

Impact of Denture Cleansers on the Flexural Properties of Auto-Polymerizing PMMA Resins: A Comparative In Vitro Analysis

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Diş Protez Temizleyicilerinin Oto-Polimerize PMMA Reçinelerinin Eğilme Özellikleri Üzerindeki Etkisi: Karşılaştırmalı In Vitro Analiz

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Abstract

The purpose of this study was to assess whether three commercial denture cleaners affected the auto-polymerized polymethyl methacrylate (PMMA) resins' flexural strength and elastic modulus during different immersion times. Bar-shaped specimens (2x2x25 mm) were fabricated from auto-polymerized PMMA and subjected to three-point bending tests to assess their flexural properties. The specimens were immersed in three denture cleansers ((AT), (CA), and (PS)) for durations of 3 minutes, 15 minutes, and 8 hours, following the manufacturers' guidelines. Flexural strength and elastic modulus were measured using a universal testing machine per ISO 20795-1:2013 standards. Statistical analysis was performed using SPSS software, with significance set at $\alpha = 0.05$. Immersion significantly impacted the flexural properties of PMMA. Short-term immersion (3 to 15 minutes) in CA resulted in minimal changes, maintaining flexural strength and modulus of elasticity above ISO standards. On the other hand, all groups experienced a considerable decrease in mechanical characteristics after an 8-hour soak, especially when using PS and AT cleansers. Commercial denture cleansers affect the mechanical properties of resins, with the extent of impact influenced by cleanser composition and immersion duration. CA demonstrated superior performance in preserving material properties, emphasizing the importance of selecting appropriate cleaning agents for dental prosthetics.

Keywords: Denture; PMMA; Denture Cleanser; Flexural Strength; Modulus of Elasticity; Disinfection.

Öz

Bu çalışmanın amacı, üç ticari diş protezi temizleyicisinin farklı daldırma süreleri boyunca oto-polimerize polimetil metakrilat (PMMA) reçinelerinin eğilme mukavemetini ve elastik modülünü etkileyip etkilemediğini değerlendirmektir. Çubuk şeklindeki numuneler (2x2x25 mm) oto-polimerize PMMA'dan üretilmiştir ve eğilme özelliklerini değerlendirmek için üç noktalı eğilme testlerine tabi tutulmuştur. Numuneler, üreticilerin yönergelerine uygun olarak 3 dakika, 15 dakika ve 8 saat süreyle üç diş protezi temizleyicisine ((AT), (CA) ve (PS)) daldırılmıştır. Eğilme mukavemeti ve elastik modül, ISO 20795-1:2013 standartlarına göre evrensel bir test makinesi kullanılarak ölçülmüştür. İstatistiksel analiz, SPSS yazılımı kullanılarak gerçekleştirildi ve önem $\alpha = 0,05$ olarak ayarlandı. Daldırma, PMMA'nın eğilme özelliklerini önemli ölçüde etkiledi. CA'da kısa süreli daldırma (3 ila 15 dakika) minimum değişikliklere yol açtı, eğilme mukavemetini ve elastik modülünü ISO standartlarının üzerinde tuttu. Öte yandan, tüm gruplar 8 saatlik bir daldırmadan sonra, özellikle PS ve AT temizleyicileri kullanıldığında, mekanik özelliklerde önemli bir azalma yaşadı. Ticari diş protezi temizleyicileri, reçinelerin mekanik özelliklerini etkiler ve etki derecesi temizleyici bileşiminden ve daldırma süresinden etkilenir. CA, malzeme özelliklerini korumada üstün performans göstererek, diş protezleri için uygun temizlik maddelerinin seçilmesinin önemini vurguladı.

Anahtar Kelimeler: Protez; PMMA; Protez Temizleyici; Eğilme Dayanıklılığı; Elastiklik Modülü; Dezenfeksiyon.

