# EFFECT OF BRUSHING SIMULATION ON THE SURFACE ROUGHNESS OF CONVENTIONAL AND STRONTIUM HYDROXYAPATITE NANOPARTICLES BASED COMPOSITES

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**ABSTRACT:**

**INTRODUCTION:** Strontium Hydroxyapatite Nanoparticles have emerged as a promising material in various fields, especially in biomedical and dental applications. Composite materials play a pivotal role in dental and biomedical fields due to their versatility, biocompatibility, and tailored properties that mimic natural tissues. The aim of the study is to compare surface roughness between Strontium Hydroxyapatite Nanoparticles-based Composites and conventional composites after brushing simulation. **MATERIALS AND METHODS:** A total of 4 conventional samples and 4 strontium hydroxyapatite nanoparticles based composite samples were prepared and were tested for surface roughness before and after brushing. The samples were placed in a brushing simulator for 10000 cycles 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 its results are demonstrated in the form of bar graph. **RESULTS:** On an average value of the results was noted, From the results, It was noted that post brushing surface roughness of conventional composites and strontium hydroxyapatite nanoparticles based composites was increased after brushing simulation using fluoridated toothpaste. The p value for Ra parameter was 0.602 which is ($p<0.05$), hence statistically not significant. **CONCLUSION:** It was noted that the pre brushing surface roughness and post brushing surface roughness of strontium hydroxyapatite nanoparticles based composites is similar, but it's comparatively lower than the pre brushing and post brushing surface roughness of conventional composites.

**KEYWORDS:** Composites, Nanoparticles, Dental, Surface roughness, Strontium Hydroxide

## INTRODUCTION:

Strontium Hydroxyapatite Nanoparticles (SHN) have emerged as a promising material in various fields, especially in biomedical and dental applications. This compound, a variation of hydroxyapatite (HA), possesses unique properties owing to the incorporation of strontium ions into the HA lattice structure.(1)(2) Its potential advantages over traditional composites have

garnered significant attention within the scientific community(3). The incorporation of strontium into hydroxyapatite nanoparticles presents an exciting avenue for advancing materials used in orthopedics, dentistry, and biomedical engineering. Further research and development in this area hold promise for innovative and enhanced solutions in regenerative medicine and implantology(4). Strontium incorporation can enhance the mechanical properties of HA, leading to improved strength and durability, essential for load-bearing applications in orthopedics and dentistry(5). Strontium within HA nanoparticles may possess antibacterial properties, making it advantageous in preventing infections(6).

Composite materials play a pivotal role in dental and biomedical fields due to their versatility, biocompatibility, and tailored properties that mimic natural tissues(7). They are extensively used in restorative dentistry, orthodontics, prosthodontics, and various biomedical applications. (8)Composite materials continue to evolve, driven by ongoing research and development efforts aimed at enhancing their mechanical, biological, and functional properties.(9) The adaptability of composites in mimicking natural tissues while offering tailored properties makes them indispensable in advancing dental treatments, orthopedic interventions, and various biomedical applications(9)(10). These materials are widely employed in dentistry for restorations, crowns and veneers. They consist of a resin matrix (commonly bisphenol-A-glycidyl methacrylate or dimethacrylate) reinforced with inorganic fillers (like silica, quartz, or glass particles). Dental composites offer excellent aesthetics, durability, and adhesive properties, mimicking the appearance and strength of natural teeth.

Surface roughness is a critical parameter in various fields, including engineering, manufacturing, and dentistry, as it directly impacts the functionality, aesthetics, and longevity of materials.(11) Surface roughness is defined as the irregularities and deviations present on a surface at a microscopic level, surface roughness influences properties such as friction, wear resistance, adhesion, and overall performance of a material. In dentistry, it plays a crucial role in plaque accumulation, bacterial adhesion, and the longevity of dental restorations. This article explores the factors affecting surface roughness, measurement techniques, and its significance across different applications, highlighting advancements in technology to improve surface quality and functionality(12).

Composite resins are widely used in restorative dentistry due to their excellent aesthetics, adaptability, and biocompatibility. However, their long-term success depends on various factors, including wear resistance, surface integrity, and durability under oral conditions(13). One significant factor affecting composite restorations is brushing simulation , which involves the mechanical wear and surface changes caused by regular toothbrushing. The abrasiveness of toothpaste, brushing technique, and bristle stiffness can influence surface roughness, gloss retention, and material degradation over time. Understanding the effects of brushing simulation on composites is crucial for improving material formulations, enhancing their longevity, and guiding clinical recommendations for patients. (14) This article explores the impact of brushing on composite restorations, including surface wear, mechanical properties, and preventive strategies to maintain restoration quality**.** The aim of the study is to compare surface roughness between

Strontium Hydroxyapatite Nanoparticles-based Composites and conventional composites after brushing simulation.

