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Research Article

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Effect of Artificial Saliva Aging on The Surface Properties of CAD/CAM and Heat-Compressed Molded PMMA Dentures

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ABSTRACT

This study simulates the oral environment by immersing the denture specimens in artificial saliva aging of the surface properties - micro-hardness and surface roughness - of Poly Methyl Methacrylate (PMMA) denture bases fabricated using Computer-Aided Design and Computer-Aided Manufacturing (CAD/CAM) and conventional compressed molded (CCM).

Methodology: CAD/CAM and CCM PMMA denture bases were fabricated and immersed in artificial saliva at 37ºC for a week. Surface micro-hardness and roughness of the samples were subsequently measured. The data was analyzed statistically to draw comparisons between the two fabrication techniques.

The CAD/CAM PMMA denture bases exhibited significantly higher surface micro-hardness (mean: 25.26) than the CCM denture bases (mean: 18.76), suggesting enhanced abrasion resistance. Similarly, the surface roughness of CAD/CAM PMMA was found to be within the clinically acceptable value (0.13), and significantly less than the CCM PMMA (1.61), indicating better biofilm resistance.

Conclusion: Under one-week artificial-saliva aging at 37 ºC, CAD/CAM-milled PMMA denture base specimens showed higher surface micro-hardness and lower surface roughness than PMMA, indicating better maintenance of surface properties under the tested *in vitro* conditions.

***Keywords**- Computer-Aided Design and Computer-Aided Manufacturing (CAD/CAM); Artificial Saliva Aging; Poly Methyl Methacrylate (PMMA); Surface Micro-Hardness; Surface Roughness.*

INTRODUCTION

Complete tooth loss, or edentulism, significantly affects the elderly, disrupting aesthetic, phonetic, and functional aspects of the oro-facial region and reducing quality of life.[1] Complete dentures, acrylic-based removable prostheses that replace the entire dentition and associated structures of the maxilla and mandible, serve as an essential treatment solution for edentulism, thereby facilitating the resumption of normal life.[2]

Since Dr. Walter Wright's pioneering clinical evaluation of methyl methacrylate resin in 1936, polymethyl methacrylate (PMMA) resin has remained the preferred material for complete denture fabrication.[3] Acting as an intermediary between teeth and the jaw, the denture base transfers masticatory forces to the underlying tissues. PMMA's widespread use stems from its favourable properties, including excellent aesthetics, low water sorption and solubility, relative lack of toxicity, repair ability, and simple processing techniques. Nevertheless, the question remains whether the strength and design limitations of such prostheses meet the functional demands of the oral cavity.[4]

The CAD/CAM milling technique for the fabrication of complete removable dental prostheses (CRDPs) involves a subtractive process, where a prepolymerized PMMA blank puck is milled into the desired denture form. This technique contrasts the traditional method where uncured resin is molded under pressure and then polymerized. While the CCM heat polymerization of CRDPs has been a reliable method for decades, it has its limitations, often leading to heat polymerization errors like denture porosity, crazing, and denture warpage, including volumetric and linear shrinkages.[5,6]

Surface roughness (SR) is a crucial property of acrylic resin. A rough surface may jeopardize tissue health due to microorganism adhesion and growth.[7] Therefore, smooth and highly polished denture surfaces are paramount for aesthetic outcomes, good oral health, low plaque retention, prevention of oral diseases, patient comfort, and denture durability.[8,9] Additionally, surface hardness (SH), defined as a material's resistance to indentation or penetration, is an integral factor. A correlation has been observed between a material's mechanical properties and its surface hardness.[8] For instance, the susceptibility of

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acrylic-polymer to surface deterioration makes it prone to fracture, increases the risk of plaque and microorganism adhesion, thereby endangering the denture base's lifespan.[9] Continuous exposure of denture base resins to saliva, storage solutions, or aqueous cleansers results in the gradual absorption of water or saliva.[10] Despite studies addressing storage solutions and temperature variations, limited knowledge exists about how evolving salivary pH levels specifically affect denture base resins.[11]

Given these considerations, this study aimed to provide an effect of artificial saliva aging at a constant temperature of 37ºC for one week, of surface micro-hardness and surface roughness for PMMA material manufactured via two different routes - CAD/CAM and CCM heat cure resin techniques.

