ORIGINAL RESEARCH

Preserving Integrity: Investigating the Influence of Disinfecting Agents on Polymethylmethacrylate Dental Prosthesis Surface Characteristics in Children

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Abstract

Introduction: In children, polymethylmethacrylate (PMMA) is a commonly used material for fabrication of dental prostheses, such as obturators, removable space maintainers, habit-breaking appliances, removable orthodontic appliances, and removable partial and complete dentures. Regular cleaning of such prostheses is vital for maintaining the health of the oral tissues as well as the longevity of the prosthesis. The chemical method of disinfection, using different chemical cleansers, is commonly used for cleaning a dental prosthesis. Some of these disinfecting agents have been reported to alter the physical and mechanical properties of PMMA.

Aim: The aim of the study was to analyze the effect of two commonly used disinfecting agents on the surface roughness and surface hardness of two PMMA-based materials processed using different curing cycles.

Materials and methods: PMMA samples were made using short and long curing cycles. The surface roughness and hardness of the samples before and after immersion in the two disinfecting agents were recorded. A profilometer was used to measure surface roughness, whereas hardness was measured using the Vickers hardness tester.

Results: Both disinfecting agents increased the surface roughness and decreased the hardness of the PMMA samples. The effect was more profound in samples made using the short curing cycle.

Conclusion: It is important to select the appropriate disinfecting agents and follow the manufacturers' instructions to ensure that the other properties of the prosthesis are not affected.

Keywords: Cleansers, Hardness, Polymethylmethacrylate, Surface roughness.

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Introduction

Polymethylmethacrylate (PMMA) is one of the most popular materials for fabricating dental prostheses, such as removable complete or partial dentures, orthodontic appliances like retainers, and obturators, etc.[1] The ease of fabrication and repair, stability in the oral environment, pleasing esthetics, low water solubility, and cost-effectiveness are reasons for its popularity among dental professionals. These materials have low surface hardness and can be easily finished and polished in the dental laboratory to produce a relatively smooth and glossy surface. A dental prosthesis with smooth, polished surfaces provides excellent esthetics and is more comfortable for the patient to wear, resulting in better patient compliance.[2] One of the main limitations of PMMA is that it allows microorganisms to attach and colonize readily on its surfaces, leading to biofilm formation.[3] The biofilm on dental prostheses harbors several microorganisms such as *Candida albicans*, *Streptococcus mutans*, *Staphylococcus aureus*, etc., which are implicated in several local diseases such as denture stomatitis, as well as systemic infections like bacterial endocarditis, gastrointestinal disorders, and chronic obstructive pulmonary disease, etc.[4] Therefore, it is of utmost importance to maintain oral prostheses' hygiene to avoid biofilm formation and the associated oral and systemic diseases. A vast majority of patients use manual brushing methods for cleaning their prostheses. However, the efficacy of this method is questionable, as brushing may not be able to remove the microorganisms harbored in the rough surfaces created over time due to the abrasive effect of manual brushing or hard foods on the surface of the prostheses.[5] Alternatively, the chemical method for cleaning the prostheses is also commonly recommended by dentists. Bleach-based cleansers (e.g., those containing sodium hypochlorite or sodium peroxide) or effervescent cleansers supplied as tablets containing hydrogen peroxide or $NaHCO_3$ that release CO_2 or O_2 bubbles when dissolved in water are commonly used. Enzyme-based cleansers containing proteolytic or lipolytic enzymes are also available and effectively decrease the number of viable microorganisms but

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are ineffective in removing any biofilm already formed on the surface of the prosthesis.[6,7] Chemical disinfection can be used alone or with mechanical methods to maintain the hygiene of the prostheses. Any disinfection method employed to clean the prosthesis should be effective without detrimental effects on other material properties used for making the prosthesis. Studies have reported that the use of mechanical methods of cleaning increases the surface roughness of PMMA over time. The higher surface roughness of PMMA promotes the adhesion and colonization of microorganisms on its surface, leading to biofilm formation.[8]

Significant alterations in the mechanical properties, such as surface hardness and optical properties of PMMA, have also been reported after repeated immersion in certain chemical disinfectants.[9,10] The surface hardness of PMMA is an indicator of its abrasion resistance. A surface with low surface hardness is more likely to undergo wear under the masticatory forces in the oral environment or during the cleaning of the prosthesis with cleansers/toothbrushes, etc.[11,12] This makes the surface rough, compromising the esthetics and increasing microbial adhesion. The scratches produced on the surface may act as stress concentration points, compromising the prosthesis's strength.[13] As daily use of cleansers is recommended for maintaining the hygiene of PMMA-based prostheses, it is necessary to determine the effect of such agents on the physical and mechanical properties of the material.

