of a meter. Therefore, in dentistry, the goal of nanotechnology is to emulate the natural tissue architecture, encompassing both soft and hard tissues, through the utilization of innovative dental biomaterials. This aims to improve the restoration of lost tissue resulting from disease and to offer better biomechanical properties when needed.<sup>74</sup> Jasnik Singh et al conducted a comprehensive literature review discussing the diverse nanoparticles employed in dentistry, including graphene, silver nanoparticles, carbon nanotubes, zirconia, titanium, among others. The review explores their utilization across different dental specialties such as prosthodontics, endodontics, periodontology, implantology, highlighting their applications in enhancing both biological and mechanical properties in dentistry.<sup>75</sup>

Yin Zhang et al.'s literature review on the biomedical applications of ZnO nanoparticles revealed that ZnO showcases a diverse range of nanostructures, and possesses distinctive semiconductor, piezoelectric and optical characteristics. Consequently, nanomaterials which are ZnO based have been extensively investigated for various applications including nano-optical and nano-electronic devices, cosmetic formulations, nanosensors, energy storage and more. Notably, zinc-oxide nanomaterials are valued for their low toxicity and biodegradability, making them particularly appealing for biomedical applications. This review provided an overview of the current utilization of ZnO nanomaterials in biomedicine, encompassing areas of

biomedical imaging, drug delivery, gene delivery, and biosensing.<sup>76</sup> Mustafa et al. looked at the effects of adding ZnO nanoparticles to the basic resin used in 3D printed dentures.

The findings indicated a notable increase in strength values across all concentrations tested, with the greatest enhancement observed at the 3% concentration level. Interestingly, the addition of nanoparticles did not influence Shore D hardness, while a significant decrease in surface roughness was seen with all concentrations. These results suggest potential possessed by ZnO as a material for improving denture bases fabricated through 3D printed resins.<sup>77</sup>

Numerous investigations have been carried out with the aim of enhancing the physical characteristics, including surface roughness and hardness of provisional resins. These studies have focused on reinforcing the resins with diverse agents to improve their properties. The current study aimed at comparing and evaluating the effects of zinc-oxide nanoparticles reinforcement into two different provisional resins to enhance their mechanical properties, specifically focusing on surface roughness and hardness. These evaluations were conducted in vitro, following conditioning in artificial saliva.

Polymeric resins, comprising acrylic and composite resins, are commonly utilized for interim restorations in dentistry. Among these, self-curable polymethyl methacrylate (PMMA) gained widespread acceptance shortly after its introduction. This popularity stems from its ease of fabrication, cost-effectiveness, and the simplicity of achieving a polished surface.<sup>78</sup> A difunctional monomer Bisphenol A glycidyl methacrylate, is with a relatively high molecular weight. These resins, which are derived from Bis-GMA, have gained popularity for the fabrication of interim fixed

prostheses due to several desirable properties. These include high strength, excellent polishability, and low polymerization shrinkage, making them suitable for use in temporary restorations in dentistry.<sup>79</sup> Protemp 4 is the most recent innovative product from 3M ESPE in the Protemp family. One notable improvement in Protemp™ 4 is its enhanced translucency compared to previous versions. This improvement in translucency can offer better esthetics, closely mimicking the natural appearance of teeth, which is crucial for temporary restorations. Hence in the current study, DPI tooth molding material and Protemp 4 were chosen as the two materials for comparison, representing PMMA (polymethyl methacrylate) and Bis-acryl resins, respectively. Surface roughness measurement can be achieved using various methods in dentistry. Qualitatively, scanning electron microscopy (SEM) provides visual information regarding the surface topography, while quantitative methods like profilometry offer numerical data regarding surface roughness parameters.<sup>21</sup> Micro Vickers hardness testing is commonly employed for assessing the hardness of dental materials. This testing method involves using a specialized instrument called a Micro Vickers hardness tester to measure the materials' resistance to indentation under a specific load.<sup>80</sup> Hence in this study, a digital surface profilometer and digital Micro Vickers hardness tester was utilized to assess surface roughness and hardness respectively. There has been limited evidence exploring the effect of zinc oxide nanoparticles incorporation into provisional restorative resins to enhance their mechanical properties. Consequently, the current study was undertaken to compare the two distinct properties of provisional resin formulations, each incorporating varying zinc oxide nanoparticles at various concentrations.

