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Effect of different denture cleansers on surface roughness and microhardness of artificial denture teeth

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PURPOSE. The aim of this study was to compare the effects of different denture cleansers on the surface roughness and microhardness of various types of posterior denture teeth. **MATERIALS AND METHODS.** 168 artificial tooth specimens were divided into the following four subgroups (n=42): SR Orthotyp PE (polymethylmethacrylate); SR Orthosit PE (Isosit); SR Postaris DCL (double cross-linked); and SR Phonares II (nanohybrid composite). The specimens were further divided according to the type of the denture cleanser (Corega Tabs (sodium perborate), sodium hypochlorite (NaOCl), and distilled water (control) (n=14)) and immersed in the cleanser to simulate a 180-day immersion period, after which the surface roughness and microhardness were tested. The data were analyzed using the Kruskal–Wallis test, Conover's nonparametric multiple comparison test, and Spearman's rank correlation analysis ($P<.05$). **RESULTS.** A comparison among the denture cleanser groups showed that NaOCl caused significantly higher roughness values on SR Orthotyp PE specimens when compared with the other artificial teeth ($P<.001$). Furthermore, Corega Tabs resulted in higher microhardness values in SR Orthotyp PE specimens than distilled water and NaOCl ($P<.005$). The microhardness values decreased significantly from distilled water, NaOCl, to Corega Tabs for SR Orthosit PE specimens ($P<.001$). SR Postaris DLC specimens showed increased microhardness when immersed in distilled water or NaOCl when compared with immersion in Corega Tabs ($P<.003$). No correlation was found between surface roughness and microhardness (r=0.104, $P=.178$). **CONCLUSION.** NaOCl and Corega Tabs affected the surface roughness and microhardness of all artificial denture teeth except for the new generation nanohybrid composite teeth. ***[J Adv Prosthodont 2016;8:333-8]***

KEYWORDS: Denture cleansers; Sodium perborate; Sodium hypochlorite; Complete denture; Mechanical properties; Physical properties

INTRODUCTION

Home care instructions provided to patients after insertion of complete dentures are important in maintaining oral mucosal health and the longevity of the prostheses. Beyond the concern for esthetics, poor oral hygiene can lead to biofilm formation and oral infections, especially in elderly patients.[1] The most commonly used method for cleaning denture is mechanical cleaning using detergent, soap, or toothpaste.[2] Older patients often face a difficulty in mechanical removal of plaque because of reduced manual dexterity or impaired vision or physical limitations.[3] Chemical cleansers are alternatives to mechanical cleaning. For cleaning, dentures should be immersed in the chemical solutions for a certain period of time. These solutions may include one or a combination of various active agents, such as sodium hypochlorite (NaOCl), chlorhexidine, alkaline peroxides, enzymes, and diluted acids.[4] An ideal denture cleanser should reduce biofilm accumulation and be antibacterial, antifungal, non-toxic, short-acting, easy to use, and cost-

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effective.[1,4,5] Also, an ideal denture cleanser should not have any detrimental effect on the denture materials.[4] However, long-term immersion or incorrect use of chemical denture cleansers may adversely alter the physical and mechanical properties of the artificial denture teeth and base materials.[5]

Artificial teeth are an important component of conventional complete denture and play a significant role in the esthetics and functional treatment outcomes.[6] Currently, there are different types of artificial teeth available on the market. Porcelain teeth have been used because of their superior esthetics, resistance to wear and discoloration properties.[7] However, acrylic resin teeth are more beneficial because of their natural texture, high resiliency, adequate mechanical strength, ease of occlusal adjustment, and high bond strength to the denture base.[8]

Conventional acrylic resin denture teeth are primarily composed of polymethylmethacrylate (PMMA) polymers. To improve mechanical properties, highly cross-linked acrylic resin and microfilled composite resin (Isosit) teeth have been developed.[9] A newer generation of composite resin teeth has been introduced, consisting of a nanohybrid composite (NHC) material on a urethane dimethacrylate (UDMA) matrix, which includes various types and sizes of fillers as well as PMMA clusters. The NHC material comprises a variety of fillers, including highly cross-linked inorganic macrofillers, highly densified inorganic microfillers, and silanized nanoscale fillers based on silicon dioxide.[10]

