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Effect Of Denture Cleanser Immersion on Surface Topography of Cad/cam and Conventional Polymethyl Methacrylatedenture Bases Veneered With Gingival Composite: An in Vitro Study

Abstract:

Background: Biofilm accumulation, staining, and patient comfort are all impacted by the surface roughness of denture base resins. Denture cleansers are necessary for hygiene, but frequent use may degrade the surface quality of denture materials. CAD-CAM Prepolymerized PMMA exhibits superior surface properties compared to conventional heat-polymerized PMMA, and gingival shade composite resin (GSCR) layering may further alter these characteristics. There is still little data on how denture cleansers affect conventional and CAD-CAM resins with varying GSCR thicknesses.

Aim: The aim of this experimental and comparative study was to evaluate and compare the effect of a denture cleanser on the surface roughness of conventional and CAD-CAM denture base resins modified with different thicknesses of gingival shade composite resin.

Materials and Methods: A total of sixty specimens were fabricated, comprising thirty conventional heat-polymerized PMMA and thirty CAD-CAM PMMA samples. Each group was further subdivided into three subgroups: unmodified, GSCR layered to a thickness of 1 mm, and GSCR layered to a thickness of 1.5 mm. All specimens were immersed in a sodium perborate-based denture cleanser solution. Surface roughness (Ra) was measured before and after immersion using a profilometer. The collected data were statistically analysed using paired and unpaired t-tests with the level of significance set at $p \leq 0.05$.

Results: Before cleansing, uncoated PMMA showed significantly higher roughness in heat-polymerized resin (1.554 ± 0.142 µm) than CAD-CAM PMMA (0.144 ± 0.052 µm) ($p < 0.001$), while GSCR-coated groups showed no difference ($p > 0.05$). After immersion, roughness increased in all groups, with heat-polymerized PMMA remaining rougher (1.848 ± 0.178 µm) than CAD-CAM PMMA (0.229 ± 0.093 µm) ($p < 0.001$). GSCR modification minimized differences between materials. CAD-CAM PMMA maintained the smoothest surfaces overall. Overall, GSCR application decreased surface roughness in all materials, with CAD-CAM PMMA coated with GSCR consistently maintaining values below the critical threshold of 0.2 µm.

Conclusion: Within the limitations of the present study, CAD-CAM PMMA reinforced with gingival shade composite resin exhibited better resistance to surface changes following exposure to denture cleansers than conventional heat-polymerized PMMA. The improved surface quality observed in this material may support better denture hygiene and contribute to the longevity of the prosthesis.

Key-words: Denture cleanser; Surface roughness; Gingival shade composite resin; Conventional PMMA; CAD-CAM PMMA; Injection-molded PMMA.

Introduction:

Records of the usage of denture prosthesis date back to approximately 700 B.C. A significant development in denture base materials occurred with the creation of polymethyl methacrylate (PMMA) in the late 1930s. PMMA quickly emerged as the material of choice for denture manufacture because of its favourable aesthetic attributes, biocompatibility, ease of manipulation, low weight, and cost.

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Because it offers a useful blend of reasonable strength, repairability, and cost-effectiveness, it is still commonly utilised.Nevertheless, PMMA has some drawbacks that could affect its long-term therapeutic effectiveness, including as water absorption, brittleness, decreased impact strength, and vulnerability to fatigue-related degradation.[1]

In an effort to overcome some of these drawbacks, CAD/CAM PMMA-based polymers were later introduced, especially for interim prostheses. These materials are Prepolymerized under controlled conditions and stored before use, allowing internal stresses to relax and reducing further polymerization changes. Their highly cross-linked structure and controlled composition result in improved mechanical properties compared to conventional PMMA, including reduced porosity, fewer voids, and less polymerization shrinkage. Additionally, CAD/CAM resins tend to release lower amounts of residual monomer, show better colour and optical stability, and allow precise fabrication through advanced machining techniques.[2]