MATERIALS AND METHODS

This investigation employed PMMA denture base resin materials manufactured by two distinct companies. The CCM variety of material is in resin form, composed of polymer and monomer (powder and liquid, courtesy of Ivoclar Vivadent). Conversely, the CAD/ CAM variant is constituted by PMMA discs, supplied by KINGCHR, China, with dimensions of 98mm diameter and 25mm height. These discs were prepared for the CAD process in the DC5 milling system from Dental Concept Systems GmbH, Ulm, Germany. The materials and their contents are shown in the design diagram (Figure 1).

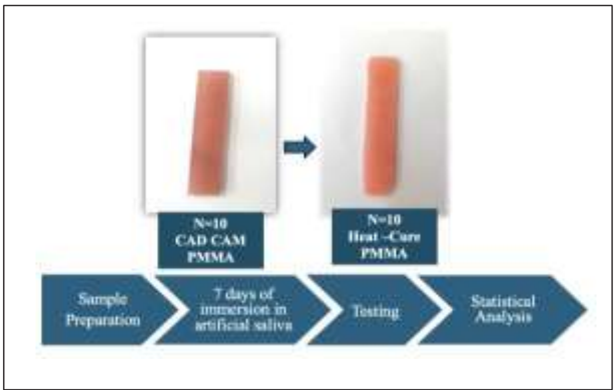

Figure 1: Study Design (PMMA: polymethyl methacrylate, Computer-Aided Design and Computer-Aided Manufacturing (CAD/CAM)).

Sample Preparation both types of PMMA materials were processed in accordance with the manufacturer's directions. A total of twenty samples were created, divided evenly between the two manufacturing techniques: CCM and CAD/CAM. Each test was conducted on five samples. Following a week-long immersion in artificial saliva at 37ºC, the surface properties of the samples were assessed using micro-hardness and roughness tests. All fabricated samples were dimensioned at (65 x 10 x 3) mm guidelines of ISO 20795-1 for denture base polymers.[12]

In the CCM process, samples were crafted using the lost wax technique. Modeling wax strips, each measuring (65 x 10 x 3) mm, were cut and checked for conformity to the required measurements. Simultaneously, the flask was prepared using improved gypsum in accordance with the manufacturer's instructions. Following the removal of the wax and ensuring the flask had cooled to room temperature, Ivoclar Vivadent resin was prepared in a ratio of 21g polymer to 10 ml monomer. The mixture was left to rest until it reached a dough-like consistency. Subsequently, the resin was compressed into the mold using a pneumatic Flask press (Coe-Bilt) under 6,000 psi pressure. The flask was then subjected to boiling water for half an hour, in line with the manufacturer's instructions. After cooling and a brief immersion in cold water, the resin samples were retrieved from the flask. All samples were meticulously hand-polished, finished, and measured for accuracy. They were then conditioned in distilled water at room temperature for a week.

For the CAD/CAM technique, the resin discs (KINGCHR, China) were secured within the DC5 milling system (Vhf K5, India). A strip of (65 × 10 × 3) mm dimensions was cut using a lathing machine. Following this, all specimens underwent a polishing process involving 400 grit silicon carbide abrasive papers under running water. Fine finishing and polishing were carried out with a micromotor, mandrel, and pumice slurry. After the polishing process, the dimensions of all specimens were verified with a digital caliper.

Artificial saliva was freshly synthesized following the formula proposed by Fusayama et al.[13] The pH was regulated between 5.3 and 5.5 and stored in separate glass containers with plastic lids.

Immersion Protocol to emulate daily patient denture use, all samples were stored in artificial saliva at 37ºC for 7 days. All samples were ensured to be fully immersed from all sides in glass bottles. Subsequent micro-hardness and surface roughness tests were performed post immersion.

The micro-Vickers hardness test was a crucial component of this study, providing insight into the resistance of the PMMA denture material to potential fracture. For this, we utilized the Micro-Vickers Hardness Number (HV) determination method.

Each group of the PMMA material was subjected to this test post immersion in artificial saliva at 37ºC for one week. For this test, samples were prepared in dimensions of (65x10x3) mm, in compliance with the manufacturer's instructions and recommendations.

The hardness measurement was performed using a digital micro-Vickers hardness tester (MVT-1000A Testing Instrument Co Ltd. China). In the procedure, the tested sample was mounted on the horizontal stage of the tester. Subsequently, the indenter was gently lowered onto the sample under a load of 300 g, sustained for 10 seconds. Data from five PMMA samples of each group (CCM, CAD) were collected. The mean hardness value was then calculated and subjected to appropriate statistical analysis (Figure 2).

