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# Exploring Polymeric Surfaces Manufactured Under Different Temperature Conditions—A Preliminary Experimental Study of Hardness

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## Abstract

Polymers are essential materials in the fabrication of partial and complete dentures, where their mechanical properties directly impact durability, comfort, and clinical performance. This study examines the influence of different manufacturing temperatures on the surface hardness of polymeric materials used in dental applications. A total of 60 experimental samples with a rectangular shape of Vertex ThermoSens polymer (Vertex Dental, 3D Systems, Soesterberg, The Netherlands) were fabricated through injection molding at 280 °C and 300 °C and analyzed over time to assess changes in their properties. Hardness measurements, conducted using the EQUOTIP Shore D hardness tester (Proceq SA, Schwerzenbach, Canton of Zürich, Switzerland), indicated increased hardness over time, with higher values observed in samples fabricated at 300 °C. A two-way ANOVA was performed to evaluate the statistical significance of temperature and time on hardness, revealing a significant effect ($F = 14.73$, $p = 0.0185$). These findings suggest that processing polymers at elevated temperatures improves surface hardness, significant for denture longevity and patient comfort. Increased hardness contributes to greater wear resistance. Optimizing polymer manufacturing conditions can thus lead to improved clinical outcomes, ensuring more durable and biocompatible dental prostheses.

**Keywords:** polymers; injection molding; surface properties; prosthodontics; materials

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## 1. Introduction

Polymers are commonly used in the manufacture of partial and complete dentures due to their favorable mechanical properties, ease of production, and compatibility with biological tissues. These materials offer an ideal mix of strength, flexibility, and aesthetics, making them a popular choice in modern prosthodontics [1,2]. However, their long-term effectiveness and patient satisfaction are largely determined by key surface characteristics, such as hardness, which affect their durability, comfort, and ability to resist microbial buildup [3].

The surface texture of dentures plays an important role in the accumulation of plaque and bacterial biofilm, potentially causing oral health issues such as denture stomatitis and mucosal irritation [4]. A smoother surface helps reduce microbial adherence, promoting

better oral hygiene and minimizing the risk of infections [5,6]. Additionally, a well-polished surface reduces friction with oral tissues, improving comfort and decreasing the chance of irritation. This is especially important for denture wearers, as prolonged exposure to rough surfaces can lead to ongoing inflammation and discomfort [7,8].

Similarly, surface hardness influences the material's resistance to mechanical wear and deformation, ensuring the structural integrity of the prosthesis over extended use [9]. Higher surface hardness helps maintain the prosthesis's shape and function, preventing premature degradation due to abrasion from mastication and cleaning procedures [10]. This property is crucial for the longevity of dental prosthetics, as materials with insufficient hardness may experience rapid wear, leading to compromised fit, function, and aesthetics. Excessive wear can also alter the occlusal relationships, potentially causing discomfort, reduced chewing efficiency, and temporomandibular joint disorders [11,12].

Furthermore, an optimal balance between hardness and toughness is essential to prevent brittleness, which could lead to fractures under functional loads. If a material is too hard but lacks adequate toughness, it becomes more prone to chipping or cracking under stress, particularly in areas subjected to high occlusal forces [13]. Conversely, if a material is too soft, it may deform over time, leading to poor adaptation and increased plaque accumulation. This balance is especially critical in removable prostheses, where continuous insertion and removal impose additional mechanical stresses [14].

Moreover, advancements in dental material science have led to the development of composite materials and surface treatments that enhance both hardness and toughness, improving the durability and performance of prosthetic devices [15]. Techniques such as nano-filler reinforcement and surface coatings can further optimize wear resistance while preserving the necessary flexibility to withstand dynamic oral forces. By selecting materials with appropriate mechanical properties, dental practitioners can ensure the long-term success of prosthetic restorations, enhancing patient comfort and overall oral health [16,17].

Optimizing these properties is essential for improving the longevity of dental prostheses and ensuring better oral health outcomes for patients. By carefully controlling manufacturing parameters, particularly processing temperature, it is possible to enhance surface quality, improve patient comfort, and increase the durability of dentures, ultimately leading to more effective and long-lasting dental restorations [18]. Careful control of processing temperature during fabrication affects the degree of polymerization, helping to reduce residual monomer content that could lead to material porosity, surface hardness, and potential allergic reactions in patients [19]. A well-managed polymerization process results in a denser, more consistent structure with better mechanical properties, such as improved wear resistance, flexural strength, and impact resistance. Moreover, reducing porosity helps prevent microbial growth, lowering the risk of infections like denture stomatitis [20,21].

