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AN IN-VITRO STUDY ON THE COMPARATIVE EVALUATION OF SURFACE ROUGHNESS IN PMMA (POLYMETHYL METHACRYLATE) DENTURE BASES INFUSED WITH ZIRCONIA AND GRAPHENE

Prosthodontics

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ABSTRACT

Surface roughness is a critical parameter influencing the quality and performance of dental prosthetic materials. This study investigates the impact of incorporating zirconium and graphene oxide into poly (methyl methacrylate) (PMMA) composites on surface roughness characteristics. Three distinct groups of PMMA composites—Pink, Light Pink, and Grey—were analyzed, revealing unique surface properties associated with each group. Group B (Light Pink) exhibited the most extensive surface roughness values, suggesting distinct material characteristics. The research explored the effects of zirconium oxide and graphene oxide additives on PMMA composite surface roughness. Results indicated that while zirconium oxide incorporation led to higher average roughness values and increased variability, graphene oxide caused a slight reduction in average roughness with a narrower confidence interval, implying more consistent outcomes. Furthermore, statistical analyses revealed significant differences in surface roughness when comparing PMMA composites containing zirconium oxide to those with graphene oxide. Zirconium oxide additives notably increased surface roughness compared to the control group, whereas graphene oxide did not induce significant changes. Overall, this study highlights the influence of additive type—zirconium oxide versus graphene oxide—on the surface properties of PMMA composites. These findings contribute valuable insights into material selection and formulation for dental prosthetic applications, emphasizing the importance of understanding how different additives affect surface roughness and, consequently, the functional and aesthetic qualities of dental restorations. Such knowledge is crucial for optimizing the design and performance of dental prosthetic materials to meet the diverse needs of patients and practitioners in prosthodontics.

KEYWORDS

PMMA, zirconium oxide, graphene oxide, surface roughness

INTRODUCTION

This comprehensive introduction highlights the challenges associated with traditional poly (methyl methacrylate) (PMMA) denture base resins and the ongoing search for improved materials in the field of removable denture prostheses. PMMA once favored for its affordability and ease of use, is now criticized for its drawbacks, including residual monomer content, poor mechanical properties, and dimensional instability, prompting researchers to explore alternative materials like graphene-impregnated PMMA and zirconia[1-3]. Surface imperfections and microscopic voids in denture materials impact their quality and durability, often leading to biofilm formation and microbial colonization, which can contribute to oral health issues such as denture stomatitis. [4-6] Surface roughness, measured by parameters like average surface roughness (Ra), is emphasized as a crucial factor influencing plaque adhesion and the longevity of dental restorations.

The text discusses the significance of surface finish and energy in predicting the clinical performance of dental materials, underscoring the importance of addressing rough exterior surfaces to mitigate plaque accumulation and subsequent bacterial growth. Despite efforts to educate patients on denture hygiene, conventional cleaning methods involving abrasive techniques are often ineffective and may even contribute to surface damage and microbial retention. The susceptibility of PMMA resin denture bases to water sorption and discoloration due to chemical reactivity further underscores the need for material advancements. Techniques such as immersion in heated methyl-methacrylate monomer are explored as alternatives to mechanical polishing for enhancing dentures' aesthetic and functional properties. [7,8] The application of surface sealant products is suggested to improve surface imperfections and enhance wear resistance, though challenges such as poor bonding and surface wetting remain.[6,9] Color assessment using spectrophotometry and the CIE lab color system is highlighted as a standard practice in dentistry for evaluating aesthetic characteristics and ensuring color stability. The study's objective to compare and assess the surface roughness of graphene-impregnated PMMA and zirconia-coated denture bases reflects a broader effort to improve material selection in denture fabrication. The aim is to enhance patient comfort, durability, and overall prosthodontic performance by understanding the complex relationships between material properties and biological compatibility. The research seeks to contribute valuable insights into the effectiveness of these innovative materials, paving the way for informed decisions by clinicians and researchers in selecting denture-based materials that promote better patient outcomes and satisfaction. By shedding light on the performance of graphene and zirconia in denture applications, this study aims to advance the field of dental prosthetics and improve the level of care provided to dental patients.

