

Evaluating the Impact of Different Cleaning Methods on the Water Absorption of “ThermoSens” Denture Base Material

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Abstract

A variety of thermoplastic materials, including “ThermoSens”, a nylon-based denture base material, can be used in the fabrication of removable partial dentures. Assessing the physical properties of these materials is crucial, as they influence not only the aesthetics but also the longevity and functionality of the dentures. Thermoplastic polyamides, known as nylons, represent a key group of flexible materials employed for partially edentulous patients with removable dentures.

Aim. The aim of this study was to evaluate the impact of ten distinct cleaning methods on the water absorption of “ThermoSens”, using the gravimetric method.

Materials and methods. The study involved 50 standardized “ThermoSens” test specimens divided into ten groups, subjected to varied cleaning protocols including Corega and Protefix tablets, soft toothbrush with toothpaste or soap, and no cleaning (control). Cleaning frequency and duration differed across groups, with all specimens stored in artificial saliva at 37°C for 24 hours. Water absorption was measured using a KERN ALJ 120-4 analytical scale, calculated as a percentage of initial mass, adhering to ISO 62 and ASTM D570 standards. Statistical analysis was performed using ANOVA ($p=0.038$) to assess differences between groups.

Results. The results indicate that cleaning methods significantly affect “ThermoSens” water absorption, with Groups 3 and 9 (using Corega tablets and toothbrush with toothpaste, respectively, three times weekly) showing the lowest uptake.

Conclusion. The hydrophobic nature of nylon 12 in “ThermoSens”, with lower amide group density, contributes to its water resistance, supporting its use in dentures, though further research is needed to refine cleaning protocols.

Keywords: denture base material, nylon, water absorption, polyamide, “ThermoSens”, gravimetric method

Introduction

The long-term success of complete and partial removable dentures depends not only on proper fit and occlusion but also on maintaining the physical and mechanical properties of the denture base material throughout years of daily use (1). “ThermoSens” by 3D Systems is a modern injectable,

monomer-free, thermoplastic polyamide resin, it has improved fit and accuracy, better aesthetic properties and hypoallergenic nature, compared to conventional PMMA dentures (2–4).

Daily denture hygiene is essential to prevent plaque accumulation, *Candida albicans* colonisation, denture stomatitis, and malodor (5). Patients choose between chemical and non-chemical cleaning methods, each of which interacts differently with the polymer surface (6). Chemical methods rely on effervescent tablets that release alkaline peroxides, sodium bicarbonate, and active oxygen when dissolved in water. Two of the most commonly prescribed tablets in Bulgaria are Corega Tabs (Stafford Miller/GSK) and Protefix Active Cleanser (Queisser Pharma) (5). Corega contains potassium caroate (persulfate), sodium perborate, and enzymes, generating a strongly alkaline (pH \approx 10–11) and oxidative environment, whereas Protefix uses a milder peroxide-free formula based on sodium bicarbonate, citric acid, and sulfamic acid combined with active oxygen from potassium caroate, maintaining a slightly lower pH (\approx 8.5–9.5). Both tablets are recommended for 5–15 min immersion overnight (7,8).

Non-chemical methods, in contrast, involve mechanical removal of deposits by manual brushing. Patients typically use a soft denture brush with either neutral liquid soap (pH \approx 7–8) or low-abrasive denture-specific toothpaste (RDA $<$ 70). Although brushing is universally recommended by prosthodontists, repeated mechanical action and the abrasiveness of toothpaste particles can create micro-scratches that increase surface roughness (Ra) and potentially facilitate water penetration into the polymer matrix over time (9,10).

Despite the manufacturer's claim of "almost zero water sorption", clinical reality shows that "ThermoSens" dentures are exposed daily to alternating cycles of chemical solutions, mechanical friction, and thermal fluctuations (hot beverages, hot cleaning water). Even minimal increases in water absorption can lead to hydrolytic degradation of polyamide chains, reduced flexural strength, and microscopic crazing, ultimately compromising the material's fatigue resistance (8,11–13).

Aim

The aim of this study was to evaluate the impact of ten distinct cleaning methods on the water absorption of "ThermoSens", using the gravimetric method.

Materials and Methods

A total of 50 test specimens were prepared with dimensions of 65 × 10 × 2.5 mm. The specimens were divided into two main groups—a control group (A) and an experimental group (B)—and further subdivided into ten subgroups (A11–15, B21–105) depending on the specific experimental cleaning conditions to which they were subjected. Ten experimental setups were employed, in which the test specimens were placed to simulate real-world methods of cleaning and storage of flexible prostheses. All test specimens were stored in an incubator at 37 °C for a period of 30 days, being removed only for the application of the respective cleaning methods

Experimental groups based on experimental conditions:

- **First group** (control group, samples A11-15): No cleaning, storage for 24 hours in artificial saliva at 37°C.
- **Second group** (samples B21-25): Daily cleaning with Corega cleaning tablets (GlaxoSmithKline, UK) for 5 minutes, storage for 24 hours in artificial saliva at 37°C.
- **Third group** (samples B31-35): Cleaning three times a week with Corega cleaning tablets (GlaxoSmithKline, UK) for 5 minutes, storage for 24 hours in artificial saliva at 37°C.
- **Fourth group** (samples B41-45): Daily cleaning with Protefix cleaning tablets (Queisser Pharma, Germany) for 10 minutes, storage for 24 hours in artificial saliva at 37°C.
- **Fifth group** (samples B51-55): Daily cleaning with Protefix cleaning tablets (Queisser Pharma, Germany) for 8 hours, storage for 24 hours in artificial saliva at 37°C.
- **Sixth group** (samples B61-65): Cleaning three times a week with Protefix cleaning tablets (Queisser Pharma, Germany) for 10 minutes, storage for 24 hours in artificial saliva at 37°C.
- **Seventh group** (samples B71-75): Cleaning three times a week with Protefix cleaning tablets (Queisser Pharma, Germany) for 8 hours, storage for 24 hours in artificial saliva at 37°C.
- **Eighth group** (samples B81-85): Daily cleaning with a soft brush and toothpaste for 5 seconds per sample, storage for 24 hours in artificial saliva at 37°C.
- **Ninth group** (samples B91-95): Cleaning three times a week with a soft brush and toothpaste for 5 seconds per sample, storage for 24 hours in artificial saliva at 37°C.
- **Tenth group** (samples B101-105): Daily cleaning with a soft brush and soap for 5 seconds per sample, storage for 24 hours in artificial saliva at 37°C.

The gravimetric method (measurement of mass change) was used for the completion of the aim: The specimen is dried, weighed, and then immersed in liquid at a specified temperature for a defined period. After immersion, the specimen is surface-dried and weighed again. For this task, an analytical balance model KERN ALJ 120-4A with a maximum capacity of 120 g was used.

Water absorption is calculated using the following formula:

Water absorption (%) = [(Mass after immersion – Mass before immersion) / Mass before immersion] × 100.

The gravimetric method is the most commonly used technique for investigating water absorption in polyamides, as it provides a clear indication of total water uptake.

Results

The mean weight of the control group was 1.784 g. Specimens in groups 2 and 8 exhibited approximately the same weight. The lightest specimens were those in group 3 (1.727 g), whereas the heaviest were recorded in group 5 (1.799 g) (Fig. 1).

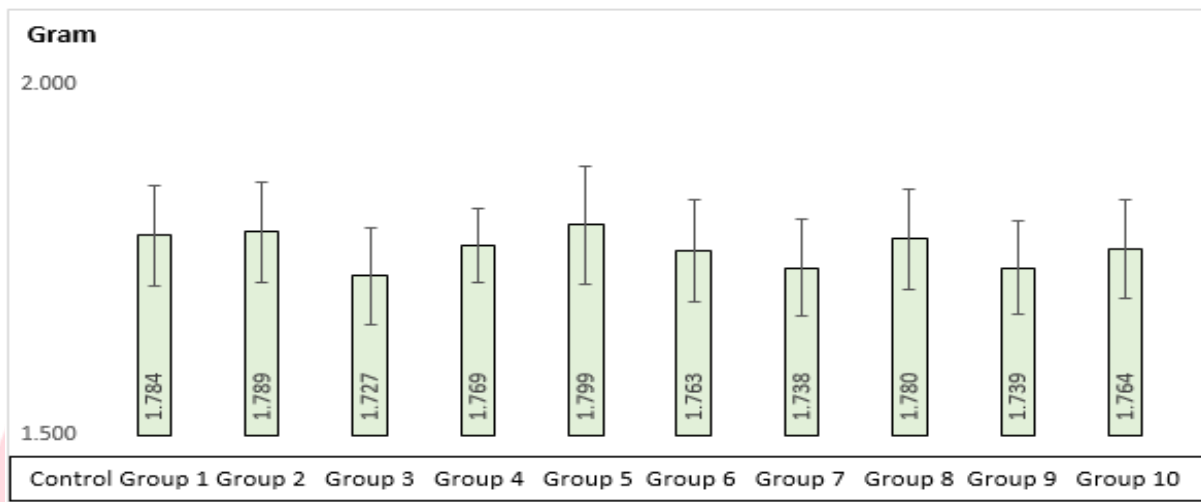


Figure 1. Mean weights of the experimental groups before the experiment (in grams)

For trauma-related indications, most dentists used biologic approaches regardless of experience; the highest proportion (92.3%) was observed in those with 16–25 years of practice. Pearson’s chi-square indicated a significant association between experience and use ($p = 0.017$) (Figure 2).

Following the experiment, the measured values are presented in Fig. 2.

