EFFECT OF BRUSHING SIMULATION ON COLOUR STABILITY OF STRONTIUM AND MAGNESIUM NANOPARTICLES BASED COMPOSITE RESINS

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ABSTRACT:

INTRODUCTION: The colour stability of dental materials is of utmost importance in ensuring their long-term durability and aesthetic appeal. In the realm of dental research, the impact of various factors on the colour stability of dental resins, particularly using innovative components like strontium and magnesium nanoparticles, is a topic of significant interest and investigation. **MATERIALS AND METHODS:** Nanoparticles based resin composites were chosen for this study. The colour stability prior to brushing of the prepared nanoparticles based on specific discs was determined using a spectrophotometer. 8 samples were placed in a brushing stimulator with 30000 cycles -10000 cycles in linear X axis, 10000 cycles in linear y axis. Another 10000 cycles were divided into 5000 cycles clockwise and the remaining 5000 cycles anticlockwise. The colour stability values prior and after brushing stimulation were obtained and the values were tabulated, with the tabulated values descriptive analysis such as "t test" was performed. **RESULTS AND DISCUSSION:** In the study, colour stability of strontium and magnesium nanoparticles based resin composites was analysed after brushing. Table 1 shows pre LAB values of Strontium nanoparticles before placing them in a brushing simulator using . L, a and b values. Table 2 shows L, a and b values samples of magnesium nanoparticles based resin composites. Table 3 shows L, a and b values for samples of strontium nanoparticles based resin composites post brushing simulation. Table 4 shows L, a and b values samples of Magnesium nanoparticles based resin composites post brushing simulation. Table 5 shows ΔE values for colour stability for samples of strontium nanoparticles based resin composites post brushing simulation. Table 6 shows ΔE values for colour stability for samples of Magnesium nanoparticles based resin composites post brushing simulation. **CONCLUSION:** On analysing the results ΔE mean value was greater for magnesium nanoparticles when compared to strontium nanoparticles. Thus, Magnesium nanoparticles samples brushed were less colour stable when compared to samples brushed with the strontium nanoparticles.

KEYWORDS: Magnesium, Brushing simulation, Strontium, Aesthetics, Restoration

INTRODUCTION:

Dental restorative materials play a pivotal role in modern dentistry, where durability and aesthetic stability are paramount for long-term success. The quest for novel materials has led to the exploration of nanoparticle-based resin formulations, particularly those incorporating elements like strontium and magnesium. These elements, in their nanoparticulate form, offer promising prospects for enhancing mechanical properties and potentially imparting bioactive characteristics to dental resins.

Strontium, a chemical element similar to calcium, has demonstrated promising effects in promoting bone formation and potentially aiding in the remineralization of tooth structures. When used in nanoparticle form within dental resins, strontium has been explored for its ability to enhance the mechanical properties of the material, such as improving its strength and wear resistance.Additionally, strontium has shown some potential in reducing bacterial growth, which could be beneficial for oral health applications.Magnesium, an essential mineral for bodily functions, has been investigated for its biocompatibility and potential in enhancing the properties of dental materials ((1)). Magnesium nanoparticles, when incorporated into dental resins, have shown promise in reinforcing the material's mechanical properties, such as hardness and fracture toughness. Moreover, magnesium has been studied for its potential antibacterial properties, which could contribute to improved oral health outcomes.The colour stability of dental materials, a critical aspect of their clinical viability and patient satisfaction, remains a focal point in material science research. Despite advancements, challenges persist in maintaining colour integrity, especially under daily mechanical stresses such as tooth brushing.

Brushing techniques can vary significantly between individuals, influenced by factors such as pressure, speed, timing, and the angulation of the brush. To address this variability, a brushing simulator was introduced. This device holds the toothbrush and comes in various configurations with 4, 8, or 12 holders, allowing for multiple brushes to be tested simultaneously. Brushing simulators have several important applications, including simulating tooth brushing, assessing the effects of brushing on tooth surfaces, evaluating the impact on restorative materials, and testing abrasion for preclinical studies (2). These specialized devices are designed to enhance oral hygiene practices, improve sensory feedback, and support therapeutic interventions. They often feature bristles or tactile surfaces that replicate the action of a toothbrush, with options for vibration, oscillation, or rotation to optimize plaque removal and gum stimulation. Brushing simulators are particularly valuable for teaching proper brushing techniques, especially for children, individuals with motor challenges, or those with oral sensory sensitivities. Additionally, they are used in clinical settings to desensitize hypersensitive oral tissues, stimulate gum circulation, and aid in the rehabilitation of patients with oral motor difficulties. In dental research, brushing simulators play a crucial role in evaluating different brushing techniques, toothbrush designs, and toothpaste formulations, providing valuable insights into their effectiveness and impact on oral health ((3)).

