Comparative analysis of denture cleanser effects on surface roughness: traditional vs. 3D-printed resin bases - a systematic review

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Abstract

***Aim:* Digital advances have streamlined dentistry and denture creation. 3D-printed denture bases may pose challenges to oral health due to their surface roughness, which can facilitate bacterial adhesion. This review aimed to evaluate the impact of denture cleansers on the surface roughness of 3D-printed denture base resins compared to traditionally fabricated counterparts. *Methods:* An electronic search of the PubMed, Scopus, and Web of Science databases was conducted, examining articles in English that met specific inclusion and exclusion criteria. Initially, 629 articles were identified, out of which only five studies were chosen. *Results:* A quality assessment based on OHAT revealed a high risk of bias in the majority of studies due to methodological insufficiencies. A majority of the studies observed an increase in surface roughness of 3D-printed denture base resins after immersion in denture cleansers. Two studies highlighted the most pronounced alteration in the surface topography of additively manufactured denture base resins compared to their heat-polymerized counterparts.**
Additionally, the increase in surface roughness was contingent upon the duration of immersion. *Conclusion:* Based on the limited evidence available, the application of denture cleansers on 3D-printed denture bases significantly augmented surface roughness compared to conventional denture bases. Heterogeneous methodologies and a high risk of bias preclude definitive conclusions. Further investigations with standardized methods are warranted.

Keywords: Bacterial Adhesion; Dentistry; Denture Cleansers; 3D-Printing; Oral Health; Polymethyl Methacrylate; Removable Prostheses; Surface Roughness.

Introduction

Complete dentures remain a pivotal treatment modality for numerous edentulous patients, particularly when advanced treatments are unfeasible(1).
Dentures play a crucial role in restoring masticatory function and maintaining aesthetic appearance for edentulous individuals. The long-term success of these prosthetic devices depends not only on their design and fabrication but also on their proper maintenance, specifically their cleanliness. Over time, the accumulation of bacterial

biofilms on dentures can lead to various oral and systemic health complications such as denture stomatitis, halitosis, and respiratory infections(2,3). Microbial overloads can subsequently manifest as denture stomatitis, angular cheilitis, and inflammatory papillary hyperplasia, among others (4,5).

The role of denture cleansers in mitigating these risks by reducing or eliminating biofilms is well-documented(6). Denture cleaning can be achieved through mechanical, chemical, or a combination of both methods. Although mechanical cleaning is prevalent, its use becomes cumbersome for older people due to diminished dexterity, necessitating the intervention of chemical agents. Common agents include sodium hypochlorite solutions and effervescent tablets containing sodium perborate, which can be used in conjunction with ultrasonic or mechanical cleaning modalities. Daily denture cleanser application mustn't compromise the integrity of the denture base material. Denture cleansers, widely recommended for optimal hygiene maintenance, can interact differentially with resin bases, potentially altering their surface topography (8–11).

Surface roughness is a critical parameter for these dental prostheses, as it intricately influences their biomechanical properties and interaction with the oral environment (12,13). An elevated surface roughness can inadvertently act as a harbinger for microbial colonization, culminating in biofilm formation, staining, and even denture-related stomatitis (14). Consequently, maintaining a polished denture surface that is resistant to wear and microbial adhesion is paramount for preserving oral health and ensuring the longevity of the prosthesis. While the choice of fabrication method, whether traditional or 3D printing, significantly impacts the inherent surface characteristics of dentures, external factors such as cleaning regimens also play a crucial role(15).

With the ongoing evolution in dentistry, materials used for denture fabrication have been consistently revisited to strike an optimal balance between function, aesthetics, and longevity. Traditionally, polymethyl methacrylate (PMMA) has been the cornerstone for denture base construction due to its biocompatibility, ease of manipulation, and acceptable esthetic outcomes. However, the advent of digital dentistry and technological advancements has ushered in a paradigm shift, with 3D-printed denture resins emerging as contemporary alternatives to traditional methods.