Artificial denture teeth usually consist of enamel and dentin layers, and some composite resin teeth may also have intermediate layers. Each layer has varying degree of hardness and roughness. The enamel layer is often removed due to masticatory wear or chairside occlusal or laboratory adjustments, leading to exposure of the subenamel layers.[6] It has been reported that the different layers of denture teeth are affected differently by denture cleansers.[11]

Studies have shown that dental materials differ in their susceptibility to oral bacteria, which has most commonly been attributed to differences in their surface roughnesses.[12-14] Surface roughness is of a particular clinical relevance for artificial teeth as it can cause staining, biofilm retention, or difficult biofilm removal.[5,15] Hardness, which is defined as resistance of a material to plastic deformation measured as a force per unit area under indentation, has been used to assess the mechanical properties of materials, ease of finishing and polishing, resistance to scratching, and wear resistance of many restorative materials, including artificial denture teeth.[6,12]

The immersion of a denture fabricated using these new generation artificial teeth to achieve disinfection or sterilization is important. However, chemical denture cleansers may have negative effects on the physical and mechanical properties of the artificial denture teeth.[3,16-18] Therefore, the findings of this study will enable dental practitioners to select the most appropriate artificial denture tooth materials and/or cleansers for their patients.

There are numerous studies that report the changes in the mechanical and physical properties of artificial teeth exposed to sodium hypochlorite[16,17,19,20] and sodium perborate.[20] However, to our knowledge, there has been no study evaluating the effects of cleansers on new generation artificial denture teeth. Hence, this study aims to compare the effect of NaOCl and alkaline peroxide solutions on the surface roughness and hardness of different types of artificial teeth with various compositions. The hypothesis tested was that immersion in NaOCl and effervescent alkaline peroxide tablets would influence the surface roughness and microhardness of all artificial teeth tested.

MATERIALS AND METHODS

Four types of artificial molar denture teeth were used in this study (Table 1). All teeth were sectioned with a low-speed cutting machine (Isomet 1000, Buehler Ltd., Lake Bluff, IL, USA) to obtain bucco-lingual slices of 2.3 ± 0.1 mm thickness. Forty-two specimens were prepared for each artificial tooth group as described in Table 1. The slice at the each end of mesial and lingual sides that was thinner than 2.3 mm was not used. Each specimen was embedded in autopolymerizing acrylic resin (Steady Resin Scheu-Dental GmbH, Iserlohn, Germany) using a rectangular plastic mold. A custom-made surveyor was used to ensure the specimen surfaces were parallel to the workbench. The specimen surfaces were ground flat and finished with silicon carbide abrasive paper (English Abrasives & Chemicals, Stafford, England) in the order of 200-, 400-, 600-, 800-, and 1200-grit, and then polished using an aluminum oxide paste (Universal Polishing Paste, Ivoclar Vivadent, Schaan Fürstentum, Liechtenstein). The same operator performed all finishing procedures. The specimens were then stored in distilled water at room temperature (23 ± 2°C) for 7 days before the immersion procedures. According to the manufacturer, the denture teeth involved two to four layering schemes (cervical-dentine-enamel-pearl effect layers). Hence, surface roughness and microhardness tests were carried out on the dentine layer of each specimen to simulate clinical conditions.

The artificial teeth specimens were randomly divided into three subgroups according to the denture cleanser types (n = 14) (Table 1):

1. Corega Tabs
2. NaOCl
3. Distilled water (control)

Corega Tabs (effervescent denture cleanser) were prepared according to the manufacturer's instructions, by adding one tablet to 200 mL of warm water (40°C). After each cycle of 5 minutes, the soaking solution was discarded and the specimens were rinsed thoroughly under running water. Between the soaking procedures, the specimens were kept in distilled water at room temperature. Immersion procedures were repeated 180 times to simulate 180-day of use. For the group immersed in NaOCl, the total immersion period was 15 hours to simulate 5 minutes of daily immersion.[21] For the control group, the specimens were kept in distilled water at room temperature for 15 hours. Distilled water was preferred because of its uniformity and purity.[21]