MATERIAL AND METHODS

This laboratory study conducted at NIMS Dental College and Hospital investigated the surface roughness of three different types of denture base materials: PMMA (polymethyl methacrylate) alone, PMMA reinforced with 10% zirconia oxide nanoparticles, and PMMA reinforced with 2% graphene oxide nanoparticles.

Method: A total of 36 samples were manufactured and divided into three main groups: Group I, Group II, and Group III, each containing 12 samples.

S. No	Group	Sample Size
1	polymethyl methacrylate (PMMA) heat cure acrylic resin	12
2	10% of zirconium oxide-reinforced polymethyl methacrylate	12
3	2% of Graphene Oxide reinforced polymethyl methacrylate	12

The objective was to assess how these reinforcements impact the surface characteristics of PMMA, which is commonly used in denture fabrication. Samples were fabricated according to ADA specifications, with metal dies used to create standardized specimens. Group I comprised PMMA alone, Group II included PMMA with zirconia oxide, and Group III involved PMMA with graphene oxide. The nanoparticles were integrated into the PMMA matrix using silane coupling agents to ensure uniform distribution. After fabrication, all specimens underwent a rigorous surface finishing process involving grinding and polishing with specific equipment and materials to achieve a smooth surface. The surface roughness (Ra) of each sample was then measured using a Mitutoya surface roughness tester after 30 days of storage in artificial saliva to simulate oral conditions. Statistical analysis was performed to compare the surface roughness values among the three groups. The results indicated that the addition of zirconia oxide led to a significant increase in surface roughness compared to PMMA alone, whereas graphene oxide did not show significant changes in roughness. These findings provide valuable insights into the effects of nanoparticle reinforcements on the surface properties of PMMA for denture applications. Understanding how different additives influence surface roughness is essential for optimizing denture materials to enhance durability, biocompatibility, and patient comfort. In conclusion, this study contributes to advancing knowledge in prosthodontics by evaluating novel approaches to strengthen PMMA-based denture materials. The results may guide future research and clinical practice in selecting and developing denture base materials with improved performance characteristics.

Statistical Analysis

Data were inputted and subjected to statistical analysis using the Statistical Package for the Social Sciences (SPSS) version 21. Descriptive statistics was used to determine the mean and standard deviation. A comparative analysis was done by one-way Anova parametric test. The statistically significant difference came out to be 0.05.

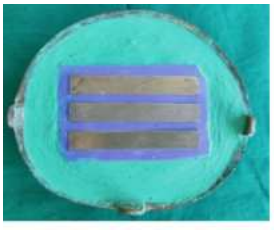


Figure 1 : Metal Die Used to Create Mold Space

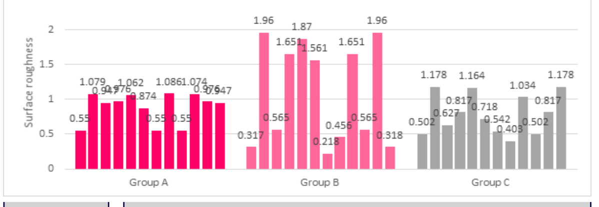
Figure 2 :- Group I: PMMA; Group II: Zirconium Oxide Reinforced PMMA; Group III: Graphene Reinforced PMMA

Figure 3:- Carbide Burs and Muslin buffa

Figure 4 :-surface roughness tester

RESULTS

This in vitro study aimed to compare and assess the surface roughness of zirconia and graphene-impregnated PMMA (polymethyl methacrylate) for denture base applications. A total of 36 samples were manufactured and divided into three main groups: Group I, Group II, and Group III, each containing 12 samples. Statistical analysis was performed using SPSS version 21. Descriptive statistics were utilized to calculate the mean and standard deviation. Comparative analysis was conducted using a one-way ANOVA parametric test, with statistical significance set at a p-value of 0.05