The study aimed to analyze the effect of two commonly used disinfecting agents on the surface roughness and surface hardness of heat-cured PMMA materials processed using different curing cycles.

Materials and Methods

Two commercially available heat-activated PMMA denture base materials, viz., Trevalon (Dentsply India Pvt. Ltd., India) and DPI Heat Cure (Dental Products of India), were used in the study.

The two disinfectants used in the study were:

- Vi Clean Liquid (Vishal Dentocare Private Limited, India)—sodium hypochlorite-based cleanser.
- Fittydent Cleansing Tablets (Dr. Reddy's Laboratories Ltd., India)—sodium perborate-based cleanser.

Preparation of Polymethylmethacrylate Samples

About 120 disk-shaped samples were prepared from Trevalon and DPI denture base materials ($n = 60$ for each type). Firstly, wax patterns with dimensions of 20 mm diameter and 2 mm thickness were prepared using modeling wax and invested in a denture flask using dental plaster. Subsequently, dewaxing was carried out, and separating medium (Dentsply India Pvt. Ltd., India) was applied to the mold surfaces. The powder and liquid of Trevalon and DPI were mixed in a ceramic jar at a ratio of 3:1 by volume and allowed to reach the dough stage. Upon reaching the dough stage, the material was packed into the mold and bench-cured for an hour. The material was polymerized using two different curing cycles. Half of the samples ($n = 30$) of both Trevalon and DPI were processed using the long curing cycle, which involved heating at 74°C for 8 hours, followed by 1 hour of boiling at 100°C.

In contrast, half of the samples ($n = 30$) were subjected to a short curing cycle, which involved heating at 74°C for 20 minutes, followed by 22 minutes of boiling at 100°C. After curing, the flask was allowed to cool, deflasked, and the samples were retrieved. The retrieved samples were finished using sandpapers of 80, 100, 220, and 400 grit sizes, then polished using a slurry of pumice and French chalk on buff wheels. All the specimens were stored in distilled water at 37°C for 48 hours, following which their surface roughness and hardness were measured.

Treatment with disinfecting agents: The Trevalon and DPI samples in long and short-curing cycle groups were divided into three subgroups ($n = 10$) based on the disinfecting agents used.

- Subgroup 1: Samples were immersed in Vi Clean Liquid for 8 hours, after which they were rinsed thoroughly and stored in distilled water at room temperature. The process was repeated daily for 12 months.
- Subgroup 2: Samples were immersed for 8 hours in a solution prepared by dissolving the Fittydent tablet in 240 mL of warm distilled water. Afterward, they were rinsed thoroughly and stored in distilled water at room temperature. The process was repeated daily for 12 months.
- Subgroup 3 (control): Samples were immersed in distilled water for 12 months at room temperature.

The surface roughness and hardness of samples were recorded at the end of 12 months and compared with the initial value before treatment with disinfecting agents.

Measurement of Surface Roughness

The surface roughness of samples was measured using a contact surface profilometer (Form Taly Surf 50, Taylor Hobson, United Kingdom). The samples were mounted onto a flat surface. A diamond stylus with a tip radius of 0.2 mm was moved across the surface of each specimen three times in 3 different directions for a distance of 1 mm at a speed of 0.5 mm/second. The average roughness, Ra, was expressed in μm ($n = 10$).

Measurement of Surface Hardness

The surface hardness of the samples was assessed with a digital microhardness tester (MMT-X7A700, Matsuzawa Co. Ltd., Japan). An indenter point in the form of a square-based pyramid was applied at a load of 30 gm for 30 seconds at room temperature. For each sample, five indentations were made at different points on the surface with a minimum distance of 1 mm between any two indentations. The hardness value was obtained directly as Vickers hardness number (VHN) ($n = 10$).

Statistical Analysis

The data obtained were expressed as mean and standard deviation. The data were statistically analyzed using one-way ANOVA followed by the Tukey *post hoc* test at a 95% confidence interval ($\alpha = 0.05$).