1. Introduction

Maintaining the health of oral tissues can be achieved by effective and regular denture cleaning (Kurukcuoglu *et al.* 2016). Polymethyl methacrylate (PMMA) based dentures are prone to Candida adhesion, and various disinfection methods are used to address this issue (Kiesow *et al.* 2016). Patients are typically advised to schedule routine dental checkups for upkeep and to receive further instruction on how to prevent infections by cleaning their dentures using chemical or mechanical means. Numerous

studies have documented the many techniques used by denture users to keep their dentures clean. The most basic of these techniques is brushing with water and toothpaste, which is regarded as standard practice. More sophisticated techniques include the use of chemical solutions and tablets (Gad *et al.* 2024). Mechanical cleaning methods like toothbrushes are common but can cause surface abrasion, impacting aesthetics and biology. While abrasive toothpastes are affordable and accessible, they are ineffective for those with poor motor skills and

often fail to eliminate micro-organisms on resinous materials (Tanoue *et al.* 2000). Another technique for disinfecting entire dentures is to use microwave application or photodynamic therapy (PDT) to irradiate them (Ribeiro *et al.* 2012). Denture cleaners as a chemical method are often used to clean dentures by soaking them in chemical solutions, particularly beneficial for elderly patients while they are not in use. Incorporating solvent, detergent, and antibacterial and antifungal solutions into the prosthesis is one of the chemical approaches for cleaning dentures. These methods can be used alone or in conjunction with brushing or ultrasonic equipment (Paranhos *et al.* 2007, Andrade *et al.* 2011). Ultrasonic devices combine the simultaneous application of a chemical agent with the mechanical removal of biofilm (Pitt and Ross 2003). A variety of therapies, such as mouthwashes, hypochlorites, peroxides, enzymes, acids, and crude medications, can be used as chemical cleansing procedures (Saraç *et al.* 2007). Microorganisms should be effectively inactivated by a denture disinfection procedure that doesn't negatively impact the denture components. Specifically, a denture material's dimensional stability is seen to be a requirement for its clinical longevity (Papadiochou and Polyzois 2018). The surface properties of acrylic resins may also be influenced by hardness, a property that shows how easy a material is to finish and how resistant it is to in-service scratches during cleaning processes (Machado *et al.* 2009). Certain disinfection solutions have been found to soften acrylic resins, lowering their surface hardness (Machado *et al.* 2009). The hardness of denture has been shown to change with different denture immersion solutions. (Tinastepe *et al.* 2023).

PMMA is the most often used denture base resin because, in comparison to other materials available for denture production, it is less expensive, easier to manipulate, easier to create, and easier to repair (Porwal *et al.* 2017). PMMA-based dentures frequently experience fractures; between 50% and 78% of removable dentures experience various fractures within a few years of usage (Chladek *et al.* 2024). The most popular technique for repairing these fractures is auto-polymerized PMMA (Alkurt *et al.* 2014). To our knowledge, no study has been conducted on flexural properties of auto polymerizing acrylics after immersion denture cleaners. Therefore, the present study aimed to investigate flexural properties of auto polymerizing acrylic after immersion at 3 commercial denture cleaners.

In regard to the null hypothesis, denture cleaners would not significantly alter flexural characteristics.

2. Materials and Methods

In the present study flexural strength and elastic modulus of the cold-cure acrylic specimens at the 3rd minute, 15th minute and 8th hour immersion in the 3 commercial denture cleanser solutions investigated. Table 1 provides details on the items used in this investigation.

2.1 Sample Preparation

To characterize the flexural properties of auto-polymerizing acrylic specimens, a two-component (powder and liquid) commercial auto-polymerized PMMA dental material (Imicryl SC, Konya, Türkiye) was used to fabricate bar-shaped specimens measuring 2 × 2 × 25 mm, in accordance with the manufacturer's instructions. Polymerization was performed using a cold-curing pressure device (BF Electronic Pressure Acrylic Furnace, Las, Ankara, Türkiye) at 55 °C for 10 minutes under 20 psi pressure.

Three commercially available denture cleansers were selected for this study: an alkaline peroxide-based tablet (AT), a citric acid-based solution (CA), and a peracetic acid solution (PS). These products were chosen due to their widespread availability in the local market and their representation of distinct chemical classes commonly found in commercial denture cleansers. Previous studies have reported that such agents are frequently used in clinical practice and can significantly affect the mechanical and surface properties of denture base resins (Gad *et al.*, 2024; Sato *et al.*, 2003).