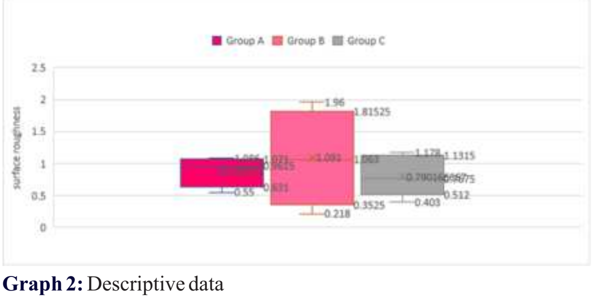
Graph 1: Master Chart

The dataset comprises measurements from 12 samples distributed across three groups: Group A (Pink), Group B (Light Pink), and Group C (Grey). Group A consistently displays measurements ranging from 0.550 µm to 1.086 µm. In contrast, Group B exhibits a broader range of measurements, spanning from 0.218 µm to 1.960 µm, indicating greater variability within this group. Group C falls in the middle, with measurements ranging from 0.403 µm to 1.178 µm. Notably, Group B stands out due to its wider range of measurements, suggesting more diverse characteristics within this group. Further investigation is required to gain a deeper understanding of these observed differences.

Table 1: Descriptive data

Groups	Mean±SD	95% confidence interval	Minimum	Maximum
PMMA n=12	0.89±0.22	0.75-1.03	0.55	1.09
PMMA + zirconium oxide	1.09±0.73	0.63-1.56	0.22	1.96
PMMA + graphene oxide	0.79±0.28	0.61-0.97	0.40	1.18

The study explored the impacts of various additives on PMMA composites by analyzing mean values, standard deviations, confidence intervals, and ranges. For pure PMMA (n=12), the mean surface roughness was 0.89 with a standard deviation of ±0.22. The 95% confidence interval ranged from 0.75 to 1.03, with observed values between 0.55 and 1.09. Introducing zirconium oxide led to an increase in the mean to 1.09 with notably higher variability (±0.73). The confidence interval expanded to 0.63-1.56, indicating wider data dispersion, with values ranging from 0.22 to 1.96. Conversely, incorporating graphene oxide into PMMA resulted in a slight reduction in the mean to 0.79 (±0.28). The confidence interval narrowed to 0.61-0.97, and values ranged from 0.40 to 1.18, suggesting a more consistent effect compared to zirconium oxide.

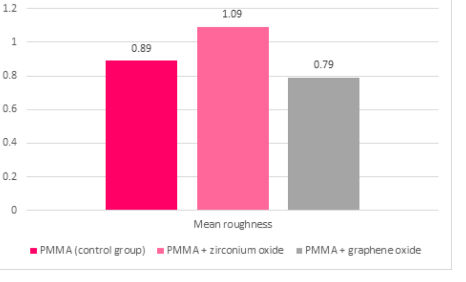


Graph 2: Descriptive data

Table 2: Average surface roughness (mean±SD[standard deviation])(ANOVA)

Groups n=12	Surface roughness (µm)	p-value
PMMA (control group)	0.89±0.22	0.293
PMMA + zirconium oxide	1.09±0.73	
PMMA + graphene oxide	0.79±0.28	

This study investigated how different additives affect the surface roughness of polymethyl methacrylate (PMMA) using three groups of 12 samples each. The control group, comprising pure PMMA, showed a surface roughness of 0.89±0.22 µm. Adding zirconium oxide to PMMA resulted in a slight increase in surface roughness to 1.09±0.73 µm, although this change was not statistically significant (p-value = 0.293), indicating variation in texture. Conversely, incorporating graphene oxide into PMMA led to a slight decrease in surface roughness to 0.79±0.28 µm. These results suggest that while the addition of zirconium oxide and graphene oxide affects the surface roughness of PMMA, the observed changes were not statistically significant in this study.