Driven by the advent of digitization, there has been an evolution of fabrication techniques and material science in creating denture bases(16–18) . The incorporation of CAD/CAM technology has revolutionized denture fabrication, bifurcating it into two methodologies: subtractive and additive. In the former, pre-polymerized PMMA blocks are milled to create the prostheses(19,20). Recent years have seen a surge of interest in 3D-printed denture bases. After designing a digital template, a 3D printer, in conjunction with photocurable methacrylate 3D resin, facilitates fabrication via stereolithography. Such resins yield a smooth finish, and the resultant dentures demonstrate mechanical properties on par with traditional methods (21).

Inherent limitations of PMMA, such as its propensity to fracture, risk of inducing oral infections, and potential for dimensional instability, can compromise the aesthetic appeal and oral health of the wearer (22,23). The surface roughness of the utilized resins plays a pivotal role in determining the long-term implications of the prosthesis. Clinically, heightened surface roughness can predispose to staining, biofilm accumulation, and gloss reduction, and elevate the risk of denture-associated stomatitis (12,13). Empirical evidence suggests that enhanced microbial adhesion with increased surface roughness (14). To obviate the accrual of plaque and biofilm, the surface roughness of restorative materials must remain below 0.2μm (24,25). Elevated surface roughness can also precipitate external staining and material matrix alterations (26).

An increase in surface roughness can pave the way for a cascade of undesirable events, including enhanced microbial colonization, biofilm formation, and increased susceptibility to staining. These events not only compromise the aesthetics and function of the denture but also raise potential health concerns such as denture-induced stomatitis.

To counteract these challenges, regular cleaning using denture cleansers has been universally advocated. However, as with any external agent, the interaction between denture cleansers and the denture base material is multifaceted. Potential alterations in surface roughness, especially in the context of newer 3D-printed resins, need rigorous scientific scrutiny.

Given the surging inclination towards 3D-printed dentures, questions arise regarding the prudence of employing denture cleansers and their ramifications on resin surface roughness. The surface roughness of denture bases is significant as it is implicated in plaque formation and bacterial colonization. Understanding the interplay between denture cleansers and varied resin bases becomes indispensable. Despite a substantial body of literature on PMMA, a noticeable gap exists in research regarding the effects of denture cleansers on newer, alternative 3D m-printed materials.

The existing literature lacks a systematic examination comparing the effects of denture cleansers on the surface roughness of conventionally fabricated and 3D-printed resin bases. Understanding these interactions is crucial for both clinicians and patients in making informed choices regarding denture materials and maintenance protocols, ultimately contributing to better oral health and prosthetic longevity. Consequently, this systematic review aimed to examine and critically appraise the impact of denture cleansers on the surface roughness of 3D-printed resins compared to conventionally fabricated dentures. This may provide clinicians and researchers with a comprehensive, evidence-based perspective, guiding informed decisions in clinical practice.

Materials and methods

This systematic review adheres to the guidelines of the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA). The present review was registered in the Prospective Register of Systematic

Reviews (PROSPERO) (registration number: CRD4202347021).
Focus question: *"Do denture cleansers affect traditionally fabricated and 3D-printed denture bases differently in terms of surface roughness?"*

Search Strategy

To ensure a comprehensive collection of relevant studies, a meticulous and multi-faceted search strategy was designed. Multiple electronic databases, including PubMed, Scopus, Web of Science, and the Cochrane Library, were searched from their inception until September 2023. Keywords and MeSH terms, such as "denture cleanser," "surface roughness," "conventionally fabricated denture," and "3D printed denture base resins," were utilized either individually or in combination to broaden the search scope. Search strings were adapted to the specific requirements of each database. Moreover, the reference lists of all included studies and relevant reviews were manually scanned to identify additional pertinent publications. Studies not published in English were excluded from the analysis.