To evaluate the hardness and surface roughness of the resins, 40 such samples of dimensions 15mm x 2mm were fabricated according to ADA specification number 27 for the control group. Following fabrication, each specimen underwent finishing and polishing using a different grade of sandpapers. This process was conducted to ensure uniformity and smoothness of the surfaces of the specimens before further evaluation of surface roughness and hardness. For the test group specimens, ZnO nanoparticles were weighed and incorporated into the polymer of DPI samples and Protemp 4 base and catalyst paste respectively, to form 40 samples of 2% and 4% ZnO nanoparticles. According to a study by Mariusz Cierech et al., ZnO nanoparticles released from PMMA–ZnO nanocomposites at different percentages of 2.5%, 5%, and 7.5% w/w did not exhibit any negative effects in HeLa cells up to a concentration of 20 mg/L.

This finding likely influenced the decision regarding the concentration of these nanoparticles chosen for incorporation into the provisional resins in the current study.<sup>81</sup> To assess the hardness and surface roughness of the resin types, 40 samples were fabricated with dimensions of 15mm x 2mm, adhering to ADA specification number 27, for the control group. For the test group specimens, ZnO nanoparticles were accurately weighed and then integrated into the polymer of DPI samples and the base and catalyst paste of Protemp 4, respectively. This process resulted in the formation of 40 samples each containing 2% and 4% concentrations of ZnO nanoparticles. Following fabrication, the samples underwent conditioning in artificial saliva for periods of 24 hours and 7 days to simulate intraoral conditions for evaluation of surface roughness and hardness. The decision to use artificial saliva was based on a study by V. W-H. Leung, which assessed the effectiveness of artificial saliva in mimicking intraoral conditions in in-vitro studies. Therefore, to replicate oral

environment conditions as closely as possible, the samples were immersed in artificial saliva during the testing period.<sup>82</sup> For evaluating the surface roughness, the samples underwent digital surface profilometric evaluation. Each sample was positioned perpendicular to the device, and the stylus was passed over the entire length of the specimen to record readings. Three readings were recorded for each disc, and the average of these readings was used as the result of the study. Similarly, a digital Micro Vickers tester was used to evaluate hardness. A load of 50g was applied onto the surface of each sample, and a diamond indenter was used to make an indentation for 10 seconds. Again, three readings were recorded for each disc, and the average of these readings was utilized as the result of the study.

According to the study findings, when comparing the overall surface roughness between the two main groups, it was observed that group 2 samples exhibited the lowest values at 24 hours (0.19, 0.15, 0.23 $\mu$ m), while the highest values were observed with group 1 samples at 24 hours (0.33, 0.23, 0.26  $\mu$ m). This indicates group 2 samples containing Protemp 4 with and without nanoparticle incorporation, showed lower surface roughness values than the group 1 samples. The results of the study align with findings from research study conducted by Vinay Kumar et al., who evaluated the surface roughness of DPI, Protemp, and Tempofit materials. Their study concluded that Protemp exhibited the least surface roughness compared to the other materials<sup>5</sup>. This consistency in findings suggests that Protemp may indeed possess superior surface characteristics, as indicated by its lower surface roughness, when compared to other provisional materials such as DPI and Tempofit and that the incorporation of ZnO nanoparticles enhanced the surface roughness. The attribution to the superior surface properties can be due to the presence of a difunctional monomer in bis-acryl resins when compared to the monofunctional monomer in acrylic resins.<sup>5</sup>

When evaluating the hardness of samples between the two groups, it was observed that group 2 samples exhibited the highest surface hardness values (22.68, 21.91, 21.83 VHN) at 7 days, while the lowest values were observed with group 1 samples at 24 hours (16.55, 17.19, 16.35 VHN). These findings are consistent with an investigation conducted by Diaz and Arnold, where they assessed the hardness of two PMMA provisional resins and three bis-acryl resins and concluded that bis-acryl resins demonstrated superior hardness compared to PMMA resins. This alignment in results suggests that the reinforcement of zinc oxide nanoparticles may have influenced the hardness properties of the provisional resins, with group 2 samples showing higher hardness values similar to bis-acryl resins. There was a significant increase ( $p < 0.05$ ) in values after conditioning for 7 days, regardless of the groups. The findings are in accordance with a study by Akova et al., which showed that the provisional materials' hardness increased with storage in food-stimulating solutions for 7 days<sup>83</sup>. In a study conducted by Goiato on the impact of accelerated aging on the colour stability and microhardness of flexible resins for dentures, it was concluded that the notable rise in microhardness observed in all three materials following accelerated aging is likely due to their thorough polymerization<sup>84</sup>. This alignment in results suggests a common trend where the mechanical properties, including hardness, tend to improve or increase over time when exposed to oral environment-simulating conditions. On the contrary, an investigation by Omid Savabi et al, evaluating the wear resistance and hardness observed that there was a decrease in the hardness values after conditioning in artificial saliva.<sup>86</sup>