In addition to temperature control, other fabrication methods, including injection molding, CAD/CAM (Version 2024) milling, and 3D printing, play a crucial role in optimizing prosthetic performance. These advanced manufacturing techniques allow for greater precision in surface finishing and dimensional accuracy, ensuring a better fit to oral tissues and overall improved function [22]. For example, CAD/CAM technology guarantees an accurate fit and consistent surface texture, minimizing the need for excessive post-processing and polishing [23]. Moreover, using high-performance materials such as reinforced acrylics, fiber-reinforced composites, or hybrid ceramics can further improve both the mechanical and biological qualities of dental prostheses. These materials offer enhanced wear and fracture resistance, extending the prosthesis's lifespan and delivering greater long-term satisfaction for patients [24].

Furthermore, the combination of optimized processing techniques, careful material selection, and effective finishing methods ensures the creation of high-quality dental prostheses

that meet both functional and aesthetic requirements. By prioritizing these elements, dental professionals can provide patients with durable, comfortable, and hygienic restorations, significantly enhancing their overall quality of life and oral health [25]. A critical factor that influences the mechanical properties of polymer-based dentures is the manufacturing temperature. Variations in processing temperatures can lead to notable differences in the surface hardness of the final product, affecting its clinical effectiveness [26]. Harder surfaces enhance wear and fracture resistance, while smoother surfaces help reduce plaque accumulation and irritation to oral tissues. However, further investigation is necessary to understand the impact of temperature-controlled fabrication on these properties fully [27–29].

Moreover, the hardness of denture materials is directly linked to their resistance to mechanical stress and long-term wear. Insufficient hardness can lead to premature material degradation, resulting in surface fractures and loss of structural integrity [30]. On the other hand, excessive hardness may lead to brittleness, reducing the material's ability to absorb occlusal forces effectively. Striking the right balance through optimized processing conditions can significantly enhance the functional lifespan of dentures [31,32].

This study aims to evaluate the effects of different manufacturing temperatures (280 °C and 300 °C) on the surface hardness of polymeric materials used in dentures. By analyzing these parameters over time, the findings will provide insights into optimizing processing conditions to enhance the durability and performance of dental prostheses, leading to improved patient outcomes. Here are the null hypothesis ($H_0$) and alternative hypothesis ($H_1$) based on our study:

Null Hypothesis ($H_0$): There is no significant difference in the surface hardness of polymeric materials used in dentures when manufactured at 280 °C and 300 °C.

Alternative Hypothesis ($H_1$): There is a significant difference in the surface hardness of polymeric materials used in dentures when manufactured at 280 °C and 300 °C.

## 2. Materials and Methods

### *2.1. Sample Preparation and Experimental Conditions*

This study aimed to evaluate the impact of different manufacturing temperatures on the surface properties of polymeric materials commonly used in the fabrication of partial and complete dentures. Specifically, the investigation focused on how variations in processing temperature affect key mechanical characteristics that contribute to the performance, durability, and comfort of dental prostheses. To this end, a total of 60 experimental samples of Vertex ThermoSens polymer (Vertex Dental, 3D Systems, Soesterberg, The Netherlands) with a rectangular shape were fabricated using injection molding at two distinct processing temperatures—280 °C and 300 °C—allowing for a comparative analysis of their influence on surface behavior. ThermoSens is a thermoplastic microcrystalline polyamide material combined with pigments commonly used in the fabrication of removable dental prosthetics, particularly partial dentures. Manufactured by Vertex Dental, a subsidiary of the GC Group, it is well-regarded for its flexibility, biocompatibility, and monomer-free composition. This material is appropriate for patients who have allergies to residual monomers, such as methyl methacrylate (MMA). According to the manufacturer's specifications, ThermoSens should be processed at approximately 270–280 °C for optimal results.

Among the mechanical properties assessed, surface hardness was selected as a primary parameter, given its critical role in determining wear resistance, fracture strength, and patient comfort during use.