## MATERIALS AND METHODS:

### 1) Sample Preparation

The market-available conventional composite restorative substance (shofu brand) was utilized. This traditional composite was combined with strontium hydroxyapatite nanoparticles. Using a specially made mold, eight disc-shaped samples of restorative material with a thickness of 2 mm were created (Fig. 1). Two sets of four samples each were created from the samples. Group B underwent surface roughness testing using composites based on strontium hydroxyapatite nanoparticles, while Group A underwent surface roughness testing using conventional composites.

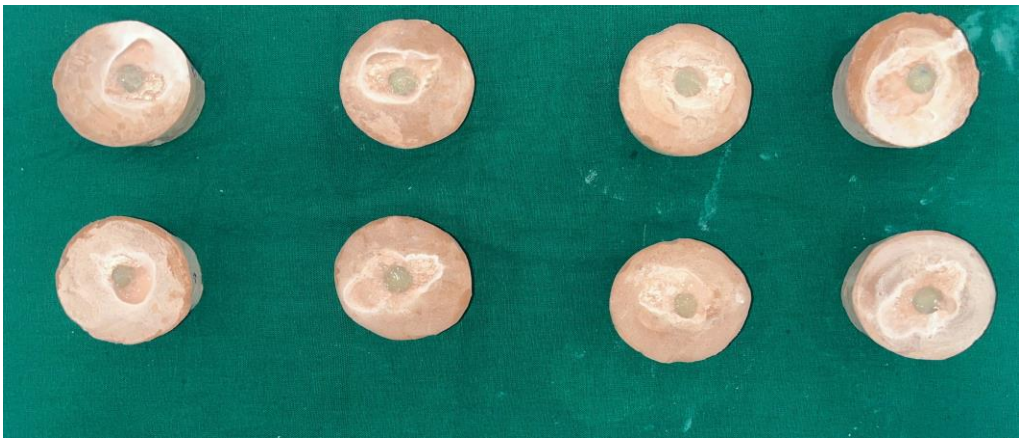


Fig 1: Samples of conventional composites and Strontium hydroxyapatite nanoparticles based composites

### 2) Brushing Simulator

Eight disc-shaped samples were put into a ZM3.8 SD Mechatronik brushing simulator. The samples are brushed for nine hours, which is equivalent to about a year of brushing, and a total of about 10,000 cycles, of which 5000 were done in the linear X axis and 5000 in the linear Y axis. The brushing simulation was carried out for 10,000 cycles using fluoride toothpaste in order to assess the long-term differences in surface roughness between the conventional composite and composites restorative material based on strontium hydroxyapatite nanoparticles (Fig. 2).


Fig 2: Samples were placed in the brushing simulation

**3) Surface Roughness Assessment**

Using a stylus profilometer (Mitutoyo SJ 310), the surface roughness of the manufactured circular composite disc samples was evaluated both before and after brushing simulation. In order to determine the surface roughness values before brushing, the device—which has a 2um tip and a 60° angle—was manually moved across the sample materials. Samples of circular discs were put in the brushing simulator after the surface roughness value was determined. The stylus profilometer was used once more to measure the surface roughness value following brushing simulation.(Figure 3).


Fig 3: Represents the stylus profilometer used to obtain the values of surface roughness

**4) Statistical Analysis**

Using the statistical program "SPSS version 23," the surface roughness values before and after the brushing simulation were acquired and tabulated. The descriptive analysis "Paired t test" was then conducted using the tabulated values, and the analysis's outcome was shown as bar graphs.