The comparison between different subgroups within the two groups yielded the following results. When surface roughness was evaluated for group 1a and 2a samples, it was observed that,

- The lowest values were seen with group 2a samples at 24 hours, indicating that Protemp 4 samples showed lower surface roughness values compared to DPI tooth molding samples.
- When 1b and 2b samples were compared, group 2b showed lowest surface roughness values at 24 hours, and
- Among 1c and 2c samples, the lowest value was seen with 2c samples at 7 days.

Based on the findings presented above, it can be inferred that Protemp 4 samples, whether with or without nanoparticle integration, exhibited enhanced surface roughness values compared to DPI tooth molding materials. Additionally, among the samples, the lowest values for surface roughness were observed with group 2b, which represents Protemp 4 with 2% ZnO nanoparticle incorporation. A study conducted by Mohammad Gad et al, conducted an investigation on addition of nanoparticles into denture base resins to assess the mechanical properties suggested that the decrease in the values for surface roughness can be due of the better distribution of nanoparticles on the specimen surface as a result of the resin matrix's capacity to fill the gaps between the polymer chains.<sup>85</sup> Furthermore, among the 2% and 4% Zinc Oxide nanoparticle groups, it was noted that as the concentration increased, the surface roughness values also increased but the values were well within the surface roughness limit of 0.2  $\mu\text{m}$ . This finding aligns with an in-vitro study by Jamel et al, which

concluded that glass fiber incorporation resulted in surface roughness values which were high with the increase in concentration. The surface roughness increase was attributed to the nanoparticles' tendency to agglomerate on the surface with increasing concentrations, leading to reduced homogeneity in the matrix and the formation of clusters on the specimen's surface.<sup>26</sup> However, it's worth noting that the the control group values were higher than the reinforced group, suggesting that the incorporation of ZnO nanoparticles potentially improves the surface roughness.

When comparing the subgroups between the groups to evaluate hardness, the following observations were made:

- Among 1a and 2a samples, at 7 days, higher values for hardness were observed with 2a samples.
- Between 1b and 2b samples, at 7 days, both subgroups showed higher values for hardness.
- Similarly, between 1c and 2c samples, at 7 days, both showed higher values for hardness after conditioning in artificial saliva.

Overall, group 2a exhibited the highest hardness values at 7 days. This difference may be because the nanoparticles were not incorporated directly into the auto mixing syringe but were hand manipulated to achieve a uniform mixture.

Upon comparison of subgroups within the main groups for surface roughness, the results indicated a significant decrease in values for group 1b samples at 7 days. Similarly, in group 2 samples, subgroup 2b exhibited a statistically significant decrease in values for surface roughness at 24 hours. These findings suggest that the

incorporation of 2% ZnO nanoparticles can effectively improve the surface roughness of acrylic resin. This aligns with a study conducted by Mostafa Ehsan Al-Douri, which concluded that ZnO nanoparticles incorporation into denture base resins showed improvement in surface roughness of the acrylic resins.<sup>24</sup>

When comparing the subgroups within the main groups for hardness, the following observations were made:

1. Among group 1 samples at 24 hours, subgroup 1b exhibited a statistically significant( $p=0.002$ ) increase in hardness compared to 1a and 1c, indicating that the incorporation of 2% ZnO nanoparticles led to better hardness compared to both the control and the 4% reinforcement group. At 7 days, both subgroups 1b and 1c demonstrated higher hardness values compared to subgroup 1a, suggesting that after conditioning in artificial saliva, there were higher hardness values in both reinforced groups when control groups were compared.