Table 1. Artificial teeth and denture cleansers used in this study

Tooth Type and denture cleansers	Composition	Manufacturer	Lot number
SR Orthotyp PE	Unfilled PMMA	Ivoclar Vivadent, AG FL-9494 Schaan, Liechtenstein	SP1496
SR Orthosit PE	Microfilled resin composite (Isosit + inorganic fillers) UDMA	Ivoclar Vivadent, AG FL-9494 Schaan, Liechtenstein	SP1494
SR Postaris DCL	DCL-PMMA/UDMA with 20% prepolymerized PMMA	Ivoclar Vivadent, AG FL-9494 Schaan, Liechtenstein	RP0304
SR Phonares II	NHC (UDMA + fillers + PMMA cluster)	Ivoclar Vivadent, AG FL-9494 Schaan, Liechtenstein	SP1018
Corega Tabs	Sodium bicarbonate, citric acid, potassium caroate (potassium monopersulphate), sodium carbonate, sodium carbonate peroxite, TAED, sodium benzoate, PEG-180, sodium laurile sulphoacetate, PVP/VA copolymer, aroma, subtilisin, CI42090, CI73015	Stafford-Miller Limited, Clocherane, Youghal Road, Dungarvan, Co. Waterford, Ireland	3T14134A
NaOCl	Sodium hypochlorite solution 1% active chlorine	Aklar Kimya, Ankara, Turkey	-

PMMA: polymethyl methacrylate; DCL: polymer double cross-linked; UDMA: urethane dimethacrylate; NHC: nanohybrid composite

Following immersion procedures, all specimens were subjected to surface roughness measurement tests. Prior to the surface roughness analysis, all specimens were cleaned in an ultrasonic bath and dried. The surface roughness (R*a* in µm) was measured on each specimen surface using the Mitutoyo Surftest-402 Surface Roughness Tester (Mitutoyo Corporation, Tokyo, Japan) with a standard cut-off value of 0.8 mm. Prior to measuring, the profilometer was calibrated against a reference block, whose the R*a* value was 3.05 µm. Three tracings at randomly selected locations on each specimen were made at a distance of 4 mm apart, and the mean value was calculated.

After surface cleaning using a steam cleaner, the Vickers hardness number (VHN) measurement was performed on all specimens with a microindentation system (HMV Micro Hardness Tester, Shimadzu Corporation, Tokyo, Japan) using the Vickers diamond indenter with a 0.5 N load for a dwell time of 15 seconds. Three indentations per specimen were made with a spacing of at least 50 µm between each indentation. The microhardness mean value was then calculated for each specimen.

Data analysis was performed using SPSS for Windows, version 11.5 (SPSS Inc., Chicago, IL, USA). Data were shown as mean ± standard deviation or median (min–max), where applicable. The statistical analyses were performed using Kruskal-Wallis test, Conover's nonparametric multiple comparison test, and Spearman's rank correlation analysis. A P value less than .05 was considered statistically significant. However, for all possible multiple comparisons, the Bonferrroni correction was applied to control Type I error.

RESULTS

The data obtained after surface roughness and microhardness tests were determined by comparing each specimen value after immersion in distilled water and denture cleansers.

Table 2 demonstrates the surface roughness values (R*a* in µm) of the different artificial teeth groups subjected to various denture cleansers. While Orthotyp PE and Postaris DLC showed no significant difference ($P > .005$), the roughness values decreased in the control group in the order of SR Phonares II, SR Orthosit PE, and Orthotyp PE ($P < .005$). When comparing denture cleanser groups, NaOCl caused significantly higher roughness values on Orthotyp PE group ($P < .001$). However, there was no statistically significant difference between denture cleansers for the other groups ($P >$ .005).