Results

The study results show that the surface roughness of both Trevalon and DPI samples increased on immersion in the two chemical disinfectants, irrespective of the curing cycle used in their fabrication. No significant change in surface roughness was observed in the control samples immersed in distilled water (Tables 1 and 2).

Table 1: Surface roughness and hardness of Trevalon samples before and after treatment with disinfecting agents

	Long curing cycle				*Short curing cycle*			
	Surface roughness (Ra) (μm)		*Surface hardness (MPa)*		*Surface roughness (Ra) (μm)*		*Surface hardness (MPa)*	
	Before immersion	*After immersion*	*Before immersion*	*After immersion*	*Before immersion*	*After immersion*	*Before immersion*	*After immersion*
Distilled water	0.04 ± 0.002	0.05 ± 0.004	20.16 ± 1	18.94 ± 4	0.06 ± 0.005	0.08 ± 0.009	17.19 ± 2	15.02 ± 1
Fittydent	0.04 ± 0.002	0.12 ± 0.006	20.16 ± 1	14.12 ± 1	0.06 ± 0.005	0.16 ± 0.004	17.19 ± 2	12.19 ± 2
Vi Clean	0.04 ± 0.002	0.10 ± 0.005	20.16 ± 1	15.19 ± 1	0.06 ± 0.005	0.13 ± 0.002	17.19 ± 2	11.72 ± 1

Table 2: Surface roughness and hardness of DPI samples before and after treatment with disinfecting agents

	Long curing cycle				*Short curing cycle*			
	Surface roughness (Ra) (μm)		*Surface hardness (MPa)*		*Surface roughness (Ra) (μm)*		*Surface hardness (MPa)*	
	Before immersion	*After immersion*	*Before immersion*	*After immersion*	*Before immersion*	*After immersion*	*Before immersion*	*After immersion*
Distilled water	0.04 ± 0.004	0.06 ± 0.001	21.24 ± 2	17.21 ± 2	0.05 ± 0.002	0.08 ± 0.003	18.11 ± 1	14.11 ± 1
Fittydent	0.04 ± 0.004	0.11 ± 0.008	21. 24 ± 2	15.32 ± 1	0.05 ± 0.002	0.15 ± 0.010	18.11 ± 1	12.21 ± 3
Vi Clean	0.04 ± 0.004	0.09 ± 0.007	21.24 ± 2	17.09 ± 1	0.05 ± 0.002	0.12 ± 0.005	18.11 ± 1	12.33 ± 2

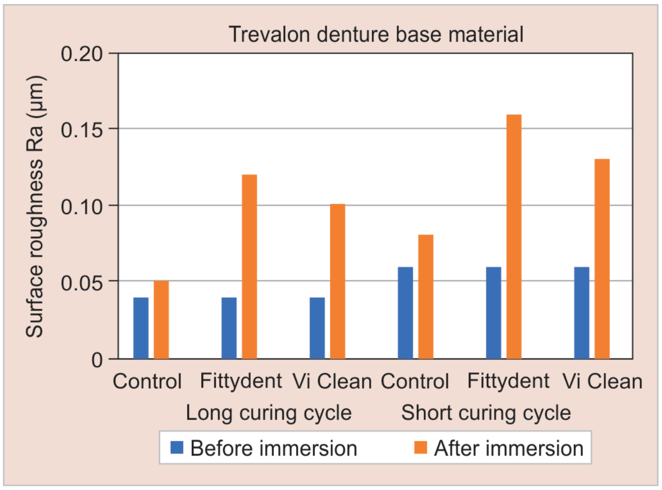

Fig. 1: Surface roughness of Trevalon samples before and after treatment with disinfecting agents

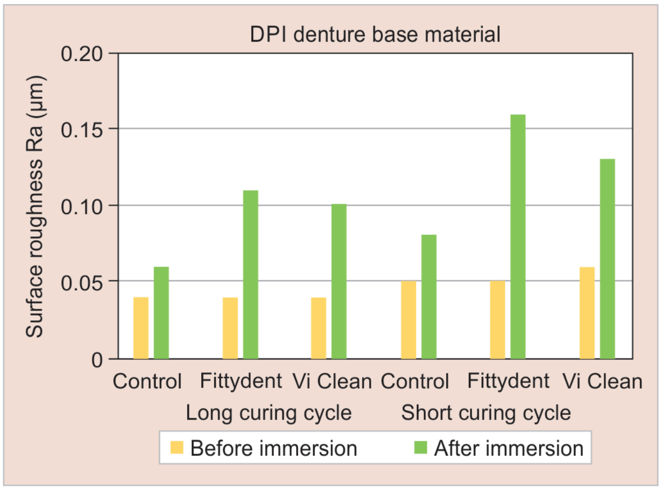

Fig. 2: Surface roughness of DPI samples before and after treatment with disinfecting agents

