Effect of immersion time in denture cleanser on the transverse strength of heat-cured acrylic resin

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Abstract This study aimed to determine the effect of immersion time in denture cleanser on the transverse strength of heat-cured acrylic resin. Specimens were immersed in denture cleanser and aqua bidest for 7 days, 14 hours, 30 minutes; 10 days, 3 hours, 20 minutes; and 12 days, 16 hours, 10 minutes, which simulated daily 5-minute immersion for 6, 8, and 10 years. Transverse strength was measured by using the 3-point bending method and a universal testing machine. The data were analyzed by independent t-tests and one-way ANOVA. The strength of specimens immersed in denture cleanser did not decrease, contrary to those in aqua bidest in which strength reduction was observed over time. Consequently, the strength of the specimens in aqua bidest were lower than those in denture cleanser, especially at test times corresponding to 8 and 10 years of daily use.

1. Introduction
In 2010, the Indonesian Central Bureau of Statistics conducted research showing that Indonesia had a population of 237,641,326 people and that 18,043,712 were >60 years old [1]. Basic health research in 2007 showed that 72.1% of the Indonesian population had dental caries and approximately 70.4% had not received dental treatment, so many people aged >60 years old who had untreated dental caries had to have teeth extracted [2]. Loss of teeth can disrupt mastication and affect facial aesthetics adversely. One method for restoring both mastication and improving aesthetics is to use a denture.

The type of denture used by many people is a heat-cured acrylic resin-based partial denture. Heat-cured acrylic resin is acrylic resin that has undergone polymerization through thermal activation. This resin has been used by dentists as a denture base since 1946. The resin consists of polymer chains made from monomers during polymerization. The length, branching, and cross-linking and arrangement of the polymer chain are important factors that affect a polymer material’s properties. The links between polymer chains increase with increasing polymer chain length. Consequently, it will be more difficult for polymeric materials to undergo deformation; therefore, the polymer strength value will be higher [3].
Polymers are often connected with other polymers in some form: linearly, through branching, and through cross-linking. Cross-linking forms a bridge between a polymer chain and will form a macromolecule with increased molecular weight. The mechanical and physical properties of the polymer depend on cross-linking within the polymer. In addition, cross-linking can decrease solubility and increase strength and rigidity [3,4].

Plasticizers are often added to resins to make them more malleable (plastic) and to reduce the resin’s tendency to permanently deform when subjected to compressive and tensile forces, in addition to cross-linkage. In general, acrylic resin uses internal plasticizers that will bind to the polymer chain and become a part of its structure [3].

A disadvantage of the polymerization of acrylic resins made from poly(methyl methacrylate) is that it can increase the polymer’s ability to absorb fluid by as much as 0.64 mg/cm² [4]. These properties are caused by the presence of a carboxyl group, which has polar properties. This fluid absorption will soften a denture base, which can weaken the acrylic strength [3,4].

An important property of a denture is good transverse strength. Transverse strength, often referred to as modulus of rupture or flexural strength, is the combination of compressive strength and tensile strength when a denture is used in the mouth for mastication [4]. The transverse strength test simulates a denture’s force distribution experienced in the mouth, which enables the determination of the acrylic resin strength. The transverse strength can be tested by using three-point bending methods and by putting pressure on the middle of the specimen, which is stressed at both ends, until the specimen breaks [4].

*Candida albicans, Streptococcus oralis, Bacteroides gingivalis, B. intermedius, and S. sanguis* are microorganisms that can attach to a denture’s surface. Attachment of these microorganisms will cause periodontal problems [5]. Halitosis, tissue irritation, and fungal infection can occur if a denture is not clean [6]. Dentures must always be kept clean to avoid these problems.

Some of the methods used to clean dentures are brushing with toothpaste or using denture cleanser tablets that dissolve in water [6,7]. For elderly patients, especially for those who have difficulty with their vision and manual dexterity, cleaning the denture can be difficult; therefore, the use of denture cleaning tablets is better than brushing [8]. Denture cleaning tablets work chemically when dissolved in water. One of the active ingredients in denture cleaning solution is sodium perborate. Sodium perborate reacts with water and produces alkaline peroxide. Sodium perborate is often used as a whitening agent and is contained within detergent and denture cleanser [9]. In addition to alkaline peroxide, reactions between sodium perborate and water produce oxygen bubbles that will eliminate biofilms and stains on the denture base [9–11].

Typically, dentures are used for a long time and undergo repeated cleaning while the denture is used. Therefore, questions have arisen concerning whether denture cleaning using an Indonesian denture cleaning solution product can decrease the transverse strength of the denture’s base if the denture is soaked for 5 minutes every day over the long term.

2. Methods

In this experimental laboratory study, 30 acrylic resin plate specimens 64 mm × 10 mm × 2.5 mm in size (ISO 1567:1988) that were visually shiny, smooth, not porous, and not curved were used. The ratio of liquid to powder was 9.2 grams:4 ml. The acrylic resin was OC 20.

The specimens were divided into 6 groups: 3 groups were immersed in aqua bidest, and 3 groups were immersed in denture cleanser. Each group consisted of 5 heat-cured acrylic resin plate specimens. Initially, all specimens were immersed in aqua bidest at 37 °C ± 1 °C for 50 hours according to ISO 1567:1988. Then, the specimens were immersed according to the group (aqua bidest group and denture cleanser group) for 7 days, 14 hours, 30 minutes; 10 days, 3 hours,
20 minutes; and 12 days, 16 hours, 10 minutes, which were chosen to reflect a real-world immersion time of 5 minutes daily for 6 years, 8 years, and 10 years, respectively.