With increasing patient expectations for more natural and lifelike prostheses, gingival-shade composite resins (GSCRs) have been developed to better replicate the appearance of soft tissues. In this approach, the acrylic denture base can first be modified with colouring agents to achieve a more realistic base shade. This is followed by the application and light-curing of GSCR on the buccal surfaces to simulate gingival contours and vascular patterns. As a result, the prosthesis blends more naturally with the surrounding oral tissues, significantly improving overall esthetics.[3]

Maintaining proper denture hygiene is crucial for maintaining oral health in addition to restoring function and beauty. Inadequate cleaning of denture surfaces can encourage the growth of bacteria, raising the possibility of diseases such denture stomatitis. Additionally, dentures may act as reservoirs for harmful microorganisms, increasing the risk of infection and cross-contamination. Additionally, systemic health issues, especially in elderly persons, have been linked to microbial biofilms on dentures. As a result, maintaining both oral and general health requires consistent and efficient denture cleaning.[4]

Dentures can be cleaned using a variety of techniques, such as chemical soaking, mechanical brushing, and microwave disinfection. The most popular technique among denture wearers is mechanical cleaning, which is thought to be successful in lowering biofilm buildup. As an additional step to enhance denture cleanliness and prevent bacteria growth, chemical cleansers are frequently advised. Long-term usage of these chemicals may change the characteristics of denture base materials, notwithstanding their advantages. Therefore, when choosing a cleaning routine, compatibility between the cleanser and denture material should be taken into account. For dentures to continue to function and look good, qualities including surface roughness, hardness, and colour stability are crucial. Surface roughness is one of these characteristics that is very important since it can improve microbial adhesion and the subsequent formation of biofilms.[4]

Denture cleansers use a range of chemical agents in their formulations to provide a cleaning effect. These could include reducing agents, oxidising compounds, chelating substances, detergents, and effervescent additives, each of which uses a different mechanism to help remove deposits. Both the cleanser's composition and the denture material it is applied to affect how well it works. Nowadays, two of the most popular denture cleaning agents are sodium hypochlorite preparations and alkaline peroxide. Although their efficacy frequently depends on extended soaking, alkaline peroxide cleansers are frequently used to remove plaque and surface stains. Sodium hypochlorite, on the other hand, has strong antibacterial action and is useful in lowering bacterial and fungal contamination as well as helping to remove stains.Sodium hypochlorite, on the other hand, has strong antibacterial action and is useful in lowering bacterial and fungal contamination as well as helping to remove organic residues and stains from denture surfaces.[5]

The physical properties of denture base materials, such as PMMA and polyamide, may be changed by exposure to denture cleaning solutions, according to several studies. The cleanser's composition and the material's processing or polymerisation method seems to have an impact on the extent of these changes. Surface roughness can be increased by improper or extended washing, which encourages microbiological retention. It is widely acknowledged that bacterial adherence is favoured by surface roughness values greater than about 0.2 μm. A roughness tester is usually used to quantify surface roughness in micrometres, and the most widely used parameter is the roughness average (Ra).[6]

The clinical performance of denture bases is significantly influenced by surface features. Inflammation and illness may result from bacteria buildup and slight damage to the oral tissues caused by rough or uneven surfaces. Additionally, characteristics like wettability, bonding strength, and surface brightness may be affected by these surface imperfections. For optimal oral health and long-term success, denture surfaces should be as smooth as possible to minimize plaque accumulation and microbial retention.[6]

Therefore, the present study aims to evaluate and compare the effects of different denture cleansers on the surface properties of various denture base resin materials layered with gingival-shade composite resin at different thicknesses.

Material and Method:

Four commercially available materials were used in this study: a conventional heat-cure denture base resin (Group I: Shiva, Maarc Pvt. Ltd.), a CAD-CAM Prepolymerized PMMA resin (Group II: Noble Cam, Vinci Smile Group LLC), a sodium perborate denture cleanser (Vovantis Laboratories Pvt. Ltd.), and a gingival shade composite resin (Beautiful II, Shofu Dental India Pvt. Ltd.).