The cleanser solutions were prepared according to the manufacturers' recommendations (Table 1). Flexural properties of specimens were assessed after immersion at 3 minutes, 15 minutes, and 8 hours at 22 °C. These immersion times were selected based on the manufacturers' instructions and previously reported protocols in the literature (Pavarina *et al.*, 2003). A total of 100 specimens were used in this study: 10 specimens for each test condition across the three denture cleanser groups and the control group (immersed in distilled water), as shown in Figure 1.

2.2 Flexural Strength and Modulus of Elasticity Tests

The flexural properties of the specimens were measured using a three-point bending test on a universal testing machine (Lloyd LRX, West Sussex, UK), in accordance with ISO 20795-1:2013 guidelines for denture base polymers (Bento *et al.*, 2024). Each specimen was placed on a support span of 50 mm, and a compressive load was applied vertically at the midpoint using a 100 kgf load cell, with a crosshead speed of 5 mm/min until fracture occurred.

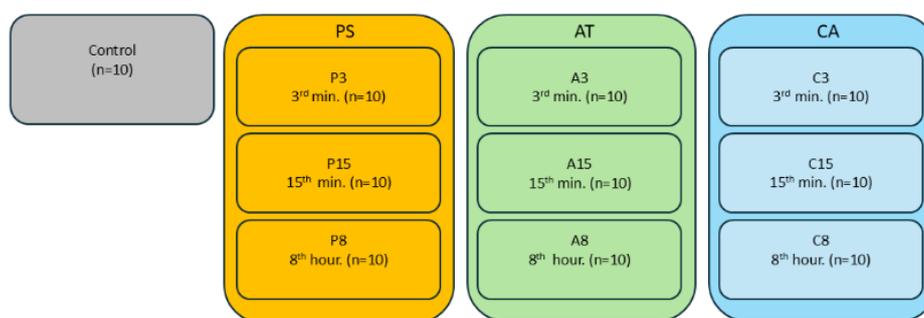


Figure 1. Schematic design of the study.

Table 1. Denture Cleaners Solutions and Auto-polymerizing Acrylic used in the study

Product Name	Abbreviation	Manufacturer	Ingredients	Manufacture Serial No
Protifix Aktiv-Reinger	PS	Bmp production gmbh Neuhofer Parchim Germany Weiche 48 19370 Parchim Germany	Potassium Caroate (Mixture of potassium monopersulfate, potassium sulphate, and potassium bisulfate.), Sodium Bicarbonate, Sodium Carbonate, Citric Acid, Sorbitol, VP/VA Copolymer, Sodium Lauryl Sulfate, Sodium Lauryl Sulfoacetate, Aroma, CI 73015.	4009932462333
Aktident Denture Care	AT	REGO X-Ray GmbH Stuttgrater Strasse 5 86154 Augsburg Germany	Potassium Carbonate, sodium Bicarbonate, Citric Asid, Sodium Carbonate, Sorbitol, VP/VA Copolymer, Sodium Lauryl Sulfate, Sodium Lauryl Sulfoacetate, Aroma, CL 73015	4260405420025
Corega Whitening Cleanser Tablet	CA	Stafford Miller (Ireland) Limited, Clocherane, Youghal Road, Dungarvan, Co. Waterford, Ireland.	Sodium Bicarbonate, Citric Acid, Potassium Karoat, (Potassium Monopersulfate), Sodyum Karbonat, Peroksit, Sodyum Karbonat, tetraacetylenediamine (TAED), Sodyum Benzoat, PEG-180, Sodyum Lauril Sülfat, Aroma, VP/VA, Kopolimer, Selüloz Sakızı, CI 42090, CI 73015	8681291000713
Cold Cure Acrylic		Imicryl SC, Dis Malzemeleri San ve Tic. Konya, Türkiye	10 ml/24 g (l/w) 30 min. mixture	8698973131641