For both materials, higher surface roughness was observed in samples treated with sodium perborate-based disinfectant (Fittydent) than in those treated with hypochlorite-based disinfectant (Vi Clean). Additionally, the effect of both disinfectants was more profound in samples fabricated using a short curing cycle than in those made by a long curing cycle (Figs 1 and 2).

The initial surface hardness of the Trevalon and DPI samples made by long curing cycles was higher than those made by the short curing cycle. The initial surface hardness of Trevalon samples made by short and long curing cycles was 20.16 ± 1 MPa and 17.19 ± 2 MPa, respectively. Similarly, DPI samples made with a long curing cycle had a surface hardness of 21.24 ± 2 MPa. In contrast, those made with a short curing cycle had a hardness of 18.11 ± 1 MPa. Upon immersion in chemical disinfectants used in the study, a significant decrease in the surface hardness of all PMMA samples was observed, irrespective of the curing cycles used in their fabrication. Though a reduction in the surface hardness of samples in the control group was observed, the difference was not statistically significant (Figs 3 and 4).

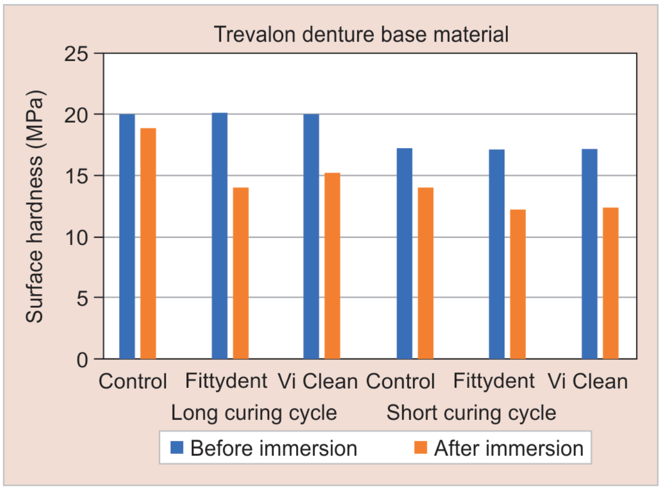

Fig. 3: Surface hardness of Trevalon samples before and after treatment with disinfecting agents

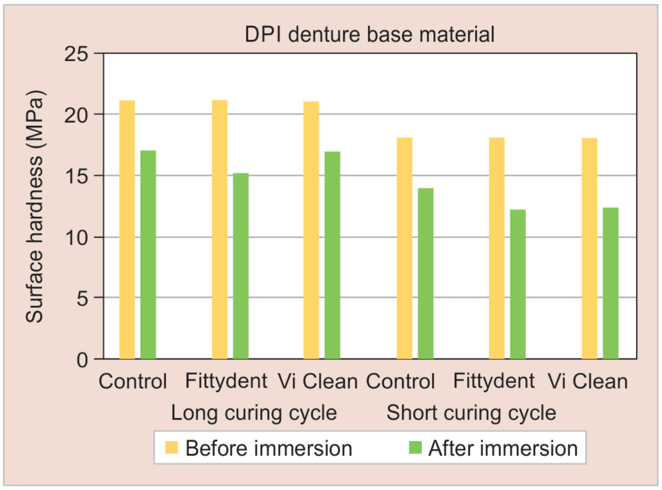

Fig. 4: Surface hardness of DPI samples before and after treatment with disinfecting agents

Discussion

Maintaining the hygiene of the oral prostheses is critical to ensure the oral health of the patient and to prevent any cross-contamination. The chemical method of disinfection, using different types of cleansers, is commonly employed by patients to clean their prostheses. Any agent used for cleaning the prosthesis should have an effective cleansing action and not cause any adverse effect on other properties of the material used to fabricate the prosthesis.