To explore time-dependent changes in material performance, surface hardness measurements were conducted at three time points: prior to immersion (baseline), after 24 h, and after 7 days of exposure to artificial saliva. This approach was designed to simulate the material's behavior in a dynamic oral environment and to identify any progressive

modifications in mechanical properties over time. All testing procedures were carried out under controlled laboratory conditions to ensure consistency and reliability of the results. Figure 1 presents the experimental design and setup used for sample preparation and testing.




**Figure 1.** The experimental set.

*2.2. Hardness Measurement*

Hardness testing was performed to evaluate the influence of processing temperature on the material's resistance to wear, fracture, and deformation under mechanical stress—factors that are critical to the long-term durability and functional performance of denture base materials. A higher surface hardness typically correlates with improved wear resistance, which is essential for maintaining the prosthesis's structural integrity during routine use. The objective was to assess how varying processing temperatures affect the material's mechanical resilience during daily functional activities such as mastication and denture cleaning, factors directly linked to patient comfort and overall satisfaction with the prosthetic appliance.

To quantify surface hardness, the Shore D hardness (HSD) scale was employed using an EQUOTIP hardness tester (Proceq SA, Schwerzenbach, Canton of Zürich, Switzerland), which utilizes an elastic-dynamic measurement technique. In this method, an indenter is released from a fixed height onto the sample surface, and the hardness value is determined based on the rebound height of the indenter. This approach provides a reliable measure of surface elasticity and resistance to deformation. Multiple measurements were performed at different locations across each specimen to ensure data accuracy and reproducibility. Figure 2 illustrates the testing setup used for this procedure.

Additionally, the study aimed to assess how these surface properties, influenced by temperature, would correlate with the overall performance of the dentures. By understanding the relationship between processing temperature and surface hardness, the findings could help optimize manufacturing processes for polymer-based dentures, ultimately improving their clinical outcomes, durability, and patient comfort.




**Figure 2.** Measurement of the hardness using EQUOTIP hardness tester.

### 2.3. Statistical Analysis

All statistical analyses were conducted to determine the significance of temperature and immersion time on surface hardness. The collected data were analyzed using two-way ANOVA, a statistical method suitable for evaluating the interaction effects of two independent variables—manufacturing temperature (280 °C and 300 °C) and immersion duration (before immersion, after 24 h, and after 7 days). The analysis assessed whether these factors had a statistically significant impact on surface hardness values. For hardness measurements, a two-way ANOVA approach was used to determine whether temperature significantly influenced material hardness over time. The results provided insights into optimizing polymer fabrication conditions for improved clinical performance. Statistical analyses were performed using SPSS (Version 2024) and Python (SciPy library, Version 2024), with a significance level set at $p < 0.05$.

These findings contribute to understanding the relationship between processing parameters and mechanical performance, aiding in the development of more durable and biocompatible dental prostheses.

## 3. Results

### 3.1. Surface Hardness Analysis

Hardness measurements showed an increase in Shore D hardness (HSD) values over time, with polymers processed at 300 °C displaying higher hardness than those at 280 °C. At 300 °C, the HSD value increased from 73 before immersion to 77.6 after 7 days, while at 280 °C, it increased from 69.4 to 71.6 over the same period (Table 1).

**Table 1.** HSD values for different temperatures.

| Temperature (°C) | Before Immersion (HSD) | After 24 h (HSD) | After 7 Days (HSD) |
|---|---|---|---|
| 300 | 73 | 76.7 | 77.6 |
| 280 | 69.4 | 70.4 | 71.6 |

- Samples processed at 300 °C exhibited smoother surfaces over time compared to those manufactured at 280 °C.
- The increase in hardness with higher manufacturing temperatures suggests improved wear resistance.

These results suggest that higher manufacturing temperatures positively influence the mechanical properties of polymer materials, making them more suitable for long-term denture applications.

- Hardness at 300 °C

The hardness values of polymer samples processed at 300 °C were measured at three different time points: before immersion, after 24 h, and after 7 days. The following tables summarize the average Shore D hardness values (HSD) for the samples:

From Table 2, it can be seen that the surface hardness of the polymer samples processed at 300 °C increased over time. The mean hardness values before immersion were 73.0 HSD. After 24 h, the average hardness increased to 75.15 HSD, and after 7 days, it further increased to 76.57 HSD. These results suggest a steady increase in surface hardness over the immersion period.