Fabrication of PMMA Resin Test Specimens:

PMMA resin test specimens were prepared using two different techniques: conventional heat polymerization and CAD-CAM prepolymerization, according to ISO 20795-1:2013 standards. The specimens were made in three standard sizes: 32 × 10 × 3 mm for the control group, 32 × 10 × 2 mm for specimens planned for 1 mm GSCR application, and 32 × 10 × 1.5 mm for those planned for 1.5 mm GSCR application.

For the heat-polymerized specimens, wax patterns of the required dimensions were first prepared. These were then invested using a two-pour technique, with Type II dental plaster followed by Type III dental stone, along with a separating medium. After dewaxing in boiling water, the flask was allowed to cool. The heat-cure acrylic resin was then mixed according to the manufacturer's instructions and packed into the mould at the dough stage. The flask was closed and placed under a pressure of about 100 kg/cm². The specimens were bench-cured and then polymerized at 74°C for 1.5 hours. After polymerization, the flask was allowed to cool slowly before deflasking.

For the CAD-CAM specimens, the required designs were created using Exocad software. Prepolymerized PMMA pucks measuring 98 mm in diameter and 20 mm in thickness were used to fabricate the specimens. These pucks were milled under dry conditions using a five-axis CNC milling machine to obtain samples of the desired dimensions.

For finishing, the 3 mm thick specimens were sequentially ground using 120-, 200-, and 800-grit silicon carbide papers to achieve a smooth surface. In contrast, the 2 mm and 1.5 mm thick specimens were finished only up to 120-grit abrasive, in order to maintain a suitable bonding surface for the subsequent application of gingival shade composite resin (GSCR). After finishing, all specimens were thoroughly rinsed with tap water and then air-dried before proceeding to the next step (Fig. 1).

Application of Gingival Shade Composite Resin (GSCR):

To create specimens with uniform dimensions, a silicone mould made of epoxy resin and sized 32 × 10 × 3 mm was used. To guarantee consistent placement, denture base resin samples measuring 32 × 10 × 2 mm and 32 × 10 × 1.5 mm were precisely positioned inside the mould. In accordance with the manufacturer's instructions, a light-curing unit was used to polymerise the bonding surfaces for one minute after applying a thin layer of primer. Gingival shade composite resin was applied gradually after primer application until the ultimate specimen thickness reached 3 mm, producing composite layers of either 1.0 mm or 1.5 mm. The material was adapted using a silicone-tipped instrument to achieve uniform coverage and intimate contact with the underlying resin surface. Each specimen was subsequently light-cured for 3 minutes to ensure adequate polymerization. After curing, the specimens were finished sequentially with 220, 600and 800-grit silicon carbide abrasive papers. Polishing was then carried out in two stages: an initial polishing with silicone discs followed by a final polishing procedure using diamond paste to obtain a smooth, high-gloss surface.

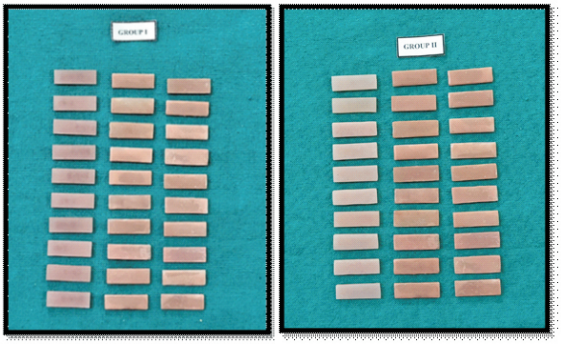


Fig 1: - Finished and Polished samplesof HP and CP (group-I-II)(original photograph)

Group Division of Test Specimens:

Sixty denture-base samples made from polymethyl methacrylate (PMMA) were fabricated and grouped according to processing method. Thirty specimens comprised conventionally heat-polymerized PMMA (Group I) and thirty were milled prepolymerized PMMA produced by CAD/CAM (Group II). All samples measured 32 × 10 × 3 mm.

