COMPARISON OF SURFACE ROUGHNESS AND GLOSS OF COPPER, CALCIUM AND YTTRIUM MODIFIED RESIN COMPOSITES AFTER POLISHING - AN IN VITRO STUDY

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ABSTRACT:

INTRODUCTION: Aesthetic principles and mechanical attributes have significantly shaped the evolution of contemporary dental restorative materials. The smoothness of a dental restoration surface is of great importance for its durability, as it mitigates concerns such as plaque retention, gingival inflammation, and recurrent caries. The aim of the study is to assess the surface roughness and gloss of calcium, copper and yttrium modified nanoparticles based composite resin after polishing. **MATERIALS AND METHODS:** A total of 4 samples in each group- copper, calcium and yttrium nanoparticles based composites were prepared and were tested after polishing. The samples were placed in 3NH gloss meter and their surface roughness was evaluated by using stylus profilometer-Mitutoyo SJ 310 and with the results collected a statistical analysis was performed using the statistical software "SPSS VERSION 23" and One Way ANOVA test was done. **RESULTS:** The surface roughness was low and gloss value was high for calcium modified resin composite in comparison with copper and yttrium modified resin composites. Therefore, calcium modified resin composite proves to be more efficient in terms of surface texture and roughness. One way anova test was done using SPSS version 23. The P value is 0.03 for surface roughness and gloss value for comparison of calcium, copper and yttrium modified composite, which is statistically significant. **CONCLUSION**: We can conclude that the surface roughness and gloss value of calcium modified composite is much more efficient than copper and yttrium modified composite. Calcium modified composite shows low surface roughness and high gloss value which are crucial factors for quality of restoration. These findings contribute to the evolving landscape of dental materials, emphasising the importance of surface characteristics in achieving both visual appeal and functional longevity in dental restorations.

KEYWORDS: Composites, Nanoparticles, Surface roughness, Gloss, Calcium, Copper, Yttrium

INTRODUCTION: Aesthetic principles and mechanical attributes have significantly shaped the evolution of contemporary dental restorative materials. The smoothness of a dental restoration surface is pivotal for its durability, as it mitigates concerns such as plaque retention, gingival inflammation, and recurrent caries. Copper (Cu), Calcium (Ca), and Yttrium (Y) modifications in resin composites can influence their physical, mechanical, and biological properties. Copper ions exhibit antibacterial properties reducing bacterial adhesion and biofilm formation, which can be highly beneficial for dental applications. Copper modifications increase mechanical strength. Copper nanoparticles can enhance the wear and resistance and hardness of the composite. However, excessive copper content may cause discolouration which affects esthetic outcomes. (1) Calcium modifications have an effect on bio activity and mineralization, calcium releasing composites can promote remineralisation that helps strengthen tooth structure. Calcium also neutralises pH and can help prevent acid-induced degradation. Ca-based fillers can enhance fracture toughness and flexural strength. (1,2) Yttrium provides structural reinforcement and can enhance the mechanical properties of resin composites, making them more durable and resistant to fracture. Yttrium-containing composites improve radiographic visibility as they are radiopaque, aiding in diagnostic applications. Yttrium modified composites show thermal stability and improved heat resistance, enhancing their longevity in high temperature environments. (3) With these already tested and proven benefits, the combination of copper, calcium and yttrium can potentially create a resin composite with superior antibacterial, bio active formula with enhanced mechanical properties. Such composites could be especially beneficial in dental healthcare where durability, biocompatibility and resistance to microbial colonisation are crucial factors. However the balance of these elements is critical to maintain esthetic qualities, mechanical integrity and long term stability. (4)

Hence, the techniques employed for finishing and polishing are crucial contributors to enhancing both the visual appeal and lifespan of restorations.(5) The final surface characteristics of restorations are determined by factors like filler particle size, hardness, distribution within the composite, and the abrasive agents utilized for finishing and polishing. (5,6)Nanocomposites have emerged as noteworthy contenders, surpassing hybrid and micro-filled composites, owing to their aesthetic and mechanical qualities suitable for both anterior and posterior restorations.(7) Surface roughness, another critical aspect, is contingent upon the composition of the resin composite and the techniques employed in polishing. The size of filler particles has been identified as a crucial factor affecting the transmittance and reflectance of the final restoration. (5,6,8)

