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The effect of cleaning substances on the surface of denture base material

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Study Design A
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Statistical Analysis C
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Background: The aim of this study was to evaluate the effect of substances used for hygienic cleaning of dentures on the surface of the denture base material.





Material/Methods: Meliodent Heat Cure (Heraeus-Kulzer, Germany) heat-polymerized acrylic resin was used to produce plates with all the characteristics of removable denture bases (subsequently, "plates"). Oral-B Complete toothbrushes of various brush head types were fixed to a device that imitated tooth brushing movements; table salt and baking soda (frequently used by patients to improve tooth brushing results), toothpaste ("Colgate Total"), and water were also applied. Changes in plate surfaces were monitored by measuring surface reflection alterations on spectrometry. Measurements were conducted before the cleaning and at 2 and 6 hours after cleaning.

Results: No statistically significant differences were found between the 3 test series. All 3 plates used in the study underwent statistically significant ($p < 0.05$) changes – the reflection became poorer. The plates were most affected by the medium-bristle toothbrush with baking soda – the total reflection reduction was $4.82 \pm 0.1\%$; among toothbrushes with toothpaste, the hard-type toothbrush had the greatest reflection-reducing effect – $4.6 \pm 0.05\%$, while the toothbrush with table salt inflicted the least damage ($3.5 \pm 0.16\%$) due to the presence of rounded crystals between the bristles and the resin surface. Toothbrushes with water had a uniform negative effect on the plate surface – $3.89 \pm 0.07\%$.

Conclusions: All substances used by the patients caused surface abrasion of the denture base material, which reduced the reflection; a hard toothbrush with toothpaste had the greatest abrasive effect, while soft toothbrushes inflicted the least damage.

Key words: dental materials • surface analysis • removable dentures • hygiene

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Background

In clinical practice, patients frequently ask their physicians about removable denture care, which is often insufficient and sometimes is absent altogether). A questionnaire-based survey was conducted at Lithuanian University of Health Sciences (LUHS) Clinic of Orthopedic Odontology. The survey showed that patients most frequently used wet toothbrushes for the care of their dentures, with sodium chloride (table salt), sodium hydrogen carbonate (baking soda), or toothpaste “Colgate Total” applied as cleaning substances. The participants of the survey stated that they usually cleaned their dentures 3 times per day for 1–2 minutes each time.

Even though there are various denture care techniques such as disinfecting tablets, disinfection with microwaves or ozone [1–3], or plaque removal with ultrasound [4], these techniques are not as common as toothbrush use is. Patients do not realize that the use of cheap additional substances available in every household may damage their dentures. Increasing rough surface area and the number of scratches result in multiple micro-retention zones that accumulate microorganisms and cause formation of dental calculi on the dentures. All these changes in dentures may result in mucosal irritation and halitosis [5,6]. This causes psychological discomfort, nausea, and social problems [7]. In some cases, patients discontinue regular use of their dentures, and eventually they become ill-fitting. The aim of the study was to evaluate the possible damage to the dentures caused by denture care measures, and to develop recommendations concerning the care of removable dentures.

Material and Methods

Plates with all the characteristics of removable denture bases were produced from heat-polymerized acrylic resin Meliodent Heat Cure (Heraeus-Kulzer, Germany) used for denture manufacturing; the plates were produced following the polymerization regimen set by the manufacturer. Polishing and buffing of the plates was carried out following the removable denture production standards; the plates were then cut into 1.5×5 cm strips, which were numbered. Following that, each strip was assigned hard-, medium-, or soft-bristled toothbrushes (Oral-B Complete) with additional cleaning substances. The following groups were formed:

1. a wet medium-bristled toothbrush;
2. a wet medium-bristled toothbrush with toothpaste “Colgate Total”;
3. a wet medium-bristled toothbrush with crystalline sodium hydrogen carbonate;
4. a wet medium-bristled toothbrush with crystalline sodium chloride;
5. a wet soft-bristled toothbrush with toothpaste “Colgate Total”;

6. a wet hard-bristled toothbrush with toothpaste “Colgate Total”.

Reflection measurements of the plates were conducted prior to the testing and after 2 and 6 hours. This test was conducted in quintuplicate.