Colour stability refers to a material's ability to retain its original color over time when exposed to environmental factors like light, temperature fluctuations, mechanical wear, and chemical interactions (such as staining from food, drinks, or saliva)(4). In the context of dental materials, particularly composite resins, color stability is of paramount importance because it directly impacts the aesthetic outcome of dental restorations. Aesthetic concerns are critical in dentistry, as patients expect restorations to blend seamlessly with natural teeth, maintaining a consistent and appealing appearance over time. It is a crucial factor in the performance and longevity of dental resin composites, directly influencing their aesthetic success in restorative dentistry((5)). Multiple factors—including material composition, environmental exposure, mechanical wear, and chemical degradation—contribute to color changes in dental materials over time. Although newer formulations with nanoparticles and advanced surface treatments have shown promise in improving color stability, challenges still exist, particularly in maintaining the appearance of dental restorations over extended periods of use. Therefore, ongoing research is essential for developing resins that can withstand the harsh oral environment while retaining their aesthetic properties for as long as possible.(6,7)

The rationale behind examining these specific nanoparticles lies in their documented potential to bolster material strength, wear resistance, and bioactivity. Strontium, known for its remineralization properties and ability to enhance mechanical strength, and magnesium, recognized for its biocompatibility and potential antibacterial effects, are envisioned as key components in developing advanced dental materials.(8)By subjecting these nanoparticle-infused resins to rigorous brushing simulation, this research seeks to elucidate their resilience against colour degradation, simulating real-world conditions and assessing their suitability for long-term clinical applications((9)). Understanding how these materials withstand mechanical stresses crucially informs their potential as durable and aesthetically reliable options for dental restorations.The findings of this study hold significant implications for advancing dental material science, potentially paving the way for the development of more resilient, bioactive, and visually appealing dental restorative solutions. Moreover, these insights could influence clinical practices, fostering enhanced patient experiences and long-term success in restorative dentistry.

Composite resins are widely used in modern dentistry for both restorative and cosmetic procedures due to their ability to mimic the natural appearance of teeth. They consist of a resin matrix (such as bis-GMA or UDMA) combined with inorganic fillers like silica or zirconia, which enhance strength, durability, and wear resistance.(10) Coupling agents, such as silane, help bond these components, while initiators trigger polymerization for hardening. Different types of composites, including microfilled, hybrid, nanocomposites, flowable, and packable composites, offer varying levels of strength and polishability, making them suitable for different clinical applications. Flowable composites have a lower filler content, making them highly adaptable and easy to apply in small cavities, liners, and minimally invasive restorations, but they are more prone to shrinkage and wear. On the other hand, packable composites have a higher filler content and a thicker consistency, making them ideal for posterior restorations where strength and durability are essential ((11)). Composite resins provide several advantages, including excellent aesthetics, strong adhesion to enamel and dentin, and minimal removal of tooth structure compared to amalgam. However, challenges such as polymerization shrinkage, wear, and technique sensitivity must be managed through proper placement techniques. Despite these considerations, advancements in material science continue to enhance the strength, longevity, and overall performance of composite resins, solidifying their place as a preferred choice in modern dentistry.

This study aims to investigate the impact of brushing simulation on the colour stability of innovative composite resins fortified with strontium and magnesium nanoparticles.

MATERIALS AND METHODS:

Sample Preparation

Commercially available composite materials were mixed with the strontium and magnesium nanoparticles in 1:1 ratio. Eight disc shaped samples of composite material brand with 2 mm of thickness were prepared using a customised mould . The samples were subdivided into two groups with 4 samples in each group. Group A was tested for the colour stability of Strontium and group B was tested for the colour stability of Magnesium .