Eligibility Criteria

For a study to be considered for inclusion, it had to meet the following criteria:
Participants: Individuals who utilized dentures, either conventionally fabricated or 3D printed.
Intervention: Application of any form of denture cleanser.
Comparator: Dentures not exposed to cleansers or other types of cleansers.
Outcome: Changes in the surface roughness of the denture base resins.
Study Design: Randomized controlled trials (RCTs), observational studies, or laboratory-based experimental studies.

Study Selection

All retrieved studies from the initial search were imported into reference management software to remove duplicates (27). Two independent reviewers screened titles and abstracts of the remaining studies to assess their relevance. Full texts of potentially eligible studies were then evaluated against the inclusion criteria. Discrepancies between the two reviewers were resolved through discussion, and if consensus could not be reached, a third reviewer was consulted.

Data Extraction

A customized data extraction form was utilized to obtain relevant information from the included studies. Extracted data encompassed study details, such as author(s) and year of publication, participant details, details regarding the intervention, and the outcome measures, along with key findings.

Quality Assessment

The methodological quality and risk of bias of the included studies were critically appraised according to the Cochrane Handbook for Systematic Reviews (28). The quality of the incorporated studies was examined using the Office of Health Assessment and Translation (OHAT) risk of bias tool from the US government's National Toxicology Program (29). Five critical domains were identified to assess the study's validity: randomization, procedural standardization, blinding of investigative personnel, treatment of missing outcome data, confidence in outcome assessment, and discernment in reporting outcomes. Each response for a domain was categorized as 'probably low', 'definitely low', 'probably high', or 'high'. A domain supported by unequivocal evidence was assigned a 'low risk of bias', while the lack thereof merited a 'high risk of bias' rating.

Results

The literature search led to 629 potentially relevant articles. After duplicates, the titles and abstracts of 433 articles were examined based on the inclusion criteria. In total, five studies were selected for this review (30–34). A PRISMA flow diagram of the search and screening process is shown in Figure 1.
All five studies examined the surface roughness of additively fabricated denture base resins. All five studies were conducted in the Middle East and North African regions (Saudi Arabia and Egypt) and were published from 2021 to 2023. The study characteristics are summarised in Table 1.

Quality assessment

A significant proportion of the included studies exhibited a heightened risk of bias. Specifically, four studies presented a high risk, while only a single study was categorized as having a low risk of bias. This elevated risk of bias in many studies predominantly originated from methodological inadequacies. A pronounced deficiency was the absence of outcome assessor blinding, the lack of randomization in multiple studies, and the lack of clear reporting contributed to the elevated risk of biased evaluations. The mode of specimen randomization for treatment designation was not reported. A detailed risk of bias assessment and a summary is shown in Figure 2.

Characteristics of the included studies

3D Printer

All authors created STL files using diverse CAD software applications, which were subsequently directed to 3D printers to actualize the specimen designs. Various CAD software was used for generating the STL file. Two out of the five studies used the Next Dent 5100, (Vertex Dental, Netherlands) (31,32). Other 3D printers used include Epax 3(North Carolina, USA)(33) and ST-1600(Satori Ltd. London, UK)(34).

Additively manufactured denture base resin

All five studies used 3D-printed or additively manufactured denture base resins. The resin NextDent Denture 3D+ emerged as the predominant choice for specimen fabrication(30–34). All five studies used resin specimens fabricated with this resin. Other resins used in the studies include ASIGA(DENTA Base, ASIGA) and Formlabs(Denture base OP) (31).