To assess the influence of a gingival-shade composite resin (GSCR) veneer, each material group was split into three subgroups. Subgroup A consisted of full-thickness 3.0 mm PMMA specimens. Subgroup B was constructed from 2.0 mm

PMMA overlaid with 1.0 mm of GSCR. Subgroup C combined 1.5 mm of PMMA with a 1.5 mm GSCR layer.

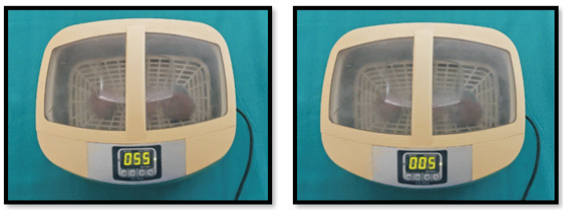
Initial surface roughness (Ra) was recorded for every specimen before any further procedures. Measurements were made using a profilometer equipped with a diamond stylus, applying a constant stylus load of 0.75 N, at a traversing speed of 0.5 mm/s across a 350 µm sampling length. Two readings were obtained at different locations on each sample and the mean of those readings was taken as the baseline Ra (see Fig. 2)



Fig 2: - Surface roughness measurement using profilometer (original photograph)

In order to simulate the thermal stresses of the mouth cavity, specimens were artificially aged by immersing them in fake saliva for three months and subjecting them to thermocycling. Samples were periodically moved between baths set at 5°C and 55°C during thermocycling; each immersion lasted 30 seconds, with a 1-second transfer interval; 10,000 cycles, or roughly a year of clinical use, were completed (Fig. 3).

Specimens were immersed in a 3.8% sodium perborate denture cleanser every day for ten minutes at room temperature following the initial surface roughness measurements. Samples were properly cleaned and kept in distilled water for a full day following each washing. To assess the long-term impact of the cleanser on material surface qualities, this routine was repeated daily for 180 days. Surface roughness was assessed once more at the same sites using the same profilometer methodology after the conclusion of the 180-day treatment and thermocycling sequence. To guarantee uniform testing conditions, specimens were rinsed and allowed to air dry before to each measurement. Every measurement was noted and statistically examined. Surface roughness values were compared before and after conditioning using paired t-tests, while intergroup comparisons were carried out using independent sample t-tests. Continuous variables were expressed as mean ± standard deviation. Statistical analysis was carried out using the Statistical Package for Social Sciences (SPSS version 21.0; IBM Corporation, USA) for Microsoft Windows, and the level of significance was set accordingly.



Samples kept at 55°C Samples kept at 5°C

Fig 3: - Thermocycling procedure (original photograph)

Results

(Table-1) presents the surface roughness values for all groups and shows an increase in roughness following immersion in sodium perborate. Among the unmodified specimens, heat-polymerized PMMA demonstrated the highest surface roughness both before and after immersion, which may be attributed to its inherent porosity. In contrast, CAD-CAM PMMA consistently exhibited lower roughness values, indicating greater resistance to chemical degradation.

Application of gingival shade composite resin reduced surface roughness in both materials. However, GSCR-layered specimens at both 1 mm and 1.5 mm thicknesses showed greater changes after immersion when compared with unmodified CAD-CAM PMMA. Despite this, CAD-CAM PMMA and its GSCR-modified groups-maintained roughness values below the critical threshold of 0.2 µm, whereas heat-polymerized PMMA exceeded this limit after conditioning.

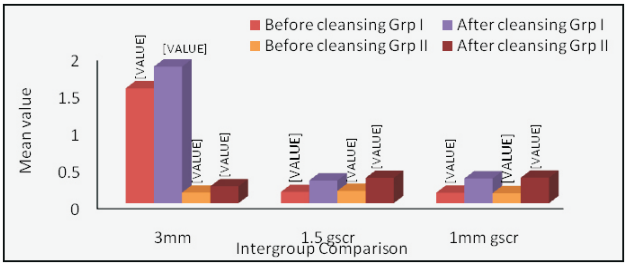
Overall, CAD-CAM PMMA demonstrated superior long-term surface stability, with the influence of GSCR dependent on the thickness of the applied layer. (Graph-1).