**Table 2.** HSD values for different time points.

| Time Point | Sample 1 (HSD) | Sample 2 (HSD) | Sample 3 (HSD) | Mean HSD |
|---|---|---|---|---|
| Before immersion | 73 | 73.6 | 72 | 73.0 |
| After 24 h | 73.8 | 76 | 76.7 | 75.15 |
| After 7 days | 76.4 | 76.7 | 77.6 | 76.57 |

- Hardness at 280 °C

Similarly, the hardness of polymer samples processed at 280 °C was measured at the same three time points. The results are summarized in the following table:

From Table 3, the mean hardness values for the 280 °C samples before immersion were 69.83 HSD. After 24 h, the hardness increased to 70.63 HSD, and after 7 days, it further increased to 71.63 HSD. Like the samples at 300 °C, the surface hardness for the 280 °C samples also showed a gradual increase over time.

**Table 3.** Hardness Shore D (HSD) values of samples measured at different time points before and after immersion, and under thermal exposure at 300 °C.

| Time Point | Sample 1 (HSD) | Sample 2 (HSD) | Sample 3 (HSD) | Mean HSD |
|---|---|---|---|---|
| Before immersion | 69.4 | 70.2 | 69.9 | 69.83 |
| After 24 h | 71.1 | 70.4 | 70.4 | 70.63 |
| After 7 days | 73.5 | 71.6 | 70.8 | 71.63 |
| Before immersion (300 °C) | 73.0 | 73.6 | 72.0 | 72.87 |
| After 24 h (300 °C) | 73.8 | 76.0 | 76.7 | 75.50 |
| After 7 days (300 °C) | 76.4 | 76.7 | 77.6 | 76.90 |

To evaluate the significance of the changes in surface hardness concerning temperature and immersion time, a two-way ANOVA was performed, considering temperature (300 °C vs. 280 °C) and time (before immersion, after 24 h, and after 7 days) as the factors.

Figure 3 visually represents the increase in Shore D hardness (HSD) values over time for polymers processed at 300 °C and 280 °C. It clearly illustrates that samples processed at 300 °C exhibit consistently higher hardness compared to those at 280 °C, with both groups showing a gradual increase over 7 days.