Microhardness values for the different types of artificial teeth subjected to the various denture cleansers are shown in Table 3. Orthosit PE had significantly higher microhardness values after immersion in distilled water when compared with the other groups ($P < .001$). For SR Orthotyp PE, Corega Tabs caused higher microhardness values than distilled water and NaOCl ($P < .005$). Microhardness values decreased significantly for the SR Orthosit PE group in the order of immersion in distilled water, NaOCl, and Corega Tabs ($P < .001$). SR Postaris DLC specimens showed higher microhardness when immersed in distilled water or NaOCl compared with immersion in Corega Tabs ($P < .003$).

There was no statistically significant correlation between roughness and microhardness values ($r = 0.104$, $P = .178$).

Table 2. Median (interquartile range) surface roughness (R*a* in μm) values according to artificial teeth and denture cleanser

	SR Orthotyp PE	SR Orthosit PE	SR Postaris DLC	SR Phonares II	*P* value
Distilled water	0.07 (0.04)[A,B,a]	0.10 (0.03)[A,C]	0.09 (0.03)[D]	0.13 (0.04)[B,C,D]	< .001
Corega Tabs	0.10 (0.03)[B,b]	0.09 (0.03)[C]	0.09 (0.03)[D]	0.13 (0.03)[B,C,D]	< .001
NaOCl	0.16 (0.06)[A,E,a,b]	0.11 (0.03)[A,C]	0.11 (0.02)[D,E]	0.13 (0.03)[C,D]	< .001
P value	< .001	.132	.096	.906	

*Same superscript letters denote statistical significance ($P < .05$)
A: There are statistically significant differences between SR Orthotyp PE and SR Orthosit PE groups ($P < .017$)
B: There are statistically significant differences between SR Orthotyp PE and SR Phonares II groups ($P < .001$)
C: There are statistically significant differences between SR Orthosit PE and SR Phonares II groups ($P < .01$)
D: There are statistically significant differences between SR Postaris DLC and SR Phonares II groups ($P < .017$)
E: There are statistically significant differences between SR Orthotyp PE and SR Postaris DLC groups ($P < .001$)
a: There are significant differences between distilled water and NaOCl groups ($P < .001$)
b: There are significant differences between Corega Tabs and NaOCl groups ($P < .001$)

Table 3. Median (interquartile range) VHN values according to artificial teeth and denture cleansers

	SR Orthotyp PE	SR Orthosit PE	SR Postaris DLC	SR Phonares II	*P* value
Distilled water	26.15 (4.05)[A,a]	33.85 (2.22)[A,B,C,a,c]	25.75 (3.47)[B,a]	27.80 (5.85)[C]	<.001
Corega Tabs	32.45 (2.80)[A,D,E,a,b]	23.70 (1.97)[A,C,a,b]	23.55 (2.35)[D,F,a,b]	26.25 (2.90)[C,E,F]	<.001
NaOCl	28.75 (10.27)[b]	28.20 (3.65)[b,c]	25.75 (1.60)[b]	27.85 (3.12)	.049
P value	.005	<.001	.003	.582	

*Same superscript letters denote statistical significance ($P < .05$)
A: There are statistically significant differences between SR Orthotyp PE and SR Orthosit PE groups ($P < .001$)
B: There are statistically significant differences between SR Orthosit PE and SR Postaris DLC groups ($P < .001$)
C: There are statistically significant differences between SR Orthosit PE and SR Phonares II groups ($P < .017$)
D: There are statistically significant differences between SR Orthotyp PE and SR Postaris DLC groups ($P < .001$)
E: There are statistically significant differences between SR Phonares II and SR Orthotyp PE groups ($P = .002$)
F: There are statistically significant differences between SR Postaris DLC and SR Phonares II groups ($P = .004$)
a: There are significant differences between distilled water and Corega tabs groups ($P < .001$)
b: There are significant differences between Corega Tabs and NaOCl groups ($P < .001$)
c: There are significant differences between Distilled water and NaOCl groups ($P < .002$)

DISCUSSION

The present study evaluated the effect of various denture cleansers on surface roughness and microhardness of different types of artificial denture teeth. The null hypothesis tested was partially accepted; NaOCl and effervescent alkaline peroxide tablets changed the surface roughness and/or hardness of only some of the artificial teeth tested. The SR Phonares II specimen surfaces showed no difference after immersion in any of the mediums.