The finishing and polishing of composite materials significantly influence surface roughness by affecting the texture, smoothness, and overall quality of the final surface. There are different means by which the overall quality of the final surface can be enhanced. Finishing removes excess material and larger irregularities, while polishing smooths out finer imperfections. Proper finishing and polishing prevent the formation of microcracks, which can compromise mechanical properties and lead to premature wear or failure.(7,9) The use of finer abrasives during polishing results in a lower surface roughness (Ra), whereas coarse abrasives can leave deeper scratches and increase

roughness.(7,9,10) A smooth surface reduces friction and wear over time, making the composite more durable and resistant to degradation. In dental composites, a highly polished surface improves aesthetics by enhancing gloss and color stability while also reducing plaque accumulation. Different polishing methods (e.g., diamond paste, rotary instruments, silicon carbide discs) affect the final smoothness. Multi-step polishing systems generally produce superior smoothness compared to one-step polishing techniques. The composition of the composite (e.g., microfilled vs. nanofilled composites) plays a role in how well it can be finished and polished, with nanofilled composites typically achieving better surface smoothness.(7,9–11)

The gloss of a composite refers to its surface reflectivity or shininess, which is an important property. Gloss is influenced by factors such as the composition, dispersion of nanoparticles, and surface smoothness. Uniform dispersion leads to a smoother surface and higher gloss, while agglomeration of nanoparticles can cause surface roughness, reducing gloss. UV curing, thermal curing, and polishing can enhance gloss by improving surface uniformity. The optical properties encompassing color, gloss, and surface texture are significantly influenced by the finishing and polishing procedures.(12) Consequently, both the composition of resin composites and the finishing/polishing system wield considerable influence over surface gloss, roughness, and microhardness. Despite the substantial impact of finishing and polishing on resin composites, the literature lacks a consensus on recommended instruments for each composite type.(13,14) Therefore, the present study meticulously explores the effects of polishing three distinct composites (one-step, two-step, and three-step systems) on the surface characteristics, including Roughness, and gloss. This investigation encompasses various resin composites, including copper composites , calcium composites and yttrium composites, employing advanced measurement tools such as a profilometer and gloss meter. The aim of the study is to assess the surface roughness and gloss of calcium, copper and yttrium modified nanoparticles based composite resin after polishing. (13)

MATERIALS AND METHODS:

A total of 4 samples in each group- copper, calcium and yttrium nanoparticles based composites were prepared and were tested after polishing. The samples were placed in 3NH gloss meter and their surface roughness was evaluated by using stylus profilometer-Mitutoyo SJ 310 and with the results collected a statistical analysis was performed using the statistical software "SPSS VERSION 23" and One Way ANOVA test was done. Firstly, copper, calcium and yttrium modified resin composites were selected as the primary materials under scrutiny. These materials were specifically chosen to explore potential variations in surface roughness and gloss resulting from modifications involving calcium and yttrium.The polishing procedures were conducted systematically, adhering to standardized protocols. The samples were meticulously prepared and subjected to a uniform polishing regimen to ensure consistency in the experimental conditions. The polishing process aimed to simulate real-world scenarios and optimize the comparison between the three different composite types. Surface roughness measurements were obtained using a precise and calibrated instrument (stylus profilometer) ensuring accurate and reliable data collection. The evaluation of gloss using 3NH gloss meter involved specialized equipment

designed to assess the reflective properties of the composite surfaces. This dual approach allowed for a comprehensive understanding of the surface characteristics of conventional ,strontium and magnesium modified resin composites after the polishing procedures.