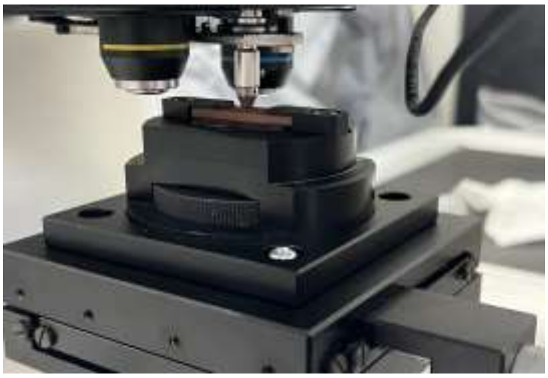

Figure 2: Micro-hardness Test

Surface roughness was evaluated using a Roughness Tester (PCE-RT 1200 Testing Instrument Co Ltd. Germany). The Stylus, as a part of the drive unit, was moved mechanically across the surface of the specimen, rising and falling over the surface irregularities. This movement was converted into a corresponding electrical signal. A high cut-off value was chosen to measure all micro- and macro-irregularities. For each specimen, three surface roughness measurements were taken, and the mean average Ra values were used for statistical analysis. Five Ra readings from various areas on each polished surface were obtained and averaged. The data collected was subsequently statistically analyzed shown (Figure 3).

Figure 3: Surface Roughness Test

Given the nature of this study, parametric tests such as t-test were employed. The design of the study was oriented to understand the impact of one independent variable (manufacturing technique) on the selected dependent variables (micro-hardness and surface roughness). An independent sample t-test was carried out to determine if there were significant differences in the means of the two groups for the variable of interest.

RESULTS

The micro-hardness of the PMMA samples was assessed and the mean value for the CAD/CAM samples was 25.26, while the mean for the CCM PMMA samples was 18.76. The standard deviation for the CAD/CAM samples was 2.493 and for the CCM PMMA samples it was 1.212. The number of samples in each condition was five, as illustrated in (Table 1; Figure 4) provides further clarification on the differences in micro-hardness between the two groups.

Table 1: Mean and Standard Deviations of Micro-hardness (HV) at *P* = 0.000.

Material samples	Mean	SD
CAD\CAM	25.26	2.493
CCM	18.76	1.212

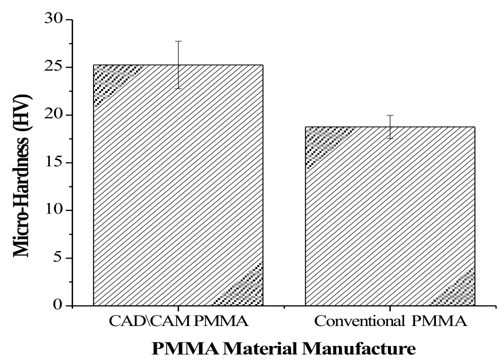

Figure 4: Comparison of Micro-hardness (HV) of the Samples

The mean surface roughness for the CAD/CAM samples was 0.13, and the mean for the CCM PMMA samples was 1.61. The standard deviation for CAD/CAM samples was 0.014 and for the CCM PMMA samples, it was 0.592. The number of samples in each condition was five, as detailed in (Table 2; Figure 5) provides further clarification on the differences in surface roughness between the two groups.

Table 2: Mean and Standard Deviations of Surface Roughness (µm) at *P* = 0.004.

Material samples	Mean	SD
CAD\CAM	0.13	0.014
CCM	1.61	0.592

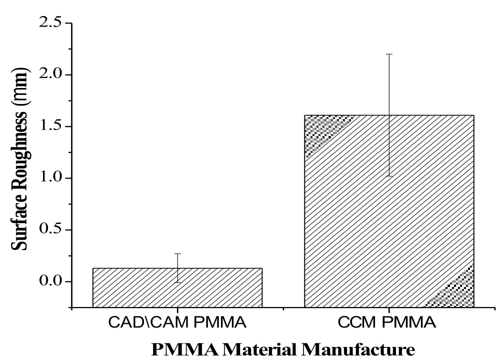

Figure 5: Comparison of Surface Roughness (µm) of the Samples

DISCUSSION

Hardness, an essential property of materials, is an indicator of the resistance to plastic deformation, often defined as permanent penetration or indentation caused by abrasion forces. Hardness can reflect the robustness and durability of the material against scratching or wearing.[14-15] It is particularly important in the context of dental materials, as the day-to-day use of dental prostheses often involves exposure to abrasive forces from factors such as denture cleaners, temperature changes, tooth brushing, and toothpaste abrasion. Furthermore, the denture base hardness can also be impacted by different polymerization systems affecting the surface properties of denture resins.