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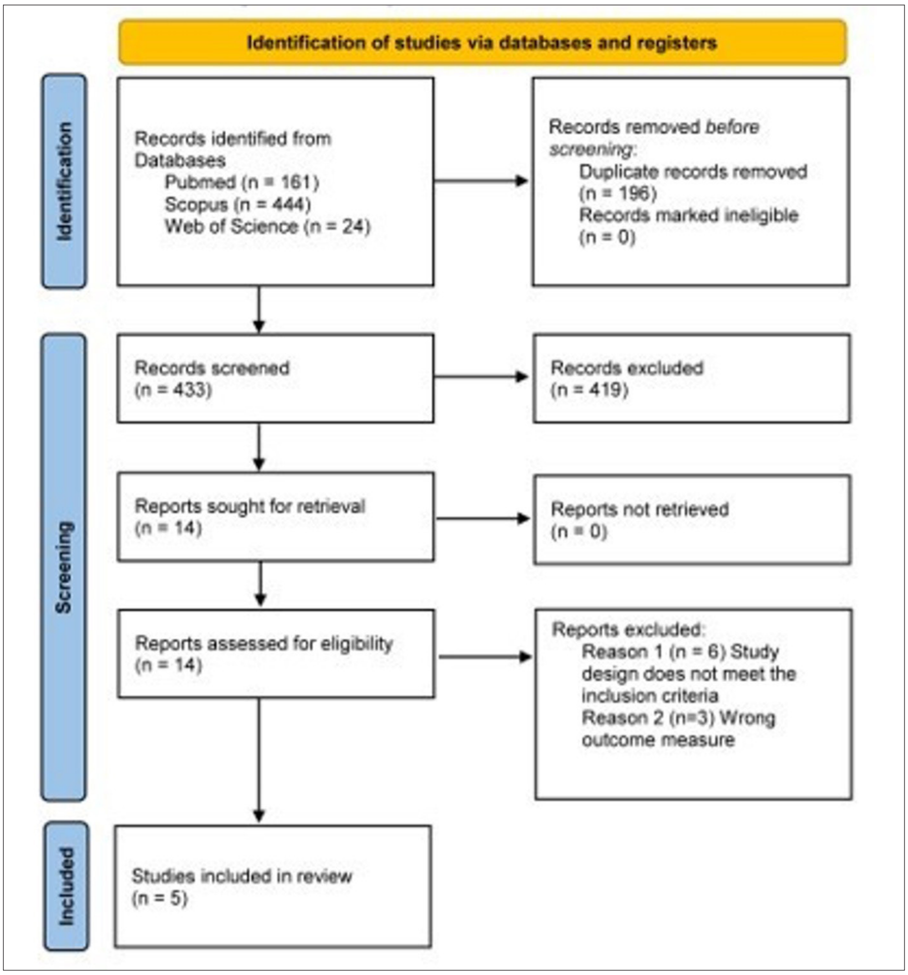