Preparation of test samples:

Four specimens were crafted using a cylindrical mould measuring 8 mm in diameter and 2 mm in height, and subsequently subjected to assessments for both surface roughness and gloss. The fabrication process involved filling each mould with composite resin, followed by the removal of excess material through compression between two glass slides to achieve a flat surface. The glass slides were then eliminated, and the resin samples, covered with a polyester matrix, underwent polymerization using a 1,000 mW/cm2 LED curing light (LED Elipar FreeLight) from 3MTM for a duration of 40 seconds. In total, three different F/P systems were employed to prepare a set of nine resin discs, ensuring adherence to standardized procedures. To maintain consistency and eliminate potential bias, the top surfaces of the discs underwent grinding with 600 grit silicon carbide (SiC) paper for 20 seconds under running water.The entire process, encompassing sample preparation and the associated finishing/polishing (F/P) procedures, strictly followed the manufacturer's guidelines. These actions were carried out by the same operator to minimize any potential bias and ensure uniformity in the application of three distinct F/P systems.

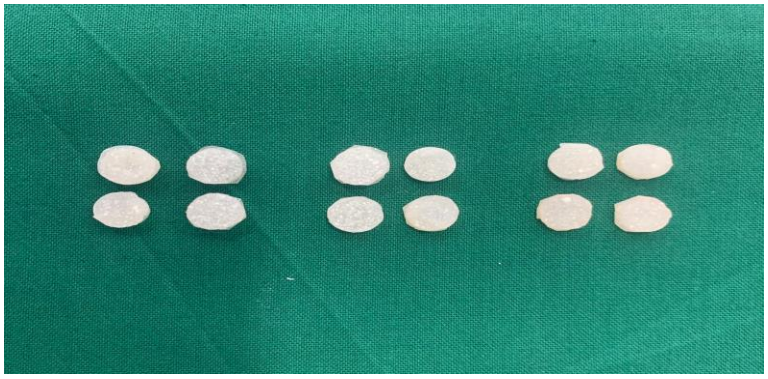


Figure 1: Samples from 3 different composite groups (Group 1- Calcium composites, Group 2- Copper nanoparticles based composites and Group 3- Yttrium nanoparticles based composites)

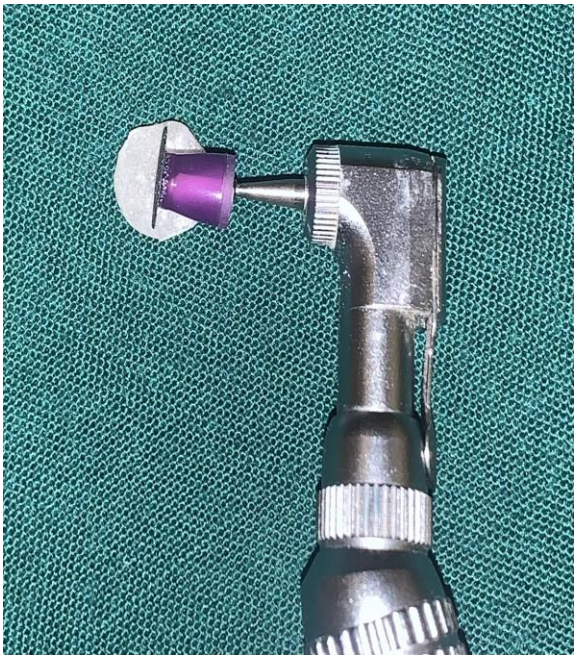
Surface roughness measurements:

Each resin composite and finishing/polishing (F/P) system underwent assessment through twelve disc-shaped specimens. Surface roughness (Ra) measurements were conducted using a stylus profilometer (Mitutoyo stylus profilometer) equipped with a 5 μm diamond stylus set at a 90° angle. The stylus traversed a length of 1.25 mm with a cut-off length of 0.25 mm. Three measurements were systematically taken at the centre of each sample in various directions, and the resulting mean value was calculated to ensure accuracy and reliability in the recorded data.