Table 1- Comparison of Surface Roughness (µm) Between Heat-Polymerized PMMA (Group I) and CAD-CAM PMMA (Group II) Before and After Denture Cleanser Immersion

Condition	Subgroup	n	Group I (HP PMMA) Mean ± SD	Group II (CAD-CAM PMMA) Mean ± SD	Mean Difference	p-value
Before Cleansing	3 mm PMMA	10	1.554 ± 0.142	0.144 ± 0.052	1.410	0.000*
	1.5 mm GSCR	10	0.153 ± 0.027	0.166 ± 0.094	- 0.013	0.674
	1 mm GSCR	10	0.142 ± 0.024	0.136 ± 0.011	0.006	0.470
After Cleansing	3 mm PMMA	10	1.848 ± 0.178	0.229 ± 0.093	1.619	0.000*
	1.5 mm GSCR	10	0.307 ± 0.088	0.342 ± 0.091	- 0.035	0.398
	1 mm GSCR	10	0.335 ± 0.105	0.346 ± 0.082	- 0.012	0.789

Level of significance $p \leq 0.05$

Graph-1: Mean Change inSurface Roughness Between Heat-Polymerizing (Group I) And Cad-Cam Prepolymerized PMMA Resin (Group II) Before Immersion in Denture Cleanser



Discussion:

Maintaining proper denture hygiene is essential, as dentures remain in constant contact with the oral environment and are continuously exposed to a wide variety of microorganisms throughout the day. Inadequate cleaning has been associated with several oral conditions, including denture stomatitis and inflammatory papillary hyperplasia. Techniques for cleaning dentures are often divided into three categories: mechanical, chemical, and combination. Many older persons have reduced manual dexterity or cognitive disability, making mechanical brushing problematic. In these situations, chemical denture cleansers offer a more practical option. Some people choose inexpensive home cures like vinegar, while widely accessible commercial options include sodium perborate solutions and effervescent tablets (like Clinsodent). 11]

The perfect cleanser should be safe for denture base materials, biocompatible, and efficient at eliminating biofilm. The physical characteristics of denture resins may be altered by prolonged exposure to chemical substances, according to some publications; however, other investigations show that according to manufacturing guidelines can prevent significant material degradation.[11]

Denture prostheses remain in the oral cavity and rapidly accumulate plaque and food debris, providing an environment that favours bacteria growth. Salivary composition, nutrition, wear length, and the porosity of the material are factors that influence the formation of biofilms. Because imperfections encourage microbial adherence and impede the clearance of plaque, surface roughness is particularly significant. Sodium hypochlorite and sodium perborate are two frequently used chemical disinfectants. For elderly or disabled individuals receiving long-term care, these cleaners are very helpful in removing stains, deposits, and microbiological biofilm. However, cleanser concentration, immersion time, and interactions with denture materials must be carefully regulated to lower the danger of material damage.[10]

Sodium perborate, a kind of chemical soak cleaner, was given as effervescent tablets in this investigation. The molecule dissolves into an alkaline peroxide solution, which releases nascent oxygen. The subsequent effervescence, which combines chemical action with mild mechanical agitation from bubbling, facilitates cleaning.[16]

The lifespan of prosthetic appliances, patient comfort, and microbiological adhesion are all impacted by surface roughness. Smoother acrylic surfaces near 0.12 µm exhibit lesser microbial risk, while Quirynen and Bollen found a key roughness threshold of roughly 0.2 µm, above which bacterial colonisation grows noticeably.[10]

Using a diamond stylus and a contact profilometer, we determined the surface roughness. Multiple traces were captured for uniformity, and readings were obtained throughout a predetermined scan length at constant load and speed. The specimen's surface roughness was determined using the average Ra value for those traces, and any alterations upon immersion were statistically assessed.[8]We simulated clinical ageing by keeping samples in artificial saliva and thermocycling them between 5°C and 55°C to approximate one year of oral service because temperature fluctuations and mechanical forces in the mouth affect denture lifetime.[7]