The point at which the load dropped to zero was considered the moment of fracture. Data were recorded using dedicated software (Tesc, Intermetric, UK). Flexural strength (σ_f , in MPa) and elastic modulus (E, in MPa) were calculated using the following formulas:

$$\text{Flextural Strenght} = \frac{3 \times F \times L}{2 \times b \times h^2} \quad (1)$$

$$\text{Modulus of elasticity} = \frac{F \times L^3}{4 \times b \times h^3 \times d} \quad (2)$$

where F is the maximum applied load (N), L is the distance between supports (mm), b is the specimen width (mm), h

is the specimen thickness (mm), and d is the deflection corresponding to the load F (mm) (Aguirre et al., 2020; Tijana et al., 2021).

2.3 Statistical Analysis

All data were analyzed using statistical analysis software (IBM SPSS Statistics, version 22, USA) with a significance threshold of $\alpha=0.05$. Conformance to the normal distribution was evaluated using the Shapiro-Wilk test, and homogeneity of variance was evaluated using the Levene test. Repeated measures are evaluated using the Friedman and Wilcoxon Signed Ranks tests. To compare the groups, the Kruskal Wallis and Post Hoc tests were employed.

Table 2. Flexural Strength Test Results According to Group and Aging Time

Group	T0	T1	T2	Control
AT	123.86 ± 8.11 ^{Aa}	100.93 ± 11.77 ^{Ba}	84.83 ± 9.32 ^{Ca}	133.42 ± 23.95 ^A
CA	133.43 ± 16.88 ^{Aa}	116.17 ± 5.34 ^{Bbc}	106.6 ± 5.59 ^{Cb}	133.42 ± 23.95 ^{AB}
PS	133.42 ± 23.95 ^{Aa}	104.18 ± 11.41 ^{Bab}	97.7 ± 7.28 ^{Cc}	133.42 ± 23.95 ^A
Control	133.42 ± 23.95 ^a	133.42 ± 23.95 ^c	133.42 ± 23.95 ^d	

T0 = 3 minutes; T1 = 15 minutes; T2 = 8 hours; There is a substantial difference (P <.05) between distinct capital letters in rows and different lowercase characters in columns. The data are displayed as mean ± SD values in MPa.

Table 3. Elastic Modulus Test Results According to Group and Aging Time

Group	T0	T1	T2	Control
AT	5522.29±791.73 ^{Ab}	4771.86±1644.28 ^{ABab}	4505.35±606.28 ^{Bab}	5734.54±639.91 ^A
CA	5630.82±738.26 ^{Ab}	5459.08±1319.09 ^{ABab}	4869.81±453.98 ^{Ba}	5734.54±639.91 ^{AB}
PS	4845.47±299.71 ^{Aa}	4534.03±785.93 ^{ABa}	3951.79±620.84 ^{Bb}	5734.54±639.91 ^A
Control	5734.54±639.91 ^b	5734.54±639.91 ^b	5734.54±639.91 ^c	

T0 = 3 minutes; T1 = 15 minutes; T2 = 8 hours; There is a substantial difference (P <.05) between distinct capital letters in rows and different lowercase characters in columns. The data are displayed as mean ± SD values in MPa.

3. Results

3.1 Flexural strength Analysis

In repeated assessments, the auto-polymerizing acrylic resin's flexural strength decreased statistically significantly (p < 0.05) for all denture cleaning agent groups. Notably, Figure 2 and Table 2 illustrate the progressive decline in flexural strength across four time points (T1–T4) for each material group. In the AT group, there was no statistically significant difference between the control (T1) and the third-minute (T2) values (p > 0.05), suggesting that short-term exposure had limited mechanical impact. Similarly, the CA group showed no significant change when comparing the third-minute and fifteenth-minute measurements to the control (p = 0.799 and p = 0.59, respectively). These trends are visually evident in Figure 2, where the CA and AT curves remain relatively stable in early time points.