Figure 1. PRISMA flow chart

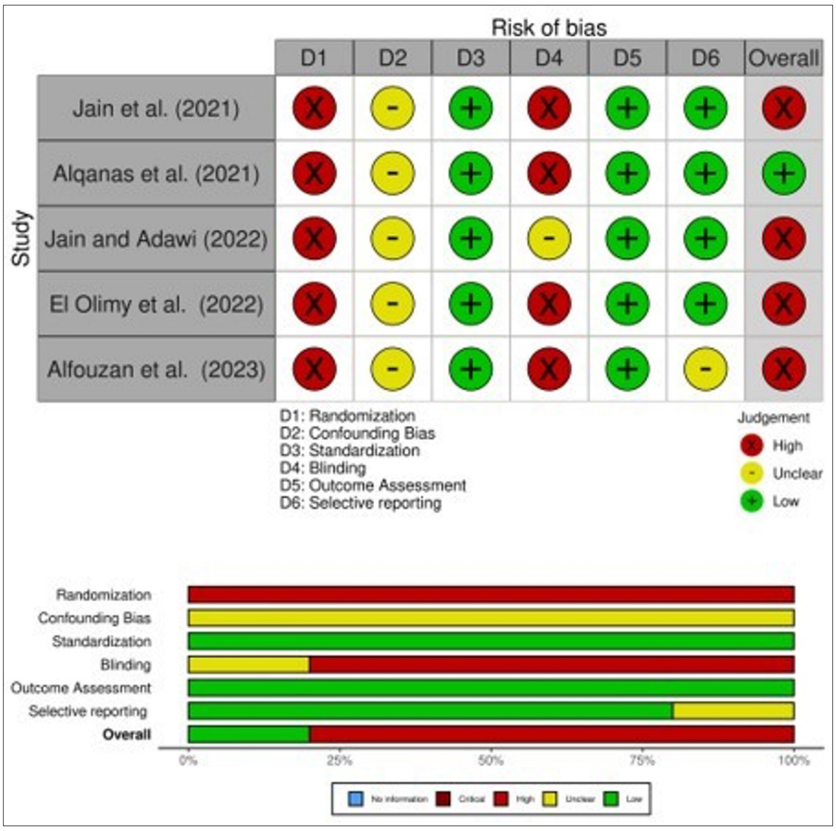

Figure 2. Summary of risk of bias assessment

Table1. Study characteristics

Author/Year	Sample Size	Study Design	Denture Cleanser Material	Intervention	Control Used	Outcome Assessment	Outcome	Inference
Jain *et al.* (2021)[32]	180 specimens	Group 1: CAD/CAM Additive Manufacturing (NextDent Denture 3D+) Group 2: CAD/CAM Milling Manufacturing(Wieland) Group 3: Injection molding technique (Bre. Flex) Group 4: Conventional Heat polymerized(Meliodent)	Subgroup A: Control Group (Distilled water) Subgroup B: Polident Denture Cleanser Subgroup C: Fixodent Plus Denture Cleanser	For each group, each tablet was placed in 250ml of warm water for 3 mins. 30 submersion cycles of 3min each were performed for 6 days to imitate 180 days of prosthesis submersion.	For accelerated aging(equivalent to 180 days) of the specimens done by thermocycling machine	Surface Roughness of the specimens - A 3D optical noncontact surface profilometer was used to assess the surface roughness before and after immersion.	In the conventional heat polymerized group, the surface roughness was highest for distilled water. When placed in denture cleanser solution, the highest surface roughness was observed in the additive manufacturing group. Surface roughness was increased on immersion in denture cleansers whereas immersion in distilled water decreased the surface roughness.	Additively manufactured denture base resin showed the highest change in surface roughness when immersed in a denture cleanser.
Alqanas *et al.* (2022) [31]	160 specimens	Group HP: Conventional Heat polymerized(Major Base20) Group AS: ASIGA (3D printed resin 1) Group FL: Formlabs (3D printed resin 2) Group ND: NextDent (3D printed resin 3)	Subgroup DW: Distilled water Subgroup Effervescent Tablet 1: Corega Subgroup Effervescent Tablet 2: Fittydent Subgroup NaOCl: NaOCl	Immersion of specimens in 2 different denture cleanser solutions, and NaOCl for 360 days for a recommended period of 3 to 10 minutes.	Immersion of specimens in distilled water for 360 days for a recommended period of 3 to 10 minutes	Surface Roughness of the specimens - A noncontact surface profilometer was used to access the surface roughness at baseline, 180 days (T1) and 360 days (T2)	Significant intergroup differences were observed ($p< 0.001$). There was a gradual increase in surface roughness of all the denture base resins, especially on prolonged immersion of 360 days in denture cleansing solution as opposed to distilled water.	The change in surface roughness exhibited by 3D printed denture base resin was similar to HP denture base resin material. The denture cleanser use resulted in time -a dependent increase in surface roughness.