The present study investigated the effect of two commonly used cleansers, Fittydent tablets (sodium perborate-based disinfectant) and Vi Clean Liquid (hypochlorite-based disinfectant), on the surface roughness and hardness of two commercially available PMMA denture base materials processed using different curing cycles. Heat-cure PMMA was selected for the study as it is one of the most widely used materials for fabricating dental prostheses. Though long and short curing cycles are routinely used for processing the material, several clinicians prefer the short curing cycle as it is faster. The long curing time is regarded as a better alternative by some researchers, as it is believed to reduce the residual monomer content and enhance the material's structural integrity.[14]

Two commercially available disinfecting agents, commonly used by patients, were chosen for the study. The disinfecting solutions were prepared as per the manufacturer's instructions, and PMMA samples were immersed in them for 8 hours daily for 12 months. In our study, both disinfecting agents increased the surface roughness of PMMA. However, the sodium perborate-based disinfectant (Fittydent) had a more significant effect on surface roughness compared to the hypochlorite-based disinfectant (Vi Clean). When the sodium perborate-based tablet (Fittydent) is dissolved in water, it produces hydrogen peroxide, sodium metaborate, and nascent oxygen.[15] There is a rapid release of oxygen bubbles, which facilitates both mechanical and chemical cleansing. The higher surface roughness observed in the PMMA samples after immersion in sodium perborate-based disinfectant can be ascribed to the rapid release of oxygen from the solution, which may have affected the surface of the immersed PMMA samples. Similar findings have been reported by Machado et al., 2009, and Ozyilmaz and Akin, 2019.[9,16]

The effect of disinfecting solutions depends upon their concentration and duration of the period. It has been reported that higher concentrations of sodium hypochlorite (1–5.25%) can cause detrimental effects on the surface characteristics as well as color stability of the denture.[17] Lower concentrations of sodium hypochlorite have been proven to be effective in reducing the bacterial count without altering the properties of the PMMA material. However, long-term or repeated use of these disinfectants has been shown to modify the mechanical properties even when used in low concentrations.[8]

The PMMA samples made with the short curing cycle had significantly higher surface roughness than those made with long curing cycles when treated with the two disinfecting agents used in the study. This can be attributed to the fact that the samples made with a short curing cycle may contain a more significant amount of residual monomer, which may leach out when immersed in disinfectant solutions and cause porosity and irregular surface texture. The conversion of monomer to polymer is reported to be higher for PMMA samples when subjected to a long curing cycle, which increases their resistance to dissolution.[18] Hence, the effect of disinfecting solutions was more significant in the case of samples made by a short curing cycle, which demonstrated higher surface roughness. The surface roughness of a prosthetic material has great clinical significance, as rougher surfaces are known to increase microbial adhesion and colonization. A surface roughness value of 0.2 µm is considered the threshold for microbial colonization.[19,20] In the present study, the surface roughness of all PMMA samples increased upon immersion in the two disinfecting solutions, but the value was within the threshold limit (<0.2 µm).

A material's surface hardness indicates its abrasion resistance.[21] High surface hardness prevents the material from wearing/abrading easily under the masticatory forces in the oral environment or during cleaning of the prosthesis with cleansers/toothbrush, etc., thereby enhancing its longevity. The surface hardness of PMMA samples made with a longer curing cycle demonstrated higher surface hardness. This can be attributed to a longer curing cycle resulting in more complete polymerization with higher monomer-to-polymer conversion, enhancing the surface structural integrity and hardness.[22] The surface hardness of all the PMMA samples was lowered upon immersion in the two disinfectant solutions. Similar findings have been reported by Moslehifard et al., 2022 and Rocha et al., 2021.[23,24] PMMA tends to slowly absorb water when placed in aqueous environments such as in water, cleaning/disinfecting solutions, etc. The water molecules within the resin matrix act as plasticizers and affect the entanglement of polymer chains, pushing them apart and decreasing the surface hardness and mechanical properties of the resin.[25]

Conclusion

Within the limitations of the study, repeated use of the sodium perborate-based disinfectant and hypochlorite-based disinfectant used in the study brought about a significant decrease in the surface roughness and surface hardness of the two PMMA denture bases. The effect of the two disinfectants was more profound in samples processed by a short curing cycle. It is crucial to select the appropriate denture cleanser and follow the manufacturers' instructions to ensure that the other properties of the prosthesis are not affected.

Data Availability

The data used to support the findings of this study are available from the corresponding author upon request.

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