Figure 2 shows stylus profilometer-Mitutoyo SJ 310

Gloss measurements

Gloss measurements, quantified in gloss units (GU), were conducted using a gloss metre (3NH glossmeter, Dalian Teren Industry Instrument Co., Ltd., Liaoning, China). The gloss metre featured a square measurement area measuring 15 × 10 mm and operated with a 60° geometry to ascertain the gloss values of the samples. This device gauges the intensity of a reflected light beam upon striking the surface and then compares this measurement to a reference value. To ensure precision and consistency, an opaque black plastic mould was positioned over the specimen during measurement, effectively eliminating the impact of ambient light and maintaining the sample's precise position for repeated measurements. Three measurements were taken for each specimen, and the resulting mean value was calculated to provide a comprehensive assessment of gloss.



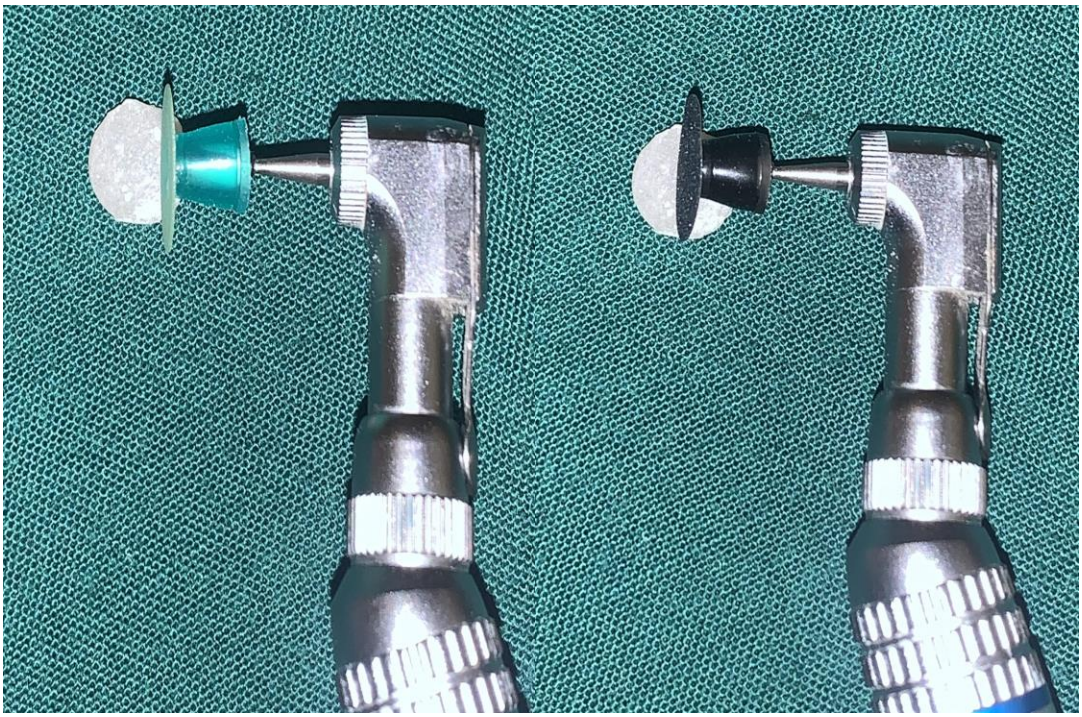


Figure 3, 4, 5, 6 depicts polishing done using Shofu Super Snap Polishing kit.

RESULTS

The surface roughness and gloss values between group- calcium composites, copper composites and yttrium composites are presented in Table 1,2,3. Significant differences were found between the groups.

GROUP 1 - CALCIUM	ROUGHNESS VALUE	GLOSS VALUE
SAMPLE 1	0.678	5.5
SAMPLE 2	2.286	4.1
SAMPLE 3	0.430	6.3
SAMPLE 4	1.952	4.5

Table 1 displays the results for the calcium composites, showcasing the roughness and gloss values for each of the four samples in Group-1

GROUP 2- COPPER	ROUGHNESS VALUE	GLOSS VALUE
SAMPLE 1	2.169	4.6
SAMPLE 2	0.228	4.4
SAMPLE 3	0.015	2.2
SAMPLE 4	1.911	3

Table 2 displays the results for the copper composites, showcasing the roughness and gloss values for each of the four samples in Group-2