However, at both the 15-minute (T3) and 8-hour (T4) marks, the PS group exhibited statistically significant reductions in flexural strength (p = 0.022 and p = 0.005, respectively), as detailed in Table 2 and shown by a pronounced downward trend in the PS bars in Figure 2. This reflects the more aggressive nature of peracetic acid on the polymer network over time. When comparing the third-minute values across groups, no statistically significant differences were observed (p = 0.755). Yet, marked inter-group differences emerged at the fifteenth minute and the eighth hour (p = 0.000 for both), which are clearly reflected by the separation of the group curves in the figure. At the 15th minute, pairwise comparisons revealed no significant differences between the AT vs. CA,

AT vs. Control, and PS vs. Control groups (p = 0.16, p = 0.12, and p = 0.24, respectively). In contrast, by the 8th hour, Figure 2 demonstrates that all group comparisons showed statistically significant differences (p < 0.05).

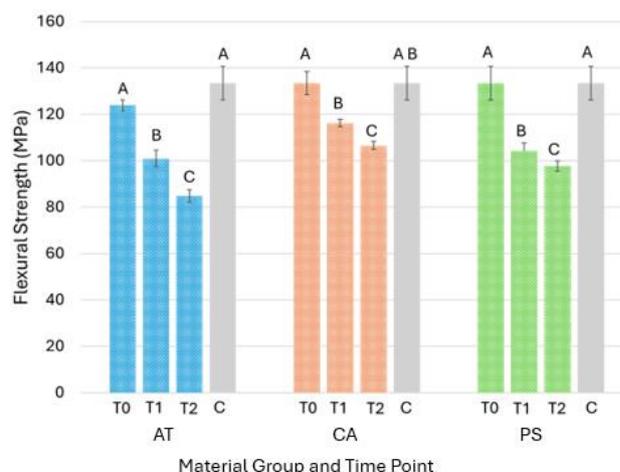


Figure 2. Flexural strength (MPa) of acrylic resin exposed to alkaline peroxide tablet (AT), citric acid (CA), and peracetic acid solution (PS) at time points T1 (control), T2 (3 min), T3 (15 min), and T4 (8 h).

3.2 Modulus of Elasticity Analysis

For repeated measures within the AT group, a statistically significant difference was observed (p < 0.05), with Figure 3 and Table 3 showing a clear decrease in the modulus of elasticity from T1 to T4. This decline was particularly evident between the control and the 8th-hour measurements, as well as between the third-minute and the 8th-hour values (both p < 0.05), indicating that prolonged exposure weakened the material's stiffness. In contrast, the CA group showed no statistically significant differences across the time points (p = 0.197), consistent

with the relatively flat trend line seen for CA in Figure 3, suggesting that citric acid caused minimal structural degradation. For the PS group, a significant reduction in modulus of elasticity was observed over time ($p = 0.002$), with marked differences between the third minute and 8th hour and between the control and 8th hour ($p = 0.005$ for both), as also detailed in Table 3. These findings are clearly depicted in Figure 3, where the PS group demonstrates the steepest decline, emphasizing the material's susceptibility to oxidative damage under prolonged exposure.

Inter-group comparisons using the Kruskal-Wallis test revealed significant differences at the third, fifteenth-, and eighth-hour marks ($p = 0.020$, $p = 0.014$, and $p = 0.000$, respectively). As shown in Figure 3, statistically significant distinctions were present between PS and Control groups at early time points, while multiple group comparisons (PS vs. Control, CA vs. PS, CA vs. Control, AT vs. CA) became significant at the 8th hour. Accordingly, different capital letters in the figure indicate statistically significant differences within groups ($P < 0.05$), and the data are presented as mean \pm standard deviation (SD).