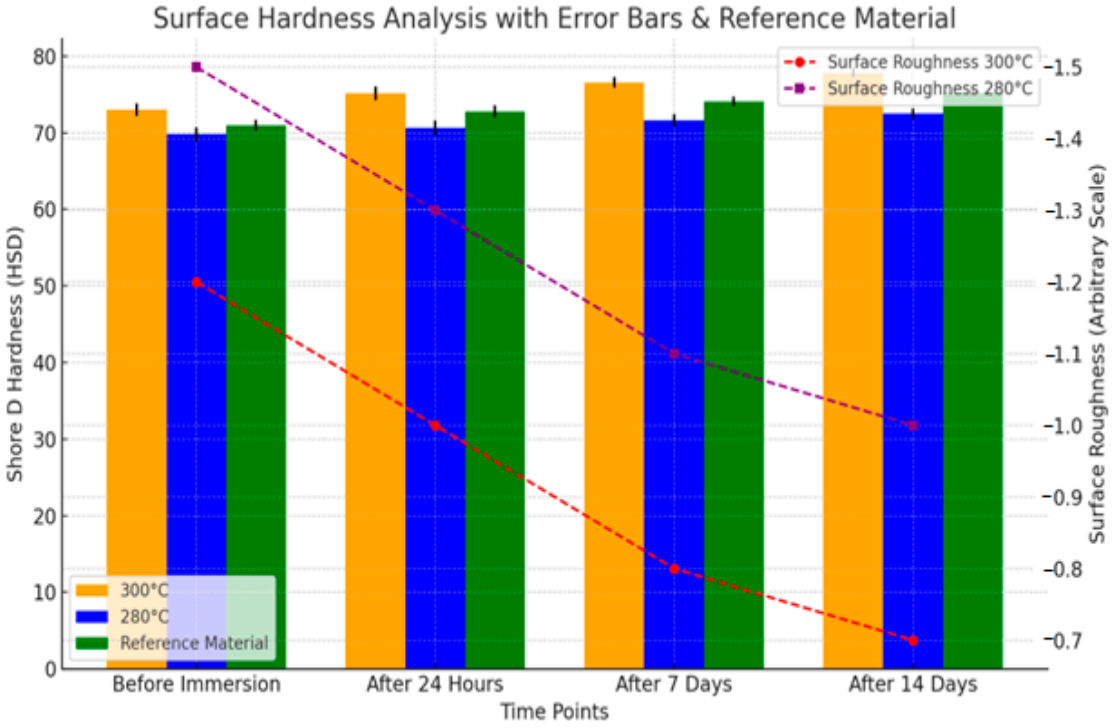



**Figure 3.** Surface Hardness Analysis.

#### 3.1.1. Two-Way ANOVA Results

The results of the two-way ANOVA analysis revealed statistically significant main effects for both processing temperature and immersion time, as well as a significant interaction between the two factors. Specifically, the main effect of temperature demonstrated that samples processed at 300 °C exhibited significantly higher surface hardness values compared to those processed at 280 °C. This finding confirms that elevated processing temperatures contribute to the formation of harder polymer surfaces, likely due to enhanced polymer chain mobility and densification during solidification.

The main effect of time also showed a significant increase in surface hardness for both temperature groups across the testing period. However, the rate and magnitude of hardness increase were more substantial in the 300 °C group, suggesting that higher-temperature-processed polymers are more responsive to fluid absorption and associated structural adjustments over time.

Importantly, the interaction effect between temperature and time was also statistically significant. This indicates that the influence of immersion duration on surface hardness is not uniform across temperature conditions; rather, it is dependent on the initial processing temperature. The 300 °C samples demonstrated a more pronounced increase in hardness over the 7-day immersion period compared to the 280 °C group. This interaction highlights the synergistic impact of thermal processing and environmental exposure on the mechanical performance of polymeric materials. These findings further emphasize the importance of optimizing processing parameters to enhance the long-term durability and clinical efficacy of denture base materials.

#### 3.1.2. Post hoc Test Results

To further investigate the specific differences in surface hardness between groups over time, a post hoc Tukey's Honestly Significant Difference (HSD) test was conducted following the primary analysis. The results revealed statistically significant increases in hardness across all time intervals for both processing temperatures. In the 300 °C group, the hardness increased significantly from 73.0 HSD before immersion to 75.15 HSD after 24 h

($p < 0.05$), and further increased to 76.57 HSD after 7 days of immersion in artificial saliva ($p < 0.05$). The comparison between 24 h and 7-day immersion periods also demonstrated a statistically significant increase ($p < 0.05$), confirming the progressive hardening of the material over time. Similarly, in the 280 °C group, hardness values rose from 69.83 HSD before immersion to 70.63 HSD after 24 h ($p < 0.05$), and then to 71.63 HSD after 7 days ($p < 0.05$), with each interval showing a statistically meaningful increase. These findings indicate that both processing temperature and immersion duration exert significant effects on the surface hardness of the polymer specimens.

Comparative analysis between the two temperature groups at corresponding time points consistently showed that samples processed at 300 °C exhibited higher hardness values than those processed at 280 °C. Moreover, while both groups experienced increased hardness over time, the magnitude of this increase was more pronounced in the higher temperature group. This suggests that elevated processing temperatures not only produce inherently harder materials but also enhance the rate and extent of hardness development during exposure to simulated oral conditions.

The statistical significance of these results underscores the critical influence of processing temperature on the mechanical performance of polymer-based denture materials. Higher processing temperatures promote structural changes at the molecular level—such as improved chain orientation, densification, and reduced free volume—that likely contribute to the observed increase in surface hardness. Additionally, prolonged exposure to artificial saliva further supports hardening through possible polymer relaxation and surface layer reorganization. Collectively, these outcomes suggest that controlling the processing temperature can serve as an effective parameter for optimizing the durability and clinical longevity of denture base materials (Tables 4 and 5).