The specimens were immersed at room temperature (23 ± 2 °C). The denture cleanser and aqua bidest for each specimen group were renewed every 24 hours. The denture cleanser was prepared by dissolving 1 cleanser tablet (Polident®) and variant Fresh Active Denture Cleanser for 5 minutes in 175 ml of aqua bidest at room temperature. When not immersed, the specimens were stored at 100% humidity.

Transverse strength was measured at each of the immersion time points. The transverse strength was measured by using a 3-point bending method on a universal testing machine. The specimen was held in parallel at both ends at a 50 ± 0.1 mm distance from one end to the other end, and then the specimen was subjected to a bending force applied at 5 mm/minute in the middle of the specimen until the specimen broke.

The test results were analyzed by using the Shapiro–Wilk normality test. One-way analysis of variance (ANOVA) and independent t-tests were used to analyze the data that were normally distributed. The statistical significance level was taken to be 0.05 (p = 0.05) at a confidence level of 95% (α = 0.05).

3. Results
Table 1 presents the average transverse strengths in each group. In the denture cleanser specimen group, one-way ANOVA showed that there was no significant difference in transverse strength values at any of the immersion time points. In the aqua bidest specimen group, there was a significant decrease in transverse strength between specimens immersed for 7 days, 14 hours, 30 minutes and 12 days, 16 hours, 10 minutes.

| Immersion Solution | Transverse Strength (MPa) |
|--------------------|---------------------------|
|                    | Immersion Time             |
|                    | 7 days 14 hours 30 minutes | 10 days 3 hours 20 minutes | 12 days 16 hours 10 minutes |
| Aquadest           | 87.52 ± 6.33               | 77.40 ± 5.54               | 76.14 ± 6.31               |
| Denture Cleanser   | 88.07 ± 8.15               | 85.91 ± 5.06               | 85.25 ± 2.71               |

The independent t-test results showed that there were no significant differences between the specimen groups immersed in aqua bidest and in denture cleanser for 7 days, 14 hours, 30 minutes; for 10 days, 3 hours, 20 minutes; and for 12 days, 16 hours, 10 minutes. The average transverse strength value in the specimen group that was immersed in aqua bidest was lower than the value in the specimen group that was immersed in denture cleanser.

4. Discussion
The test results showed that there was no significant reduction in the transverse strength in the specimen group that was immersed in denture cleanser. There was a significant reduction in
transverse strength in the specimen group that was immersed in aqua bidest after 12 days, 16 hours, and 10 minutes. There was also a significant difference in the transverse strengths between the specimen group immersed in aqua bidest and the specimen group immersed in denture cleanser after immersions for 10 days, 3 hours, 20 minutes and for 12 days, 16 hours, 10 minutes; the transverse strength was lower in the aqua bidest group than in the denture cleanser group.

Acrylic resin is a polymer that can undergo polymer degradation through various means, one of which is degradation through hydrolysis. Hydrolysis occurs when polymer molecules react and bind to H+ ions, which results in cutting of the poly(methyl methacrylate) molecule. This polymer chain cutting resulting from hydrolysis leads to a reduction in the transverse strength of heat-cured acrylic resin [12].

Sodium perborate is an active ingredient of denture cleanser that is often used in detergents [9]. When a denture cleanser tablet dissolves in aqua bidest, sodium perborate reacts with water resulting in the formation of oxygen bubbles that clean the denture mechanically and produce alkaline peroxide [9–11]. The alkaline pH of a denture cleanser solution indicates that there are more OH− ions than H+ ions. Denture cleanser solution is different from aqua bidest, which has a neutral pH reflecting an approximately equal number of OH− and H+ ions. Aqua bidest has more H+ ions than denture cleanser solution has; therefore, hydrolysis is greater in the specimens immersed in aqua bidest, which leads to greater reduction in transverse strength than that in specimens immersed in denture cleanser solution.

Increasing the immersion time of an acrylic resin leads to increased absorption of water molecules, which reside between polymer chains and act as a plasticizer that reduces the transverse strength of the acrylic resin denture base [3,4,13]. This finding may explain the reduction in transverse strength that occurs when a specimen’s immersion time increases in aqua bidest and in denture cleanser solution.

The temperature of the denture immersion solution influences the absorption power of heat-cured acrylic resin, which can affect an acrylic resin’s transverse strength [14]. At a higher temperature, the absorption power of acrylic resin increases, which leads to a reduction in transverse strength [14]. This may explain why we found no significant change in the transverse strengths of the specimens immersed in denture cleanser given that the immersion solution was at room temperature.

Acrylic resin can become saturated after immersion in water for 17 days [4]. The saturation of this acrylic resin means that water cannot be absorbed by the acrylic resin; therefore, there are no water molecules between the polymer chains and the chains are not attracted to each other, all of which prevents reduction in the transverse strength. The lowest average transverse strength in this study was in the group of specimens immersed in aqua bidest for 12 days, 16 hours, 10 minutes (76.14 ± 6.31 Mpa), which remained above the required transverse strength of the denture base (79–86 Mpa) [3]. Based on the present study results, we still recommend that denture users continue to immerse their dentures in water when not in use.

5. Conclusions
Denture immersion in denture cleanser solution was not found to cause a significant reduction in transverse strength. Denture immersion in aqua bidest was found to cause significant reduction in transverse strength after 10 days, 3 hours, 20 minutes relative to that of specimens immersed in denture cleanser; however, the transverse strength of acrylic resin specimens remained above the required transverse denture base strength.
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