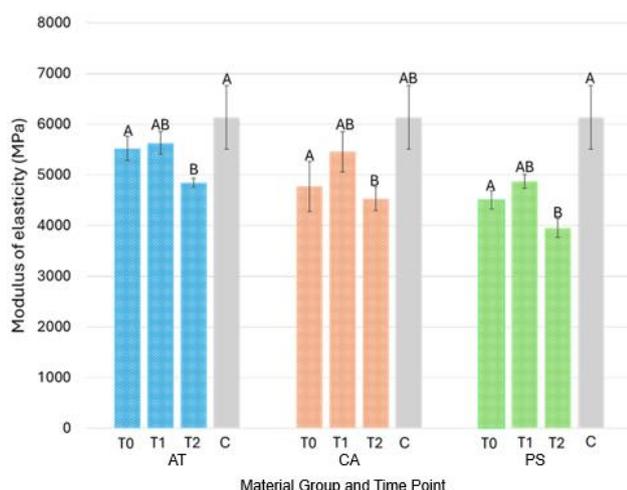


Figure 3. Modulus of elasticity (MPa) of acrylic resin exposed to alkaline peroxide tablet (AT), citric acid (CA), and peracetic acid solution (PS) at time points T1 (control), T2 (3 min), T3 (15 min), and T4 (8 h).

4. Discussion

The denture cleaners significantly affected the assessed qualities, according to the Friedman test results, which rejected the null hypothesis. The results showed that the materials' flexural qualities declined as the duration of immersion in denture cleansers increased. Similarly, Bento *et al.* (2024) stated that denture cleansers significantly influence mechanical properties of denture resins.

In the current investigation, repeated measurements at all denture cleansers showed no statistically significant

variations in flexural strength values at the third minute. Likewise, at the 15-minute values, no statistically significant changes were observed in the CA group. The 3rd minute and 15th minute immersion times evaluated in the study were based on the manufacturers' recommended durations. The absence of statistically significant variations from the control group is consistent with what the manufacturers advise. However, statistically significant differences ($p < 0.05$) were seen when comparing the 8th hour data among the three groups.

The acrylic resins' hardness was found to be affected by repeated cleaning processes in a prior study by Machado *et al.* (2009). The study showed that after multiple disinfection cycles, some types of acrylic resins showed changes in hardness. Specifically, the findings showed that certain disinfection protocols could cause either an increase or decrease in hardness, depending on the resin type and the disinfection method employed. These findings emphasize how crucial it is to choose the right disinfection techniques in order to preserve the longevity and durability of denture base materials.

Flexural strength, sometimes referred to as the modulus of rupture or transverse rupture strength, is an essential property of materials. It indicates the highest stress that a material can bear before failing a flexure test. Denture bases are subjected to various stressors in real-life conditions, making it essential for the material to possess high flexural strength to ensure durability and reliable performance (Al-Dwairi *et al.* 2020).

Since greater strength is closely correlated with more monomer conversion, flexural strength is a crucial indicator of acrylic resin's mechanical qualities (Al-Dwairi *et al.* 2020). A minimum flexural strength of 65 MPa is required for acrylic polymers used in denture bases, under the ISO 20795-1:2013 standard (Bento *et al.* 2024). Despite a notable decline in all denture cleansers after 15 minutes of aging ($p < 0.05$), the auto-polymerized PMMA resins in this investigation demonstrated flexural strength values more than 65 MPa at all aging durations. According to Bento *et al.* (2024), the resins maintained their strength above the ISO 20795-1:2013 standard's minimal criterion.

In a recent study evaluating several disinfectants, Elhagali *et al.* (2025) reported that immersion in sodium hypochlorite significantly reduced the flexural strength of both conventional and 3D-printed denture-base resins, whereas glutaraldehyde-based solutions produced no appreciable change. On the other hand, additional research has discovered that chemical disinfectants do affect acrylic resins' mechanical characteristics. Orsi and