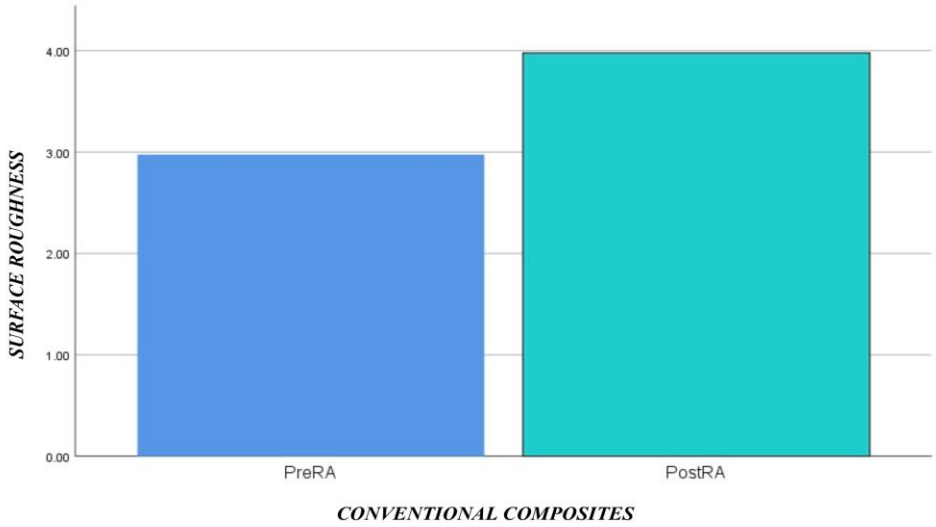
**RESULTS:**

| S.No | Pre Ra (Pre roughness) | Post Ra (Post roughness) |
|---|---|---|
| SAMPLE 1 | 0.088 | 0.252 |
| SAMPLE 2 | 3.427 | 4.606 |
| SAMPLE 3 | 6.105 | 6.528 |
| SAMPLE 4 | 2.283 | 4.522 |

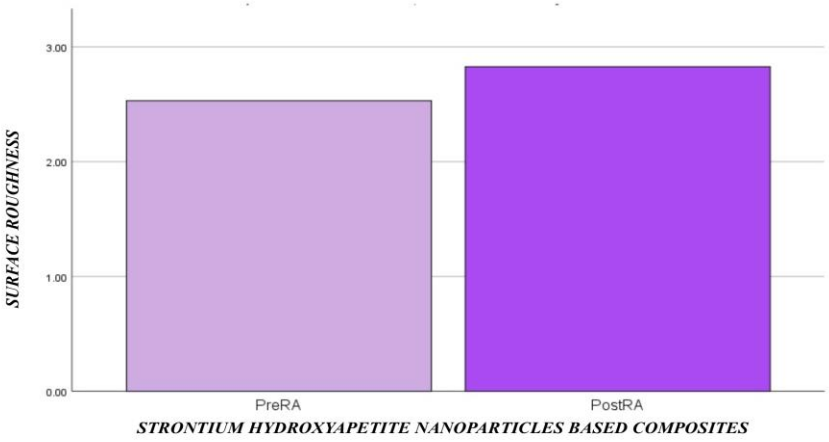
**Tab 1: Surface Roughness noted in the brushing simulation of conventional composites**

| S.No | Pre Ra(Pre roughness) | Post Ra (Post roughness) |
|---|---|---|
| SAMPLE 1 | 1.357 | 1.823 |
| SAMPLE 2 | 4.203 | 4.844 |
| SAMPLE 3 | 2.286 | 2.585 |
| SAMPLE 4 | 2.277 | 2.057 |

**Tab 2: Surface Roughness noted in the brushing simulation of Strontium hydroxyapetite nanoparticles based composites**




**Graph 1: Graph represents the Pre and post roughness values of conventional composites**




**Graph 2: Graph represents the Pre and post roughness values of Strontium hydroxyapetite nanoparticles based composites**

The average value of Pre Ra of conventional composites was 2.97. The average value of Post Ra of conventional composites is 3.97 was noted. The average value of Pre Ra of strontium hydroxyapatite nanoparticles based composites was 2.53. The average value of Post Ra of strontium hydroxyapatite nanoparticles based composites is 2.82 was noted. The statistical "paired t test" analysis depicts that the p value for Ra parameter was 0.6027 which is ($p<0.05$), hence statistically insignificant.

This paragraph explains the results of tab 1. Surface roughness of each sample before brushing simulation was recorded as Pre Ra and after brushing simulation was recorded as Post RA of conventional composites. Pre Ra of Samples 1, 2, 3 and 4 are 0.088, 3.427, 6.105 and 2.283 respectively. Post Ra of samples 1, 2, 3 and 4 are 0.252, 4.606, 6.528 and 4.522 respectively . When compared to Pre Ra, Post Ra is higher in brushing simulation of conventional composites .

This paragraph explains the results of tab 2. Surface roughness of each sample before brushing simulation was recorded as Pre Ra and after brushing simulation was recorded as Post RA of Strontium hydroxyapetite nanoparticles based composites. Pre Ra of samples 1, 2, 3 and 4 are 1.357, 4.203, 2.286 and 2.277 respectively. Post Ra of samples 1, 2, 3 and 4 are 1.823, 4.844, 2.585 and 2.057 respectively. Post Ra is higher than Pre Ra comparatively.