A device imitating tooth brushing movements was constructed. Within 1 minute it performed 100 reciprocal movements with the amplitude of 1.5 cm, and with 2.4 N pressure force of the toothbrush on the plate. The plates were monitored with a USB4000 (OceanOptics) spectrometer by measuring surface reflection in 2 wavelengths: 250–400 nm – for small scratches, and 600–800 nm – for large scratches. During the denture cleaning simulation, a new 0.5 g dose of the abrasive substance and 0.5 mL of water were reapplied on the plates every 10 minutes. The plates were placed in a holder under the spectrometer so that their measured areas would coincide.

During each studied exposure, 708 automatic spectrometry measurements were performed at the wavelength of 250–400 nm in each plate. Every plate was examined prior to the simulation, and after 2 and 6 hours of testing. In total, the monitoring of each studied plate yielded 2124 reflection measurements of different points of the evaluated surface. At the wavelength of 600–800 nm, 1075 spectrometry measurements were performed in each plate. In total, 3225 reflection measurements of different points of the evaluated surface were obtained from each studied plate after the simulation sequence.

Results

The evaluation of differences in plate surface reflection showed that all abrasive substances altered the reflection. Evaluation of the mean values by applying the dispersion analysis, ANOVA, and Tukey’s method showed no statistically significant difference between the results of the 5 tests ($p > 0.05$). Statistically significant ($p < 0.05$) changes were observed in all studied plates after the tooth brushing simulation (Table 1).

Medium-bristle toothbrushes inflicted most damage when used with baking soda (NaHCO_3) – they reduced the surface reflection by $4.82 \pm 0.1\%$. Table salt inflicted the least damage when applied on a medium-bristle toothbrush – the surface reflection reduction was $3.5 \pm 0.16\%$ (Figure 1).

When comparing the effect of toothbrushes with toothpaste (“Colgate Total”) applied, the least damage was observed with a soft-bristled toothbrush – the surface reflection decreased by $3.01 \pm 0.12\%$ ($p > 0.05$). The most damage was inflicted with a hard-bristled toothbrush – the surface reflection reduction was $4.6 \pm 0.05\%$.

Table 1. Surface reflection variations.

Wavelength (nm)	Reflection at 0 h (%)		Reflection after 2 h (%)		Reflection after 6 h (%)		Total reflection (%)		Total reflection reduction (%)
	250–400	600–800	250–400	600–800	250–400	600–800	At 0 h	After 6 h	
Mirror (calibration)	95.43	99.37							
1 plate (water)	3.31±0.18	4.88±0.26	2.15±0.2	4.01±0.22	1.28±0.25	3.02±0.42	8.19±0.1	4.3±0.24	3.89±0.07
2 plate (toothpaste)	3.67±0.17	4.18±0.34	3.61±0.18	4.06±0.38	0.97±0.29	2.77±0.05	7.85±0.14	3.74±0.33	4.11±0.13
3 plate (baking soda)	3.63±0.28	5.05±0.15	3.33±0.38	3.56±0.18	1.92±0.34	1.67±0.42	8.41±0.1	3.59±0.03	4.81±0.1
4 plate (table salt)	3.92±0.29	3.97±0.24	2.74±0.36	2.92±0.26	1.61±0.27	2.79±0.55	7.9±0.14	4.4±0.38	3.5±0.16
5 plate (toothpaste)	3.56±0.24	2.28±0.24	2.67±0.22	1.18±0.2	1.77±0.35	1.06±0.45	5.84±0.12	2.83±0.33	3.01±0.12
6 plate (toothpaste)	3.66±0.29	2.13±0.19	2±0.34	2.01±0.33	0.05±0.25	1.14±0.39	5.79±0.12	0.19±0.2	4.6±0.05

* ±SD.