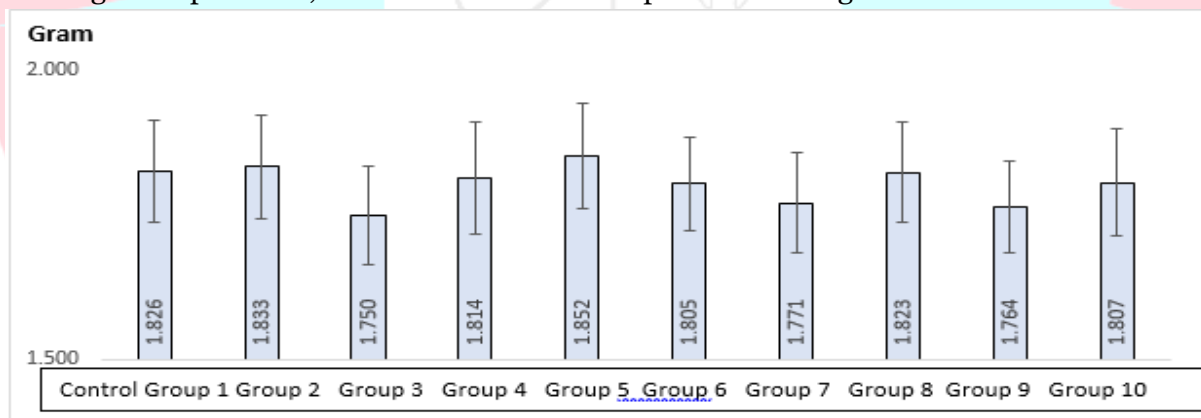


Figure 2. Mean weights of the specimens in the control and experimental groups after the experiment

The results were analyzed using the ISO 62:2008 formula (standardized gravimetric method):
 $\%Absorption = \frac{M_{wet} - M_{dry}}{M_{dry}} \times 100$

The %absorption for all the tested groups ranges from 1.33 – 2.95%. The mean %absorption is 2.22%.

All results were within the normal and clinically accepted range for water absorption of medical devices (ISO 10993-1:2018)

Visual inspection of the graph suggests differences between the control group and certain experimental groups. Whether these differences are statistically significant is determined by the results of the hypothesis testing summarised in Table 1.

Table 1. Results of statistical comparison of weights between the control group and experimental groups after the experiment.

Tested Groups	Characteristics		
	Average	±SD	N
Control Group 1	1.826 ^A	±0.088	5
Group 2	1.833 ^A	±0.089	5
Group 3	1.750 ^B	±0.085	5
Group 4	1.814 ^A	±0.096	5
Group 5	1.852 ^A	±0.090	5
Group 6	1.805 ^A	±0.081	5
Group 7	1.771 ^B	±0.086	5
Group 8	1.823 ^A	±0.087	5
Group 9	1.764 ^B	±0.079	5
Group 10	1.807 ^A	±0.092	5
ANOVA test	p=0.038		

The results clearly indicate an increase in specimen weight across all experimental groups, which was anticipated. Significantly lower water absorption was observed in experimental group 3 (cleaning three times weekly with Corega denture cleansing tablets (GlaxoSmithKline, UK) for 5 minutes, followed by 24-hour storage in artificial saliva at 37 °C).

Group 9 (cleaning three times weekly using only a soft toothbrush and toothpaste for 5 seconds per specimen, followed by 24-hour storage in artificial saliva at 37 °C) also demonstrated relatively low water absorption.

Discussion

The chemical structure of the thermoplastic polyamide “ThermoSens” has a significant impact on its water absorption (14). There is little information regarding the effects of different disinfection and cleaning methods on the water absorption of this polyamide 12 material.

In a study conducted by Takabayashi in 2010 (15), the water absorption of two tested polyamide materials (Valplast and Flexite Supreme) complied with the ISO 62 standard (16), however, Lucitone FRS exhibited the highest water absorption due to its greater degree of hydrophilic properties, as determined by contact angle measurements. The authors concluded that a higher concentration of amide groups leads to increased water absorption. In this regard, it is suggested that the concentration of amide groups in polyamide materials for prostheses can be adjusted to a level comparable to that of widely used materials such as nylon 6 or 66 (15).

In another study by Shah and colleagues in 2014, the water absorption and solubility of conventional PMMA resin were compared with those of flexible polyamide (nylon) resin for prostheses; it was found that heat-cured PMMA exhibited higher water absorption and solubility compared to the flexible resin (17).

Among all experimental groups, group 3 (cleaning three times weekly with Corega cleansing tablets (GlaxoSmithKline, UK) for 5 minutes, followed by 24-hour storage in artificial saliva at 37 °C) demonstrated a significantly lower level of water absorption. A similar conclusion was reached by Helaly and colleagues in a 2018 study investigating whether the use of Corega cleansing tablets affects water absorption in nylon material (18).

All of the tested groups demonstrated water absorption changes within the clinically acceptable ranges (19). The differences in the different disinfection methods can be explained by the effect of these methods on the mechanical properties of the nylon 12 material (19–21).

When comparing polyamide material for partial removable prostheses with materials used for 3D printing of removable prostheses, Aliem Elbanna et al. (22) concluded that the 3D printing material exhibited higher water absorption compared to the thermoplastic polyamide material.

Conclusion

Water absorption was observed in all experimental groups, however it remained in the clinically accepted margins. Experimental groups 3 and 9 demonstrated the least amount of water absorption. The lower water absorption of nylon 12 is attributable to its longer hydrocarbon chain, reduced density of amide groups, and more hydrophobic molecular structure. These properties render it particularly suitable for applications such as dental prostheses, where dimensional stability and moisture resistance are of critical importance.

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