Andrade (2004) observed a significant decrease in the flexural strength of heat-polymerized acrylic resins following disinfection with 1% sodium hypochlorite, suggesting that certain disinfectants can negatively impact the strength of denture base materials. In a similar vein, Sharan *et al.* (2012) noted a reduction in the transverse strength of heat-polymerized acrylic resins after exposure to disinfectants. In contrast, Sato *et al.* (2005) found that when applied in accordance with the manufacturer's instructions, heat-polymerized acrylic resins were submerged in denture cleansers for soaking cycles that simulated 30 days of use. They also found that these cleansers did not significantly alter the resins' color or flexural strength. Additionally, Machado *et al.* (2009) found that reline and denture base acrylic resins' hardness and surface roughness were unaffected by repeated cleaning processes. Additionally, the study by Pereira *et al.* (2019) showed that the hardness and polishing qualities of heat-cured acrylic resin used in denture manufacture were not significantly harmed by the use of alternate cleaning agents such as vinegar and hydrogen peroxide. In contrast, studies such as that by Bulut and Türksayar (2023) found that immersion in disinfectants significantly reduced the flexural strength of acrylic blocks. This disparity in results demonstrates the intricacy of the problem and raises the possibility that different disinfectant types, concentrations, application times, and resin compositions may have different effects on the characteristics of acrylic resin. While some studies, such as those by Sato *et al.* (2005) and Machado *et al.* (2009), did not find significant negative effects, other studies, including those by Fotovat *et al.* (2024) and Orsi and Andrade (2004), reported a reduction in mechanical properties, indicating the importance of carefully selecting disinfection protocols to preserve the integrity of denture base materials.

Commercial denture cleaners contain substances and enzymes that release oxides, which can cause the intermolecular gap to expand and allow water and chemicals to seep into the polymeric matrix (Bento *et al.* 2024). Commercial denture cleaning products fall into a number of types, such as mouth rinses, acids, peroxides, hypochlorite, neutral peroxides with enzymes, and crude medications. Disinfectant solutions can have a major impact on the flexural properties of resins. Disinfectant solutions can significantly impact the mechanical performance of denture base resins, particularly their flexural strength and surface characteristics. These effects are primarily attributed to chemical interactions between the disinfectant agents and the polymer matrix. AlHamdan *et al.* (2023) demonstrated that immersion in

various commercial disinfectant solutions led to a marked reduction in both the flexural strength and surface hardness of 3D-printed and heat-polymerized PMMA materials. Similarly, Schmutzler, *et al.* (2021) reported that prolonged exposure to denture cleansers increased surface roughness, potentially weakening the structural integrity of the acrylic resin. These findings suggest that the chemical composition and application time of disinfectants are critical factors influencing the long-term durability of denture base materials. Alternative chemicals, doses, and immersion durations had few negative effects in earlier research (Pavarina *et al.* 2003). The poor flexural strength of auto-polymerizing acrylic resin is associated with the low degree of conversion achieved by employing a chemically activated initiator method. Specimens mended using auto-polymerizing acrylic resin have around 60% to 65% of the denture's original strength, whereas heat-polymerized acrylic resin repairs have a strength range of 75% to 80% of the original bulk material (Arun *et al.* 2019). Young's modulus, sometimes referred to as the modulus of elasticity, is a material's mechanical ability to tolerate compression or elongation relative to its length. The modulus of elasticity value shall be at least 2000 MPa to overstand the stress that occurs in the dentures during functional forces (Bento *et al.* 2024). The modulus of elasticity of repeated measurements showed that there was a significant decrease between the 8th hour AT and CA vs the control group. There was a notable difference between the control group and the eighth hour in the PS group. According to the statistically significant differences between the control group and the denture cleaners' 8th hour values, putting the dentures in the solution for eight hours at night poses a risk of denture fracture.

Commercial denture cleaners fall into three categories: mechanical devices, abrasive cleansers, and immersion or soak-type solutions. Alkaline hypochlorites and peroxides are the main types of immersion cleaners. Alkaline peroxide effervescent tablets mechanically remove light stains and debris through oxygen release, are generally odor-friendly and safe for metal components of partial dentures, but are ineffective against calculus or stubborn stains (Alfouzan *et al.*, 2023). The usual ingredients of effervescent denture cleaner tablets are sodium bicarbonate and sodium perborate. As sodium perborate breaks down when dissolved in water, they produce an alkaline peroxide solution. Debris is mechanically removed by the oxygen released by this solution (Yadav *et al.* 2013)

Continuous polymerization, monomer release, and the interaction of these monomers with free radicals by

bonding with oxygen have all been implicated in the decrease in elasticity of auto-polymerized PMMA material. Considering that structural variations could result in different results, a variety of denture cleansers based on alkaline peroxide were chosen.