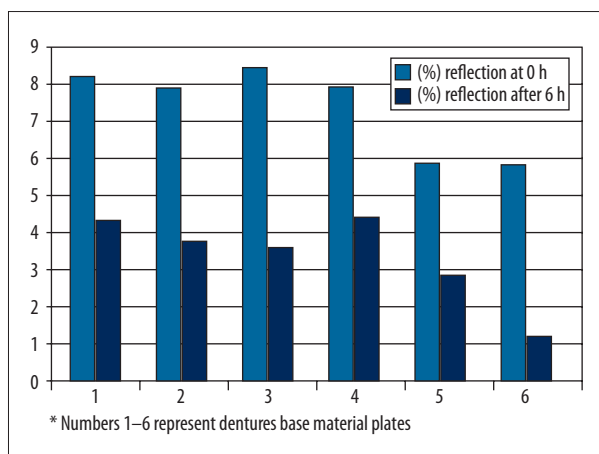


Figure 1. Surface reflection changes (%) in the studied groups within six hours of testing.

When testing medium-bristle toothbrushes, the fewest small scratches were detected with the tested toothpaste – the surface reflection dropped by $2.7\pm 0.11\%$. The greatest number of large scratches was found when using baking soda – the surface reflection reduction was $3.38\pm 0.2\%$.

Discussion

Removable denture care has been actively researched for a number of years, yet the number of articles in the literature

suitable for this study was scarce. More attention is usually paid to denture attrition, its mass reduction, or measurement of microgrooves left by toothbrushes [8,9]. The results of our study were based on changes in plate surface reflection, indicating the general wear of the denture surface.

Other authors found no statistical difference between scratches inflicted by various toothbrushes on the surface of different heat polymerized acrylic resins [9]. In our study, we used heat-polymerized acrylic resin, Meliodent Heat Cure (Heraeus-Kulzer, Germany). This would mean that the results of the study should be irrespective of the manufacturer of the heat-polymerized acrylic resin.

According to some authors the main difference between artificial teeth and denture base materials is the incorporation of tooth-colored pigments rather than pink ones. The Vickers hardness number (VHN) of both materials is 20 [10]. Because there is no difference in the hardness, there were no tests conducted to test the acrylic teeth wear caused by the toothbrush.

The technique of this study was based on the questionnaire survey data concerning the most common hygienic denture care techniques used by 110 patients with removable dentures. The study simulated all variants of the additional substances used in the cleaning of dentures, taking into account the most common use of medium-bristle toothbrushes. Surveyed patients indicated that they mostly used “Colgate Total” toothpaste for

denture cleaning. To evaluate the effect of toothbrushes with different brush head types on the surface of the acrylic resin, soft-bristled and hard-bristled toothbrushes were used in the test with toothpaste.

When constructing the device that imitated tooth brushing, we tried to reproduce the actual movements of the toothbrush in the oral cavity, thus the rotational movement (which causes greater surface changes) was replaced with the reciprocal movement [11]. The toothbrush was pressed against the surface with a force of 2.4 N; the selection of such force was based on the mean value of the force most frequently applied during tooth brushing [9,12,13]. The toothbrush movement speed (50 mm/s) was selected on the basis of *in vivo* studies, where it ranged between 30 and 150 mm/s [14,15].

The results of our study confirmed that baking soda has stronger abrasive characteristics compared to table salt, although both substances are of equal hardness according to the Mohs scale – 2.5 [16]. The literature also describes baking soda as a strong abrasive substance [17]. This is associated with the crystal structure and a better solubility of NaCl in water (35.89 g/100 g water at 20°C), compared to NaHCO₃ (9.6 g/100 g water at 20°C) [18]. The residual amount of undissolved crystals causes changes in the surface of the acrylic

resin. We also noticed that table salt was rather aggressive during the first 2 hours, but later on its abrasiveness dropped due to the dissolution and consequent shrinking of its sharp crystals. In other words, more rounded crystals moved between the bristles of the toothbrush and the surface of the plate, thus reducing the abrasiveness of table salt.

Conclusions

In removable denture care, all mechanical cleaning techniques that involve toothbrush use have a negative effect on the denture base surface, yet the use of chemical measures alone is insufficient. When using toothpaste, hard-bristled toothbrushes cause the greatest surface damage. The usage of baking soda is not recommended for removable denture care. Soft-bristled toothbrushes are the best for cleaning removable dentures. Physicians should re-polish removable dentures during their patients' periodic visits.

Statement of conflicts of interest

The authors state they have no financially conflicting relationships with manufacturers of any materials or devices described in the manuscript.

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