Both paragraphs describe the surface roughness (Ra) measurements of different composite samples before and after a brushing simulation. The first paragraph focuses on conventional composites, where all samples show an increase in roughness after brushing, with some experiencing significant changes (e.g., Sample 4: 2.283 to 4.522). The second paragraph discusses Strontium hydroxyapatite nanoparticle-based composites, which also show increased roughness after brushing, but the changes are generally smaller compared to the conventional composites (e.g., Sample 4: 2.277 to 2.057, which slightly decreases). Overall, conventional composites and nanoparticles based composites exhibit a more pronounced increase in roughness post-brushing.

**DISCUSSION:**

The results from both tables reveal that brushing simulation generally alters the surface roughness (Ra) of composite materials, albeit to varying degrees for conventional composites versus those reinforced with Strontium hydroxyapatite nanoparticles. For conventional composites, all samples exhibited an increase in surface roughness after brushing. The Pre Ra values ranged from very low (0.088) to higher levels (6.105), and after brushing, each sample demonstrated a noticeable increase (e.g., Sample 1 increased from 0.088 to 0.252, and Sample 4 from 2.283 to 4.522). This consistent elevation in roughness indicates that the conventional composite surfaces are significantly affected by the mechanical abrasion of brushing, which may be attributed to the inherent material properties such as the matrix composition or filler-matrix interactions.

In contrast, the Strontium hydroxyapatite nanoparticle-based composites showed a more varied response to the brushing simulation. Although most samples still exhibited an increase in Ra (for example, Sample 1 increased from 1.357 to 1.823 and Sample 2 from 4.203 to 4.844), the changes were generally less pronounced compared to conventional composites. Notably, Sample 4 even displayed a slight decrease in roughness (from 2.277 to 2.057), suggesting that the inclusion of nanoparticles may contribute to a stabilization of the surface under brushing conditions.

The comparative analysis indicates that while both composite types experience changes in surface roughness due to brushing, the conventional composites are more susceptible to surface degradation. The enhanced performance of the nanoparticle-based composites could be linked to improved filler distribution or a stronger interfacial bond between the nanoparticles and the resin matrix, which may help resist the abrasive forces during brushing. These findings have practical implications. In applications where surface integrity and resistance to wear are critical—such as in dental restorations or other load-bearing composite structures—the incorporation of Strontium hydroxyapatite nanoparticles might offer a significant advantage. The improved surface durability could lead to better longevity, aesthetic retention, and reduced plaque accumulation in dental applications.

In a previous article, Mohammadi Basir et al., In their 2013 electron microscopy investigation, Mohammadi Basir et al. demonstrated a uniform dispersion of nanoparticles in the matrix when 5wt% NHA was present. When relatively big glass particles and smaller NHA particles are combined, the particles are widely distributed, their packing density is increased, and their mechanical properties are improved(15). In 2011, Garoushi et al. assessed the impact of adding 0, 10, 15, 20, and 30 weight percent silica nanoparticles to the resin matrix of microfilled composites. They discovered that adding nanoparticles up to 30 weight percent did not increase the wear resistance of microfilled composites; their results differed from ours, most likely because they assessed microfilled composites.(16)

For instance, Atta et al. (2015)(17) and Moraes et al. (2016) observed that the mechanical action of brushing leads to noticeable increases in Ra values for conventional composites, likely due to the abrasion of the resin matrix and loss of filler particles. These changes in surface texture are concerning because increased roughness can contribute to plaque accumulation, staining, and potentially accelerated material degradation.(18) Moreover, studies such as those by Karabiyik & Aydin (2019) and Zahra & Amin (2017) have compared conventional composites with those

reinforced with nanoparticle fillers. Their findings suggest that while both types of materials experience changes in surface roughness, nanoparticle-based composites tend to exhibit a moderated response(19). The improved filler-matrix interactions in these formulations appear to confer additional resistance against the abrasive forces of brushing, thus preserving the surface integrity better than conventional composites.(20)

In summary, the brushing simulation demonstrates a clear detrimental effect on the surface roughness of conventional composites, while Strontium hydroxyapatite nanoparticle-based composites display a comparatively moderated response. This suggests that nanoparticle reinforcement can play an important role in enhancing the wear resistance of composite materials under conditions of repeated mechanical stress.

**CONCLUSION:**

From the study, it is well clear that the post surface roughness of both conventional and strontium hydroxyapatite nanoparticles based composites is higher after brushing simulation using fluoridated toothpaste. It was noted that the Pre surface roughness and post surface roughness of strontium hydroxyapatite nanoparticles based composites is moreover similar, but it is comparatively lesser than the Pre and post surface roughness of conventional composites.

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