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Jain and Adawi (2023) [30]	117 specimens	Group 1: Conventional Heat polymerized (Meliodent) Group 2: Subtractive Manufacturing(Wieland) Group 3: Additive Manufacturing (NextDent Denture 3D+)	Subgroup A: Distilled water Subgroup B: Denture Cleanser 1 (Fixodent) Subgroup C: Denture Cleanser 2 (Fittydent)	Immersion of specimens in 2 different denture cleanser solutions to simulate 180 days of denture cleansing.	Immersion of specimens in distilled water to simulate 180 days of denture cleansing.	Surface Roughness of the specimens - A 3D optical non-contact surface profilometer was used to assess the surface roughness before and after immersion.	On immersion, the highest change in surface roughness was seen in additively manufactured denture base resin followed by heat polymerized denture base resin while the least change was seen in subtractive manufactured material. Fixodent denture cleanser had a higher surface roughness when compared to Fittydent denture cleanser.	Subtractive manufactured denture base showed the lowest change while additively manufactured denture base resin showed the highest change in surface roughness when immersed in denture cleanser.
El Olimy *et al.* (2022) [33]	140 specimens	Group 1: Conventional heat-cured denture base resin material PMMA Group 2: 3D-printed resin	Subgroup 1: Distilled water Subgroup 2: Aloe vera gel 100% Subgroup 3: Corega denture cleanser.	Subgroup 2- immersion in a solution prepared by dissolving 2.5gm of aloe vera gel in 200ml warm water. Subgroup 3 - immersion in Corega solution prepared in 200ml of warm water. 10 sessions of soaking for 18,36,53 days to simulate 6,12,18 months of cleansing.	soaking in distilled water for 18,36,53 days to simulate 6,12,18 months of cleansing.	surface roughness of the specimens was determined using a Surface Profile Gauge.	at baseline, the surface roughness of the 3D printed denture base material was significantly lower than the conventional denture base resin material. There was a significant difference in the roughness of 3D printed denture base material by comparing the immersion of college and aloe vera at 18,36,54 days.	3D printed denture base resin exhibited significantly more favorable surface roughness as compared to conventional denture base resin.
Alfouzan *et al.* (2023) [35]	180 specimens	Group 1: Conventional Heat polymerized (Meliodent) Group 2: CAD/CAM Milled (Wieland) Group 3: 3D printed (NextDent Denture 3D+)	Subgroup A: Distilled water Subgroup B: Fittydent Denture Cleanser Subgroup C: 0.2% CHG solution Subgroup D : 2% CHG solution Subgroup E : 0.5% NaOCl solution Subgroup F : 1% NaOCl solution	immersion in the various solutions for varying time period	Immersion of specimens in distilled water for 72 hrs.	Surface Roughness of the specimens was assessed using an optical non-contact profilometer before and after immersion .	After immersion in denture cleanser, all the materials exhibited significantly higher surface roughness ($p < 0.05$). The highest Ra was demonstrated by 3D printed discs, followed by conventional and milled group.	After treatment all the PMMA material groups showed a significant increase in roughness.

Conventionally manufactured denture base resin

All five studies used heat-cured denture base resins. Meliodent (Kulzer, GmbH) was the most commonly used material in three studies (30,32,34). A Study conducted by El-Olimy et al (33) used Acrostone(Acrostone Manufacturer, Egypt) and another study by Alqanas et al (31) used MajorBase 20 (Major Prodotti Dentari SPA, Italy).

Standardization

A majority, four of the studies, crafted disc-shaped specimens, with El-Olimy et al (33) deviating by fabricating a square configuration design. Three studies mentioned that post fabrication the specimens were cleaned using isopropyl alcohol and then post-curing for completion of polymerization(31,32,34). The specimens were then finished and polished using various methods. All studies mentioned the use of a single operator for standardization.

Assessment of Surface roughness

Surface roughness evaluations predominantly employed a 3D Optical non-contact profilometer in four out of the five studies(30–32,34). Each specimen was positioned horizontally below a visual device at a specific magnification and the specimens were examined. El-Olimy et al (33) used a Surface Profile Gage(Positector, SPG, Delflesko corporation, New York, USA) – a handheld instrument gauging the differential between peak and valley heights of a given surface profile. The assessment of the surface roughness due to denture cleansers is shown in Table 2.