The specific combination of oxidizing agents, citric acid, and Tetraacetythylenediamine (TAED) in CA appears to balance cleaning and surface interactions without causing excessive material degradation. TAED is a noteworthy compound found in some effervescent cleansers (e.g., CA in this study). TAED activates and produces peracetic acid which increases antimicrobial action (Ginsburg 2020). TAED acts as a bleach activator, generating active oxygen species upon reaction with peroxygen compounds. These reactive intermediates may affect the PMMA matrix by altering surface roughness or contributing to microstructural changes. While effective for cleaning, the balance between cleaning efficiency and potential surface degradation is crucial (Sharan et al. 2012; Bento et al. 2024). The high flexural properties could result from oxidation removing microdefects or residual stresses in PMMA, surface smoothing effects due to balanced cleaning agents. CA exhibited the least adverse effects due to its balanced formulation of oxidizing and stabilizing agents. This unique balance may explain why CA outperforms the other cleansers in preserving or even enhancing PMMA's mechanical properties in the short term. Also, PS contains a similar oxidizing agent (potassium caroate) but lacks additional stabilizing components like TAED and citric acid in sufficient amounts, possibly leading to more aggressive oxidation and surface degradation of PMMA. AT Denture Care has a more basic formulation, dominated by strong alkalis (potassium carbonate and sodium carbonate). This high alkalinity can hydrolyze PMMA, weakening its structure over time.

Denture wearers can maintain the integrity of their prostheses by opting for short (3–15 minutes) effervescent tablet soaks as recommended by the manufacturer. Prolonged immersion (such as overnight for 6–8 hours) may increase surface roughness and weaken the prosthetic material. It is thus essential to follow the specified soaking times, avoid abrasive cleaning agents, and rinse thoroughly with lukewarm water. Regular dental check-ups are also advised to detect early signs of surface wear or biofilm accumulation, ensuring greater comfort and durability over the long term.

It is important to recognize the various limitations of this study. First off, the intricate clinical circumstances

present in the mouth cavity might not be perfectly replicated by the in vitro design. In the actual world, variables including saliva quality, dental care routines, dietary habits, and pH variations can all affect the results.

In the present study, 3 min, 15 min, and 8 hours of immersion were applied to the samples. These periods are the times that companies recommend to users in their boxes. Since the use of the denture is continuous, its use for more than 8 hours will exceed natural time. However, as a limitation of this study, immersion of 1 month will provide the opportunity to evaluate the effects on the samples in more detail.

More detailed data on TAED's interaction with PMMA could help optimize both the design of cleansing protocols and patient guidance. Furthermore, the study's specimens did not precisely replicate the way dentures would appear in the mouth.

5. Conclusions

Within the limitations of this in vitro study, the following conclusions can be drawn:

1. Immersion in commercial denture cleansers significantly impacts the flexural properties of auto-polymerizing acrylic resins. The extent of this impact varies depending on the cleanser type and immersion duration.
2. Short-term immersion (3 to 15 minutes) in certain cleansers, such as CA, showed minimal changes in flexural strength and modulus of elasticity, maintaining values above ISO 20795-1:2013 standards for denture base polymers.
3. Prolonged immersion (8 hours) in all tested cleansers resulted in a significant reduction in mechanical properties, particularly in the PS and AT groups. This highlights the potential risks of extended overnight soaking on the durability of prostheses.
4. The specific composition of denture cleansers plays a critical role in their interaction with PMMA materials, with formulations balancing cleaning efficiency and material preservation (e.g., CA) demonstrating better performance.

Declaration of Ethical Standards

The authors declare that they comply with all ethical standards.

Credit Authorship Contribution Statement

Author-1: Conceptualization, investigation, Methodology / Study design, visualization and writing – original draft.

Author-2: Conceptualization, investigation, Methodology / Study design, supervision and writing – review and editing.

Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Data Availability Statement

Datasets are available on request. The raw data supporting the conclusions of this article will be made available by the authors, without undue reservation.

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