2. For group 2 samples evaluated at 24 hours, subgroup 2b demonstrated statistically significant decrease( $p<0.05$ ) in the hardness values than subgroups 2a and 2c. Similarly, at 7 days, subgroup 2a exhibited higher hardness values than subgroup 2b and 2c. These results suggest that for group 1 samples, nanoparticle addition increased the hardness at a 2% concentration, whereas for group 2 samples, the nanoparticle addition decreased the hardness values compared to control group. This result is in accordance with an in-vitro investigation carried out by Vaibhav Deorao et al. on the impact of flexural strength with various fiber reinforcements of provisional restorative resins, which suggested that the decrease in hardness values with bis-acryl resins may stem from inadequately bonded nanoparticles within the resin matrix, resulting in the

incorporation of voids. Improper impregnation could lead to increased watersorption, consequently diminishing the mechanical properties of these resins.<sup>3</sup>

This study's objective was to assess whether addition of ZnO nanoparticles into two provisional resins led to decrease in surface roughness and increase in hardness. The findings of the study indicate a clear positive influence on the improvement of mechanical properties in provisional resins with 2% and 4% incorporation of ZnO nanoparticles.

## **SCOPE OF THE STUDY**

- The study aimed at comparing the effect of incorporating ZnO nanoparticles on the surface roughness and hardness of provisional restorative resins after conditioning in artificial saliva.
- Further research can be conducted at different concentrations of ZnO nanoparticles evaluating the other mechanical properties of provisional resins.
- Further research can be conducted on the various other mechanical and optical properties such as flexural strength, compressive strength, color stability.
- Further research on the stability and cytotoxicity of ZnO nanoparticles can be conducted.
- Since this is an in-vitro study, in-vivo studies can be carried out since intraoral parameters such as pH, presence of saliva, different loading parameters can affect the mechanical properties of provisional resins.
- Furthermore, long-term studies can be conducted for validation of results.

## **LIMITATIONS OF THE STUDY**

- The primary limitation is that the results obtained through in vitro investigation might not accurately reflect on the outcomes under clinical conditions.
- Several other optical and mechanical properties, such as impact strength, compressive strength, flexural strength, wear resistance, and color stability, were not evaluated.
- Long-term studies could provide better validation of the results in cases of full mouth reconstructions, Implants etc.
- The comparison was conducted using only two types of provisional resins, and different resins may yield different outcomes.
- The assessment of ZnO nanoparticles was limited to only two concentrations. Evaluating additional concentrations could lead to varying results.
- To better simulate intraoral conditions, the samples were stored in artificial saliva. Using methods like cyclic loading or accelerated aging could enhance the validity of the results.

## **CLINICAL IMPLICATIONS**

- Incorporating ZnO nanoparticles at concentrations within non-cytotoxic levels has shown potential in enhancing mechanical properties of provisional restorative materials. On integrating such filler particles during the manufacturing process, these resins could see increased efficiency, mitigating issues like void incorporation and non-uniform mixing of the monomer-polymer/base-catalyst paste that may arise during manual manipulation thereby increasing the lifespan of provisional materials.

## **CONCLUSION**

Considering the limitations of the study, it can be inferred that,

- Group 1 samples exhibited notably higher surface roughness and lower hardness values in comparison to bis-acryl resins at 24 hours and 7 days.
- Reinforcement of 2% ZnO nanoparticle resulted in reduced surface roughness values compared to both the control and reinforced groups between the two main groups. Protemp 4 without nanoparticle integration demonstrated enhanced hardness compared to the reinforcement group on evaluation of group 1 and 2. Following a 7-day conditioning period, there was a significant overall increase in hardness values across all samples between group 1 and group 2.
- The inclusion of 2% ZnO nanoparticles resulted in a statistically significant reduction in values for surface roughness among the samples in group 1. Samples without nanoparticle incorporation within group 2 displayed a statistically significant increase in hardness values compared to reinforced groups.
- In conclusion, the addition of 2% and 4% ZnO nanoparticles effectively reduced surface roughness in provisional resins without substantially altering hardness parameters.

## **SUMMARY**

The study aimed at assessing the impact of Zinc Oxide nanoparticles incorporation on the surface roughness and hardness of provisional resins following conditioning. According to ADA specification number 27, samples were fabricated, measuring 15mm x 2mm, resulting in 40 samples per group. Zinc oxide nanoparticles were precisely weighed and integrated into the polymer-monomer/base-catalyst paste to create 2% and 4% nanoparticle groups. Surface roughness evaluation was carried out using a digital profilometer. The hardness was measured with a digital Micro Vickers hardness tester.

Statistical analysis using SPSS software version 20 was performed. To analyze underlying data descriptive statistics were used. An independent t-test compared the two main groups, while one-way ANOVA and Tukey's Post-Hoc test were employed for within the group comparisons.