In this study, we found a higher mean micro-hardness for PMMA bases manufactured using the CAD/CAM technique (25.26) compared to the CCM PMMA bases (18.76). This statistically significant difference ($P < 0.000$) implies that CAD/CAM PMMA bases exhibit higher abrasion resistance than their CCM counterparts. The elevated micro-hardness is advantageous as it significantly impacts the longevity, durability, and fracture resistance of a denture, potentially leading to better clinical outcomes and patient comfort.[16-17]

This observation aligns with our understanding of the CAD/CAM technique, which has the potential to produce denture bases with superior hardness compared to the CCM method. Our findings mirror those of Al-Dwairi et al.[15] and Moslehifard et al.[17] where CAD/CAM PMMA groups demonstrated significantly higher surface hardness compared to the CCM group. The enhanced surface properties of the CAD/CAM groups can likely be attributed to the distinctive processing method employed for CAD/CAM PMMA billets, where high temperatures and pressure values are applied during polymerization.[18] This unique approach results in a significant superiority in surface wettability, surface roughness, and surface hardness of the CAD/CAM PMMA.[14]

Moving on to the surface roughness, another key property that can significantly impact the performance of dental prostheses, it contributes to bacterial colonization; the initial adhesion of microorganisms to a surface is a prerequisite for its colonization.[19-21] Conceptually, surface roughness is a reflection of small irregularities and inconsistencies present on surfaces, which can influence the wettability, bonding quality, and brightness of the denture.[22] Rougher surfaces tend to induce halitosis, are prone to discoloration, and potentially reduce patient comfort.[18,23] They have also been implicated as one of the contributing factors in denture-induced stomatitis.[24] Therefore, for optimal dental hygiene, dental prostheses should strive to achieve smooth surfaces to minimize the retention of plaque and microorganisms.[18-24]

Literature suggests that to effectively reduce the accumulation and colonization of microorganisms, the surface roughness of dental prostheses should ideally not exceed a threshold of 0.2 µm.[18,24-25] Above this threshold, an increased likelihood of plaque accumulation exists. However, the current study presents encouraging results, showing CAD/CAM PMMA within the acceptable range of surface roughness (less than 0.2 µm). A comparison between the two techniques revealed that the CAD/CAM PMMA (0.13) had less surface roughness than the CCM PMMA (1.61), although the difference was not statistically significant ($P < 0.004$). These findings echo the results of Al-Dwairi et al.[25] and a study by Sara et al.[27] highlighting the promising surface properties of CAD/CAM PMMA groups compared to the CCM heat-polymerized groups. Therefore, we can anticipate that CAD/CAM dentures would offer increased durability and longevity, improving the overall patient experience.

However, it is also necessary to note the role of factors such as the inherent characteristics of the denture base materials, the polishing methods employed, and the operator's manual skills. These variables can significantly influence the surface roughness of the final product.[14] Additionally, research has shown that surface roughness, in conjunction with other material properties, is a known contributor to oral biofilm adhesion, highlighting its importance in the field of dental prosthetics.[28-29]

It is also noteworthy that the unique processing conditions of the CAD/CAM technique could possibly have an effect on the molecular structure of the PMMA, potentially contributing to the observed improvements in hardness and surface roughness. The high temperature and pressure conditions used in the CAD/CAM process may lead to a denser polymer network, enhancing the mechanical properties of the resulting material.[18]

Moreover, it's important to remember that the clinical acceptability of a dental prosthesis is not determined by hardness and surface roughness alone. Other factors such as comfort, fit, aesthetics, and cost also play a significant role in the decision-making process for both dentists and patients. Future research could thus focus on a holistic evaluation of effect of artificial saliva aging CAD/CAM and CCM PMMA dentures, considering all these factors to determine the best approach in different clinical scenarios.

Lastly, while our findings shed light on the benefits of the effect of artificial saliva aging CAD/CAM technique in producing PMMA denture bases with superior hardness and acceptable surface roughness, further studies should aim to validate these results in larger samples and real-world clinical settings. Long-term studies assessing the performance and patient satisfaction with CAD/CAM dentures could also provide a comprehensive understanding of their potential advantages over CCM methods.

CONCLUSION

In this *in vitro* model simulating one week of artificial-saliva aging at 37 ºC, CAD/CAM-milled PMMA denture base specimens showed greater surface micro-hardness and lower surface roughness than CCM.

PMMA. Under the tested conditions and materials, CAD/CAM processing better maintained surface properties relevant to clinical performance; confirmation over longer aging periods and across additional brands is warranted.

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