Graph 3: Average surface roughness (mean±SD[standard deviation]

Table 3: Comparison of control group vs PMMA + zirconium oxide (unpaired t-test)

PMMA + zirconium oxide	PMMA (control group)	Mean difference	p-value
1.09±0.73	0.89±0.22	0.20	0.001*

(*p<0.05= statistically significant)

When comparing PMMA composites, the addition of zirconium oxide to PMMA (1.09±0.73) demonstrated a significant improvement over the PMMA control group (0.89±0.22), with a mean difference of 0.20 and a p-value of 0.001, signifying a statistically significant enhancement.

Table 4: Comparison of control group vs PMMA + graphene oxide (unpaired t-test)

PMMA + graphene oxide	PMMA (control group)	Mean difference	p-value
0.79±0.28	0.89±0.22	0.10	0.20

(*p<0.05= statistically significant)

The study examined PMMA with and without graphene oxide and observed that the addition of graphene oxide did not produce a significant impact, evidenced by a mean difference of 0.10 and a non-significant p-value of 0.20

Table 5: comparison PMMA + zirconium oxide vs PMMA + graphene oxide (unpaired t-test)

PMMA + zirconium oxide	PMMA + graphene oxide	Mean difference	p-value
1.09±0.73	0.79±0.28	0.30	0.001*

(*p<0.05= statistically significant)

The comparison between PMMA combined with zirconium oxide and PMMA with graphene oxide shows a notable difference in their average values: 1.09 (±0.73) versus 0.79 (±0.28) respectively, with a mean difference of 0.30. The statistical analysis yielded a p-value of 0.001, signifying a highly significant distinction between the two materials and highlighting the impact of oxide type on PMMA's properties.

DISCUSSION

The provided text discusses several studies focused on assessing the impact of additives, specifically zirconium oxide and graphene oxide, on the surface roughness and properties of polymethyl methacrylate (PMMA) composites, particularly in dental and biomedical applications.

Key points from the studies include:

1. Surface Roughness Importance: Surface roughness of PMMA significantly affects its performance in dental prostheses, with smoother surfaces being preferable to reduce staining, and microbial colonization, and improve patient comfort.[10]

2. Effect of Zirconium Oxide: The addition of zirconium oxide generally increases surface roughness but enhances mechanical properties like strength and wear resistance. Zirconium oxide shows potential for improving the durability and performance of PMMA-based materials.[10-15]

3. Impact of Graphene Oxide: Graphene oxide incorporation can slightly reduce surface roughness, leading to smoother PMMA surfaces. Graphene oxide also enhances mechanical properties, suggesting benefits for denture base materials.[16-20]

4. Statistical Analysis: Studies employ statistical tests (e.g., unpaired t-tests) to validate differences in surface roughness and other properties when additives are introduced. Significant changes in surface roughness are noted between PMMA composites with different additives, highlighting the effectiveness of these additives.

This research thoroughly investigated the impact of zirconium oxide and graphene oxide additives on the surface roughness and properties of polymethyl methacrylate (PMMA) composites. Zirconium oxide increased surface roughness significantly, suggesting potential improvements in texture and mechanical interlocking. In contrast, graphene oxide slightly reduced surface roughness, possibly enhancing biocompatibility by reducing plaque adhesion.

CONCLUSION

the study investigated the influence of zirconium oxide and graphene oxide on the surface roughness of PMMA composites:

- Differences in surface roughness were observed among different composite groups, suggesting unique characteristics associated with each group.
- Zirconium oxide increased average surface roughness and variability, while graphene oxide slightly reduced average roughness and resulted in more consistent outcomes.
- However, the changes in surface roughness with these additives did not reach statistical significance in the study.

Further research is needed to fully understand the effects of zirconium oxide and graphene oxide on PMMA composite properties and their implications for dental and biomedical applications. These findings provide valuable insights for refining PMMA composite formulations and optimizing material performance based on specific application needs.

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