There are controversial opinions in the literature related to the effects of denture cleansers on surface roughness and hardness of denture materials.[17,18,22] Differing compositions of cleansing solutions and materials, and different testing methods may be responsible for the controversy.

The surface roughness of dental materials has been shown to be of particular importance for adhesion of oral bacteria;[12-14] hence, smoother surfaces will result in denture longevity.[18] Profilometry and its numerical data has been shown to be useful in the evaluation of the roughness of dental materials.[18] Bollen *et al.*[13] found a threshold value of 0.2 μm, suggesting that low roughness levels do not influence adhesion. In the present study, although NaOCl caused significantly higher roughness values on Orthotyp PE group specimens, the surface roughness values were lower than the threshold for all tested specimens; therefore, adverse effects of denture cleansers on surface roughness may be neglected.

A valid tool for determining the hardness of rigid polymers is the Vickers microhardness test, which is based upon the ability of the surface of a material to resist point penetration under a certain load.[23] Hence, this test has been used in many studies,[19,20] including the present study, to evaluate the hardness of denture base acrylic resin and artificial denture teeth.

Cross-linkage is a descriptive term for the composition of artificial denture teeth, and the manufacturers do not indicate the number or exact type of covalent links present in the polymeric structure.[17] It is possible that different cleansing solutions have variable influences on commercial teeth. This suggests that the number of pressing during the tooth's manufacturing process is equally as important as cross-linkage, mainly because of the residual monomer absence. In the present study, immersion in Corega Tabs increased the hardness of SR Orthotyp PE group specimens. This result may be explained by the fact that these artificial teeth are less resistant to the loss of plasticizers and do not have cross-linking chains, which reduce their resistance. This is also in accordance with the results of Pisani *et al*.[16] However, a decrease in hardness was noted in SR Orthosit PE and SR Postaris DCL group specimens immersed in Corega Tabs. In agreement with the results of previous studies,[16,20] the absorption of aqueous cleansing solutions may have caused a decrease in hardness because these solutions may have acted as plasticizers. Small molecules of water diffuse into the polymer mass and cause relaxation of polymer chains, consequently reducing the hardness of the artificial teeth, which is similar to the process that occurs in acrylic resin.[24] Grinding the tooth surfaces may have formed microcracks, leading to infiltration of the solutions and accelerating the process of PMMA plasticization.

Denture cleaning by immersion in a chemical solution should not involve any physical, mechanical, or chemical change in the artificial teeth. No significant effect on surface roughness or microhardness of the new generation nanohybrid artificial teeth was found after immersion in any of the cleansing mediums used in the present study, which reflected a promising future preference. However, *in vivo* and further *in vitro* research should be carried out to clarify the mechanical, physical, and optical properties of this new material.

There are a number of limitations in the present *in vitro* study. Examination of the artificial teeth surfaces using scanning electron microscopy could have been carried out after immersion in the various cleansers for visual comparison. Furthermore, several types of artificial teeth of different compositions of only one brand have been evaluated in this study, and *in vitro*, not clinical, tests were performed. In future studies, other oral environment conditions, such as continuous cyclic loading and the use of artificial saliva, could be evaluated. Furthermore, chemical denture cleansers could be accompanied by mechanical brushing to determine the association related to changes in surface properties.

CONCLUSION

Within the limitations of the present *in vitro* study, the following conclusions may be drawn:

NaOCl caused significantly higher roughness values on Orthotyp PE group specimens ($P < .001$).

Corega Tabs caused higher microhardness values than distilled water and NaOCl for SR Orthotyp PE specimens ($P < .005$). Microhardness values decreased significantly for the SR Orthosit PE ($P < .005$) and SR Postaris DCL groups ($P < .003$) following immersion in Corega Tabs.

There was no statistically significant correlation between roughness and microhardness values ($r = 0.104$, $P = .178$).

Immersion in any of the tested cleansing solutions did not cause a significant change in the surface roughness or microhardness of the new generation SR Phonares II artificial teeth.

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