Frederico Silva et al.'s earlier research demonstrated that hypochlorite can successfully kill microorganisms at even low doses.[15]Tablets containing 3.8% sodium perborate were employed in the current regimen for daily 180-day immersions; when the tablets dissolve, they produce alkaline peroxide and release oxygen, providing cleansing and disinfecting chemistry through effervescence.[16]

The results showed that all resin materials, whether modified or unmodified, exhibited an increase in surface roughness following cleanser immersion. However, specimens modified with gingival shade composite resin (GSCR) at both 1 mm and 1.5 mm thicknesses consistently demonstrated lower roughness values before and after immersion. Surface texture in resin composites is influenced by filler particle size and distribution, with smaller particles producing smoother finishes. [14]

With respect to processing methods, conventional heat-polymerized PMMA displayed the highest surface roughness, whereas CAD/CAM-milled resins showed the lowest values, likely due to the homogeneous and Prepolymerized nature of industrial PMMA blocks.[9-17] Takhtdar et al. reported that

manual processing and additive manufacturing techniques increase roughness because of void formation, while subtractive CAD/CAM fabrication yields smoother surfaces, supporting the findings of the present study.[9]

Some discrepancies exist in the literature. Tripathi et al. reported no significant increase in roughness of heat-cured PMMA after immersion in Fittydent, which contrasts with the present findings.[8] Garcia et al. suggested that sodium perborate may increase surface roughness due to pellicle formation,[13] whereas Ural et al. observed no significant differences between hypochlorite and commercial cleansers.[14]

These variations may be related to differences in materials, immersion protocols, and surface finishing procedures.

Finally, Bollen et al. emphasized that surface roughness values above 0.2 µm markedly enhance plaque retention and microbial accumulation.[18]The ability of CAD/CAM PMMA, particularly when modified with GSCR, to remain near or below this threshold highlights its potential clinical advantage in reducing biofilm formation and improving long-term denture performance.

Conclusion:

The study's limitations allow for the following conclusions to be made:

- When compared to traditional heat-polymerized PMMA, CAD-CAM PMMA showed a higher resilience to surface roughening following exposure to chemical denture cleaners.
- Gingival shade composite resin was applied to form a protective coating that minimised damage from denture cleansers and maintained surface integrity.
- Even after prolonged exposure to the cleanser, the surface roughness of CAD CAM and injection-molded resins treated with GSCR stayed within clinically acceptable bounds.
- These findings support the therapeutic application of CAD CAM PMMA to enhance hygiene, prevent microbial colonisation, and prolong the functional life of complete dentures—ideally in conjunction with a gingival shade composite overlay.

Clinical Implications:

- Although sodium perborate and related denture cleansers are frequently used to keep prostheses clean, extended or inappropriate usage can cause surface degeneration, especially in traditional heat-polymerized PMMA.
- Increased surface roughness raises the risk of denture-related oral disease and mucosal irritation by encouraging biofilm formation and plaque retention.
- Cleanser-induced damage can be minimised by selecting more resilient denture base materials and using surface coverings like gingival shade composite resin.
- It seems that the best method for creating dentures that are smoother, more hygienic, and last longer is to combine CAD CAM PMMA with GSCR.

Scope For Future Research:

- To increase clinical application, validate these findings with in vivo experiments that mimic the entire oral environment, including saliva, temperature swings, and masticatory forces.
- Increase sample sizes, broaden the scope of tested cleansers beyond sodium perborate, including enzymatic, natural, and other commercial agents, and assess long-term immersioneffects.
- For more accurate results, use higher resolution surface characterisation methods as atomic force microscopy (AFM) or 3D profilometry. Additionally, include testing of GSCR bond strength, colour stability, and wear resistance under simulated functional loads.
- To guarantee that laboratory results translate into significant clinical advantages, do patient-centered research evaluating comfort, aesthetics, microbial colonisation, and user satisfaction.

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