Results indicated that incorporating ZnO nanoparticles reduced surface roughness and increased hardness significantly. Following a 7-day conditioning period, a statistically significant increase in values for hardness among the groups was observed. Consequently, it was concluded that the inclusion of 2% and 4% ZnO nanoparticles significantly enhanced surface roughness in provisional materials without significantly altering the hardness of the samples.

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ANNEXURE I

ETHICAL CLEARANCE

 **Research and Ethics Committee**  
**KLE VK INSTITUTE OF DENTAL SCIENCES**  
A Constituent Unit of KLE Academy of Higher Education & Research  
Accredited 'A' Grade by RAAC Placed in Category 'A' by MHRD (GoI)  
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**CERTIFICATE**

EC/NE/INST/2021/2435  
Research & Ethics Committee

*This is to Certify that the synopsis titled*

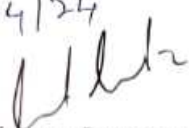
Comparative Evaluation of the Effect of Incorporating Zinc-Oxide Nanoparticles on the Surface Roughness and Hardness of Provisional Restorative Materials An- In vitro study Submitted by


Dr. REG. NO-IM0221001 \_\_\_\_\_ P. G. Student /

Staff, Guided by \_\_\_\_\_ -from Department of

Prosthodontics and Crown Bridge has been critically evaluated by committee members and granted ethical clearance to conduct the above mentioned study

Date : 3/4/24

  
**Member Secretary**  
Research and Ethical Committee  
KLEVK Institute of Dental Sciences  
Belagavi

  
**Chairman**  
Research and Ethical Committee  
KLEVK Institute of Dental Sciences  
Belagavi

ANNEXURE II  
AUTHENTICATION FORM



Mob.: 8452810712  
8800903073

**ULTRANANOTECH PVT. LTD.**  
Materials Beyond Imagination

B-205, Prime Blue Forest, Rajapallya, Hoodi, Bangalore - 560048  
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Certificate Of Analysis

Zinc Oxide (ZnO) Nano Powder 99.9% Purity

Test Item	Composition
Particle size	30-50
Surface area	120 m <sup>2</sup> /g
PbO	<=0.0005%
MnO	<=0.0005%
CuO	<=0.0005%

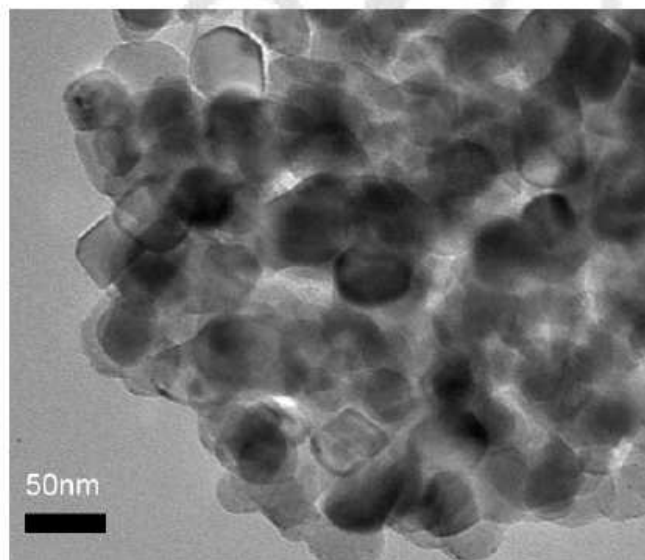


Fig : TEM image of Zinc oxide nanoparticle

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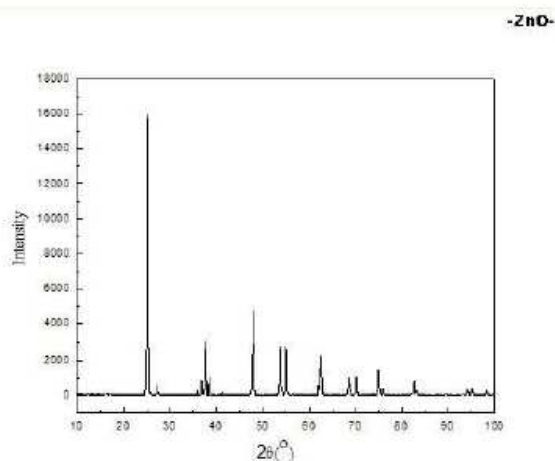


Fig : XRD of Zinc oxide nanoparticle

Conclusion of Test:  
THE PRODUCT IS UP TO THE ABOVE-MENTIONED STANDARD.

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