Denture cleansers

All five studies used denture cleansers to immerse the specimens before evaluating their effect on the surface roughness of the denture base resin. Fitty Dent (Fittydent International GmbH, Pinkafeld, Austria) was the most commonly used denture cleanser followed by Fixodent(Procter and Gamble. Co. USA). Corega(GSK, Brazil) and various concentrations of NaOCl solution(Biotischen Industry Incorporation, Alkharj, Saudi Arabia) and Chlorhexidine Gluconate (Avalon Pharma, Riyadh, Saudi Arabia), were also used. The studies spanned varied durations 72 hrs (34) to 360 days (31).

Table 2. Summary of Findings Table

Quality assessment						Summary of findings		
Outcome	**Risk of bias**	**Inconsis-tency**	**Indirect-ness**	**Imprecision**	**Publication bias**	**Impact**	**Number of participants (studies)**	**Certainty of evidence (GRADE)**
Surface roughness due to denture cleansers	serious[a]	not serious	not serious	not serious	not serious	Our confidence in the effect estimate is limited: the true effect may be substantially different from the estimate of the effect	(5)	low

[a]Four studies showed a high risk of bias

Effect of interventions

The primary outcome examined across the five studies was the surface roughness in additively manufactured denture base resin post-immersion in denture cleansers, juxtaposed with conventionally fabricated counterparts. We found heterogeneity in the results of the five studies that assessed the surface roughness of 3D-printed denture base resin on immersion in denture cleansers.

A majority of studies underscored a significant increase in surface roughness of 3D-printed denture base resins after immersion in denture cleansers. Four of the five studies reported immersion of 3D printed denture base resins in denture cleansers significantly increases the surface roughness(30,32–34). Two studies articulated that the most pronounced alteration in surface topography was evident in additively manufactured denture base resin, trailed by heat polymerized resin, with the subtractively manufactured material displaying minimal change (32,35). Alqanas et al. posited that the elevation in surface roughness of denture base resins was contingent upon the duration of immersion i.e. a time-dependent factor(31). Significant intergroup differences were observed ($p< 0.001$). An incremental escalation in surface roughness was observed across all denture base resins, accentuated markedly upon extended immersion, spanning 360 days, in denture cleansing solutions compared to their immersion in distilled water

Discussion

Summary and comparison

Dentures have long served as a cornerstone in the rehabilitation of edentulism, contributing significantly to the improvement of oral function and aesthetic appearances. Historically, the polymethyl methacrylate

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(PMMA) material, processed through conventional fabrication techniques, has been the cornerstone for denture creation. Its longstanding legacy has warranted exhaustive evaluations, rendering it an archetype in terms of its mechanical robustness, physical fidelity, and esthetics. The proliferation of digital technology in the realm of dental science has heralded a transformative era in the synthesis of removable prostheses. Two predominant methodologies underscore this digital evolution: subtractive technology, characterized by its milling processes, and additive technology, epitomized by its meticulous layer-by-layer printing. Additive technology is preferred for its sustainable advantage of minimizing material wastage. However, the effects of denture cleansers on newer, alternative materials used in additive manufacturing have not yet been comprehensively assessed.

Surface roughness stands as a pivotal attribute, wielding substantial influence over both the aesthetic appeal and hygienic efficacy of a prosthesis. A denture exemplifying minimal surface roughness is not only important for esthetics but also mitigates the adhesion of deleterious debris. This minimization of surface roughness is instrumental in preventing denture stomatitis and is imperative for proper oral hygiene. This systematic review aimed to critically appraise the existing body of evidence on the surface roughness of 3D printed denture base materials when subjected to denture cleansers.

A total of five studies were analyzed to discern the impact of denture cleansers on the surface topography of both additively manufactured resin and conventionally fabricated denture base resins. A consistent observation across the accumulated data was the increase of surface roughness in 3D-printed denture base resins upon exposure to denture cleansers. Alqanas et al. posited the role of immersion time, stating that the surface roughness of the resin may be affected by the time interval for which it was immersed, suggesting that the temporal extent of exposure can significantly modulate the surface characteristics of the resin (31).