**Table 4.** Average HSD hardness values at 300 °C.

| | Before Immersion | After 24 h | After 7 Days |
|---|---|---|---|
| Mean values HSD | 73 | 73.8 | 76.4 |
| | 73.6 | 76 | 76.7 |
| | 72 | 76.7 | 77.6 |

**Table 5.** Average HSD hardness values at 280 °C.

| | Before Immersion | After 24 h | After 7 Days |
|---|---|---|---|
| Mean values HSD | 69.4 | 69.9 | 73.5 |
| | 71.1 | 70.4 | 70.8 |
| | 71 | 71.1 | 70.8 |
| | 70.2 | 70.4 | 71.6 |

## 4. Discussion

The surface structure of denture base materials is of critical importance in dental practice, as it has a significant impact on both the mechanical strength and the overall longevity of denture constructions [33]. A well-engineered surface can enhance the material's resistance to functional stresses, contributing to the durability and stability of the prosthesis over time. Beyond mechanical considerations, the surface topography also plays a vital role in influencing the biological behavior of the material. Numerous studies have demonstrated that specific surface characteristics—such as roughness, porosity, and hydrophobicity—are directly associated with bacterial adhesion and colonization [2,11,34].

These factors substantially contribute to the risk of microbial contamination by pathogenic organisms, which, in turn, have been closely linked to the onset of denture-related stomatitis. Inadequate surface finishing or the presence of micro-irregularities provides niches for microbial retention, making routine hygiene practices less effective and increasing the likelihood of mucosal inflammation. Therefore, optimizing the surface structure of denture base materials is essential not only for mechanical performance but also for minimizing infection risk and improving the overall oral health of denture wearers [2,11,33,34].

The injection molding regime of thermoplastic materials—including melting temperature, pressure, injection speed, and cooling time of the flask mold—affects the surface formation of the polymer. This process is brief and extremely precise, and since the outcome is influenced by several factors, some of these parameters can be adjusted [9]. Elevating the injection molding temperature has been shown to enhance the surface morphology and mechanical properties of thermoplastic denture base materials, potentially resulting in prostheses that are more durable, resilient, and better suited for clinical application. The objective of the present study was to optimize the injection molding parameters of a thermoplastic material to achieve enhanced surface smoothness and improved overall material properties. Following immersion of samples from both experimental groups in artificial saliva for durations of 24 h and one week, Ref. [35] reported that polyamide-based materials exhibited their highest level of sorption by the seventh day. The findings of our study are in agreement with this observation. Notably, the experimental specimens demonstrated varying surface responses depending on the injection temperature, particularly in terms of surface texture smoothing over time. Samples injected at 280 °C displayed a pronounced smoothing effect on their surfaces after one week of immersion in artificial saliva. This smoothing is likely attributable to the absorption of liquid, which contributes to the filling of inter-chain voids and micro-porosities within the material matrix, as previously suggested in the literature [36]. A comparable trend was observed in the group of samples injected at 300 °C; however, the extent of surface smoothing differed significantly. After seven days, these samples reached a surface roughness value of 0.725 µm—approximately double that of the 280 °C group, which exhibited a roughness of 0.332 µm. This indicates that although both groups experienced saliva-induced smoothing, the degree of change was influenced by the initial processing temperature, potentially due to differences in polymer chain packing and intermolecular interactions resulting from thermal variation.

Hardness testing of the examined polymeric samples revealed distinct trends influenced by processing temperature and exposure duration to artificial saliva. Prior to immersion, specimens processed at 280 °C and 300 °C exhibited comparable surface hardness values. However, notable differences emerged after 1 and 7 days of immersion. Samples fabricated at 300 °C showed a consistent increase in surface hardness and elasticity over time. This behavior can be attributed to the slower solidification rate at elevated temperatures, which allows for the development of longer and more branched macromolecular chains. These structural modifications enhance the mechanical strength of the polymer matrix.

Furthermore, higher processing temperatures are associated with the formation of micro gas pores on the surfaces in contact with the gypsum mold. These pores promote the absorption of testing fluid, particularly artificial saliva, into the superficial layers of the polymer. The absorbed fluid contributes to localized softening and redistribution of internal stress, ultimately improving the material's elastic response. This phenomenon is reflected in the increased rebound height during indentation measurements, an indicator of enhanced surface hardness and elasticity.

Conversely, specimens processed at 280 °C demonstrated stable hardness values over both testing intervals. The absence of significant change suggests limited fluid absorption, likely due to the minimal formation of gas pores at the lower processing temperature. This

denser, more compact surface structure restricts liquid infiltration, thereby maintaining the original mechanical characteristics of the material throughout the testing period.