GROUP 3- YTTRIUM	ROUGHNESS VALUE	GLOSS VALUE
SAMPLE 1	1.278	2.8
SAMPLE 2	1.546	2.1
SAMPLE 3	0.568	3.3
SAMPLE 4	0.116	4.2

Table 3 displays the results for the yttrium composites, showcasing the roughness and gloss values for each of the four samples in Group-3

The surface roughness was low and gloss value was high for calcium modified resin composite in comparison with copper and yttrium modified resin composites. Therefore, calcium modified resin composite proves to be more efficient in terms of surface texture and roughness. One way anova test was done using SPSS version 23. The P value is 0.03 for surface roughness and gloss value

for comparison of calcium, copper and yttrium modified composite, which is statistically significant (15)

DISCUSSION

The surface roughness measurements, as obtained through a stylus profilometer, offer a quantitative evaluation of the irregularities on the composite surfaces. The results of this study can be discussed in the context of how the modification with strontium and magnesium influences the overall smoothness of the resin composite.(16,17) Any significant differences observed in surface roughness between copper, calcium and yttrium modified resin composites post-polishing could be indicative of the efficacy of these modifications in achieving a smoother and potentially more aesthetically pleasing surface.Furthermore, the gloss measurements, expressed in gloss units (GU), provide insights into the reflective properties of the resin composites. In our study, addition of Yttrium affected the gloss values and, consequently, may impact the visual appearance of the dental restorations. (16)

Differences in gloss could be attributed to variations in the composition and interactions of the modified composites with the polishing procedures. It's essential to consider the potential clinical implications of these findings. (17)A smoother surface with optimal gloss is not only visually appealing but also contributes to the longevity of dental restorations by minimising factors such as plaque retention.(12,17) Therefore, Yttrium based composite resins that may enhance or alter the clinical performance of the resin composites, impacting aspects of patient satisfaction and oral health. Additionally, any challenges or limitations encountered during the study should be acknowledged and discussed. This may include factors such as the choice of polishing systems, variations in operator technique, or any unexpected observations that could influence the interpretation of the results. Comparing the findings of the current study with prior research reveals noteworthy insights.(15)

Hanife et al, conducted a study in which single shade composite was polished using different types of polishing systems and concluded that among all the composites, both the highest surface roughness and lowest gloss values were obtained in the groups treated with the OneGloss polishing system.(18) In another study, Luca Giacomelli et al had tested the surface roughness of commercial composites after different polishing protocols and concluded that the kind of polishing protocol does not have any significant effect on the roughness of composite and no differences were observed between different polishing systems.(19) Choi et al, conducted another study to find the changes in surface characteristics of dental resin composites after polishing and concluded that composites polished with Super-Snap and Sof-Lex systems showed higher $E*_{ab}$ and $L*$ values than those polished with Enhance polishing system with SCE geometry. $E*_{ab}$ and $L*$ values between specimens with different surface conditions measured with SCE geometry were significantly higher than those with SCI ($p < 0.01$). Changes in Ra value after polishing was insignificant in most cases.(20) In another study, Nagem Filho et al, had tested the changes in

surface characteristics of dental resin composites after polishing and concluded that no significant differences were observed before and after polishing of composite. (16)

In conclusion, the discussion for this research topic provides a platform to analyse and interpret the obtained data, offering a comprehensive understanding of how yttrium modified composite resin influences the surface roughness and gloss of dental resins composites compared to the remaining two groups after polishing. The findings may have implications for future developments in dental materials and procedures, aiming to optimise both functional and aesthetic aspects of restorative dentistry. Limitations of this study are small sample size and we did not compare the mechanical properties of this novel composite. In future, the same composite can be tested in animal models and also human trials should be done.

CONCLUSION

We can conclude that the surface roughness and gloss value of calcium modified composite is much more efficient than copper and yttrium modified composite. Calcium modified composite shows low surface roughness and high gloss value which are crucial factors for quality of restoration. These findings contribute to the evolving landscape of dental materials, emphasising the importance of surface characteristics in achieving both visual appeal and functional longevity in dental restorations.

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