Brushing Simulator

Eight disc shaped samples were placed in a brushing simulator (ZM3.8 SD Mechatronik). The samples are subjected to 9 hours of brushing which is equal to around three years of brushing and to around 30000 cycles in total among which 10000 cycles were performed in the linear X axis, 10000 cycles in the linear Y axis and the last 10000 were further subdivided and 5000 cycles were performed in the clockwise direction and the remaining 5000 cycles in the anti-clockwise direction. For long term evaluation of variations in colour stability of the composite material, the brushing simulation was done for 30000 cycles.

Calculation of colour stability:

For determination of colour stability, a spectrophotometer of reflection time was used for measuring the colour changes (ΔE) based on the Commission Internationale de l'Eclairage lab(CIELAB) system in 1976. The CIELAB colour space also referred to as L*a*b. L* for perceptual lightness, represents the lightness to darkness values that range from 0 to 100. a* and b* for the four unique colours that can be seen by the human vision,where, a* represents the greenness to redness with values of -127 to +128 and b* represents the blueness to yellowness with values of -127 to +128.The colour values of specimens before immersing were considered as baseline. The L, a, b values were obtained from the Vita EasyShade Spectrophotometer for the colour stability. The ΔE values were calculated in order to determine the degree of alteration in colour at different stages. The formula used is ΔE(L* a* b*) = [(ΔL*)2 + (Δa)2 + (Δb)]

Statistical Analysis

The colour stability value prior and after performing brushing simulation were obtained and the values were tabulated, with the tabulated values descriptive analysis "Paired t test" was performed using the statistical software "SPSS version 23" and the result of the analysis carried out was depicted in the form of bar graphs

RESULTS:

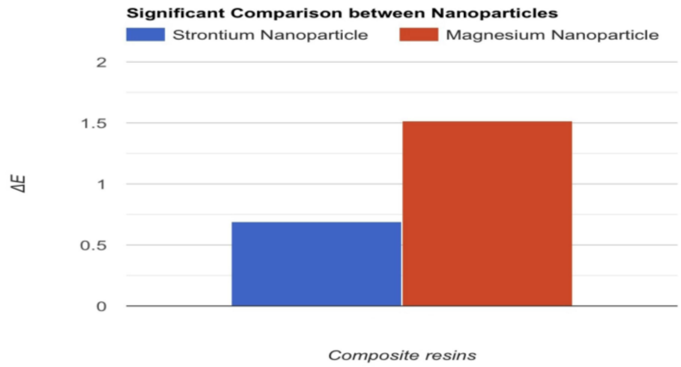
In the study, colour stability of strontium and magnesium nanoparticles based resin composites was analysed after brushing. Table 1 shows ΔE values for colour stability for samples of strontium nanoparticles based resin composites post brushing simulation. For sample 1 the ΔE was 0.94, for sample 2 was 0.21, for sample 3 and 4 was 0.99 and 0.64 respectively. Table 2 shows ΔE values for colour stability for samples of Magnesium nanoparticles based resin composites post brushing simulation as For sample 1 the ΔE was 1.72, for sample 2 was 1.10, for sample 3 and 4 was 1.68 and 1.56 respectively. The mean and standard deviation of strontium and magnesium nanoparticles based resin composites post brushing simulation 0.695 and 1.515 respectively. Mean ΔE value was higher for samples using magnesium nanoparticles when compared to samples using strontium nanoparticles . Thus, Magnesium nanoparticles samples brushed with fluoridated toothpaste were less colour stable. p value was 0.00 and was statistically significant.

Table 1 shows ΔE values for colour stability for samples of strontium nanoparticles based resin composites post brushing simulation.

S.No	Colour stability ΔE
1	0.94
2	0.21
3	0.99
4	0.64
Mean	0.695

Table 2 shows ΔE values for colour stability for samples of Magnesium nanoparticles based resin composites post brushing simulation.

S.No	Colour stability ΔE
1	1.72
2	1.10
3	1.68
4	1.56
Mean	1.515



DISCUSSIONS:

Color stability is a critical property of dental restorative materials, influencing their aesthetic longevity and clinical success. In this study, the color stability of strontium and magnesium nanoparticle-based resin composites was evaluated after simulated brushing to mimic real-life oral conditions. The results indicated that magnesium nanoparticle-infused resins exhibited greater color change (higher ΔE values) post-brushing compared to strontium-based resins, suggesting lower color stability for magnesium nanoparticle composites.