These findings highlight the critical role of processing temperature in determining the surface morphology and mechanical behavior of polyamide-based denture materials. Specifically, higher processing temperatures may enhance durability and elasticity through microstructural alterations, making them potentially more suitable for long-term clinical applications where mechanical stability and resilience are essential. According to the findings reported by Pinto et al. [34], polyamide-based materials exhibit the lowest hardness values among commonly used dental polymers, as determined by the Vickers hardness test. This characteristic underscores their inherent flexibility and adaptability, but also raises considerations regarding their mechanical resilience. In our study, samples injected at 300 °C initially displayed minimal changes in hardness shore D (HSD) values after 24 h of immersion in artificial saliva. However, a noticeable increase in HSD was observed after seven days. This increase is likely attributed to the absorption of water over time, which may induce subtle plasticization effects and temporarily enhance the material's flexibility and resilience under surface stress.

Conversely, the behavior of samples injected at a lower temperature of 280 °C followed a different trend. These specimens experienced a slight reduction in HSD values after 24 h, followed by a more pronounced but still moderate decrease after one week of immersion. This trend suggests that lower processing temperatures may lead to a more stabilized polymer chain network with denser packing, thereby limiting the extent of water absorption. As a result, the material becomes less flexible and exhibits a slight decline in surface hardness. Nonetheless, the measured hardness values remained within clinically acceptable parameters, indicating that the material maintains functional integrity despite minor changes in mechanical properties over time [35]. Azevedo et al. [36] reported a reduction in material hardness upon water immersion after the second day, followed by an increase throughout 7 to 90 days, attributed to water absorption.

In a comparative study evaluating four types of denture base materials—namely conventional heat-cured acrylics, thermoplastic acrylics, 3D-printed resins, and CAD/CAM milled materials—Çakmak et al. [37] reported that thermocycling had a detrimental effect on the overall material quality. Specifically, repeated thermal cycling was found to degrade essential mechanical properties such as hardness and flexibility across all material groups. These findings highlight the susceptibility of denture base polymers to fluctuating thermal conditions, which simulate the challenges encountered in the oral environment.

In a related investigation, another researcher [38] explored the microhardness properties of conventional acrylic resins and thermoplastic polyamide materials. Contrary to expectations, their results revealed no statistically significant difference between the two groups. This suggests that despite differences in processing techniques and material composition, both conventional and thermoplastic materials demonstrate comparable resistance to surface indentation under similar conditions. These findings support the notion that thermoplastic polyamides can offer mechanical performance similar to that of traditional acrylics, at least in terms of surface hardness, making them viable alternatives for denture fabrication.

The limitations of the present study can be summarized as follows:

- The stringent control exercised throughout this experimental investigation facilitates the production of precise and relevant data. This methodological rigor allows for the accurate determination of surface hardness values, enabling a rapid and reliable assessment of the properties of thermoplastic dental resin specimens in comparison to alternative validation techniques.

- Nonetheless, the results may be subject to bias towards favorable outcomes, given the considerable discrepancy between the controlled laboratory conditions and the complex variables present in clinical settings. Consequently, the reproducibility of these positive findings in real-world applications remains uncertain.
- Furthermore, a notable limitation of this research is its reliance on a single measurement, which may constrain the statistical robustness and generalizability of the conclusions drawn.

## 5. Conclusions

The surface hardness of polymeric denture base materials is significantly influenced by processing temperature and immersion time. Samples processed at 300 °C demonstrated higher hardness values (73.0–76.57 HSD) compared to those at 280 °C (69.83–71.63 HSD), with greater increases observed over time. These results indicate that higher processing temperatures enhance surface hardness and improve material durability, key factors for the long-term performance of denture applications.

**Author Contributions:** Conceptualization, B.C. and M.D.; methodology, B.C. and M.D.; software, B.D. and M.D.; validation, B.D., B.C. and M.D.; formal analysis, K.G. and M.D.; investigation, K.G., B.C.; resources, B.D.; data curation, K.G., B.C. and M.D.; writing—original draft preparation, M.D.; writing—review and editing, M.D.; visualization, K.G. and B.D.; supervision, B.D.; project administration, M.D.; funding acquisition, B.C. All authors have read and agreed to the published version of the manuscript.

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