Color stability refers to a material's ability to maintain its original color over time. Regular consumption of stain-inducing foods and beverages, such as tea, coffee, and cola, can affect the aesthetics of restorative materials(12). By understanding the concept of color stability and comparing the properties of various restorative materials, clinicians can select the most suitable options based on patients' dietary habits, ensuring more predictable and successful outcomes.((13)).The discoloration of dental materials is related to water absorption, cracks, porosities and surface finish, conversion rates and thermal postcuring or photochemical ageing.((14)) It may occur due to the intensity and duration of polymerization, as well as extrinsic factors, including exposure to environmental factors, ambient and ultraviolet (UV) irradiation,heat, water, and food colourants, and intrinsic factors such as the composition of the resin matrix and filler, the loading and particle size distribution, type of photoinitiator, and percentage of remaining carbon-carbon double bonds(15). A study conducted by Arregui et al. examined the color stability of two self-adhesive composites and four methacrylate-based composites before and after being stored in water. The ΔE values were measured after immersing the composites for 30 days. The study concluded that water had no impact on color change.(16)

Studies have shown that toothpastes can cause discoloration. The whitening effectiveness of certain whitening toothpastes is attributed to their abrasive properties, which remove superficial stains, as well as chemical whitening agents like peroxide or similar ingredients. Additionally, detergents in toothpastes, such as sodium lauryl sulfate, and their pH levels are believed to influence the surface properties of restorative materials.(17) Some research has found that optical whitening toothpastes have a more significant impact on discoloration compared to conventional toothpastes.(18)This study examined the impact of fluoridated toothpaste on the color stability of composite restorations. The null hypothesis was accepted, as no significant differences in color changes were observed after immersion in various dentifrices. None caused clinically significant color changes, and there was no difference between microfilled and nanohybrid composites or across different fluoride toothpaste concentrations.(19)

The findings from this study align with previous research that has demonstrated the susceptibility of resin composites to color alteration due to various intrinsic and extrinsic factors. Intrinsically, the chemical composition of the resin matrix and filler content significantly impact color stability. The resin matrix is prone to water sorption, leading to hydrolytic degradation and subsequent color changes. Magnesium nanoparticles, despite their potential biocompatibility and mechanical reinforcement properties, may interact with the resin matrix in a way that promotes higher water absorption and greater susceptibility to discoloration. This could explain the higher ΔE values observed in magnesium-based resins compared to strontium-based resins. (20)

Extrinsically, brushing simulation plays a crucial role in evaluating the mechanical effects of oral hygiene practices on resin composites. The brushing simulator used in this study applied a standardized force and motion to simulate three years of brushing. Surface roughness is a major factor influencing color stability, as rough surfaces are more prone to plaque accumulation and staining from food, beverages, and oral care products. Studies have suggested that excessive brushing, especially with abrasive toothpaste, can create microcracks and increase the surface roughness of composite resins, leading to enhanced discoloration over time.

The results of this study indicate that strontium nanoparticle-based composites exhibited better color stability compared to magnesium-based composites. Strontium has been previously noted for its bioactive properties and potential to reinforce dental materials, reducing porosity and improving resistance to mechanical wear. Additionally, the interaction between strontium nanoparticles and the polymer matrix might contribute to enhanced resistance against color change. In conclusion, the study highlights that strontium nanoparticles provide superior color stability in resin composites compared to magnesium nanoparticles. This suggests that strontium-based composites could be a more reliable choice for aesthetic dental restorations, especially in patients concerned about long-term discoloration. The limitation of the research was less sample size and comparison of other mechanical and optical properties of the Nanoparticle based composite resins can be done. Future research should continue exploring the mechanisms behind these findings and optimize material formulations to enhance the durability and aesthetics of dental restorations.

CONCLUSION:

On analysing the results ΔE mean value was greater for magnesium nanoparticles when compared to strontium nanoparticles. Thus, Magnesium nanoparticles samples brushed were less colour stable when compared to samples brushed with the strontium nanoparticles. Therefore strontium nanoparticles give promising results for the usage of aesthetic restorations and having better colour stability.

CONFLICT OF INTEREST: The author reported the conflict of interest while performing this study to be nil.

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ETHICAL CLEARANCE: Since it is in vitro study ethical clearance is not needed.

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