Additionally, a potential confounder that merits contemplation is the choice of immersion solutions employed in these assessments. Utilizing distilled water as a control medium does not adequately replicate the complexities of saliva. Although methodologically sound, distilled water may not wholly emulate the potential interactions of human saliva. Consequently, the prolonged exposure of denture resins to salivary constituents might engender differing outcomes in terms of surface roughness, necessitating further investigation to bridge this knowledge gap.

Our analysis elucidated that the application of denture cleansers on additively manufactured (3D-printed) denture resins culminated in a discernible augmentation of material surface roughness, particularly when benchmarked against conventionally fabricated denture resins. Given the ubiquity of denture cleansers as the predominant regimen for denture maintenance, an escalation in surface roughness could potentially pave the way for enhanced bacterial colonization and retention (36).

Surface anomalies and irregularities play an instrumental role in facilitating the initial bacterial adhesion. This attachment is strong enough to protect the bacterial colonies from salivary flow and masticatory function (37–39).

Streptococci and Candida are the bacterial and fungal pathogens commonly found on denture surfaces (40). Sub-optimal denture hygiene compounded by plaque accumulation can set the stage for pathologies such as denture stomatitis (3). Further, the entrenchment of microorganisms bears implications beyond local oral health, with potential ramifications including halitosis, bacterial endocarditis, pneumonia, and other pulmonary infections (41,42).

The use of denture cleanser can help remove stains, debris, and biofilms from denture surfaces. However, the use of these cleansers can cause adverse effects on the mechanical properties of polymer-based materials, hastening their degradation. A significant increase in surface roughness is documented when polymer-based materials are subjected to these chemical agents (43–45).

Given the relatively nascent introduction of 3D-printed resins in clinical dentistry, and their susceptibility to surface roughness when cleaned with denture cleansers, further studies and mitigation measures need to be scrutinized. The findings of this review underscore that the interplay between denture cleansers and 3D-printed resins leads to alterations in surface topology. Consequently, dental practitioners must exercise prudence in the selection of resin materials and recommend denture cleansers during denture hygiene consultations. Striking an equilibrium between the efficacy of the cleanser and its repercussions on the resin remains paramount (46).

Agreements and disagreements with previous studies

An earlier study by Gad et al. reported that 3D printed resins had lesser surface roughness than conventional heat-cured resin initially. However, there was an increase in roughness post-thermocycling the specimens. The author attributed the initial lower surface roughness to the thickness of the initial printed layer and the smooth packing of consecutive layers. The changes in surface roughness post-intervention were due to the printing orientation. The authors posited that water sorption due to temperature changes induces the layers to move apart, consequently influencing surface roughness (47).Corroborating this, Alfouzan et al. identified a similar trend, elucidating that agent exposure escalates the surface roughness of 3D-printed resins (35).

It is evident from these examinations that external interventions, including denture cleansers, can alter the surface quality of 3D-printed resin bases. The mechanism of action of denture cleansers typically entails oxygen liberation upon dissolution, leading to the formation of alkaline peroxide (26). This can cause hydrolysis and decomposition of the polymerized chains of the resin. Coupled with pH variances, hydrolysis, and degradation cal ultimately result in surface irregularities (48–50).

Several studies have probed the effects of denture cleansers on conventionally fabricated PMMA. Al-

Thobity et al. reported that denture cleanser interacts with traditional PMMA and increases its surface roughness(51), echoing the conclusions of similar studies (52–54-55).Conversely, studies by Peracini et al (44) and Paranhos et al (8) found no perceptible alterations in the surface topography of conventional PMMA upon denture cleanser immersion. Given this spectrum of findings, it appears that the influence of denture cleansers on PMMA's surface attributes is a confluence of multifaceted parameters. Variables such as the denture cleanser's composition and type, solution temperature, concentration, and critically, immersion duration, collectively modulate this interaction (51).

Overall completeness and applicability

The findings of this review align with the objectives, with all included papers comparing surface roughness due to denture cleansers in 3D printed bases as a primary outcome. However, methodological variances across the studies, particularly in immersion cycles detract from their generalizability and universal applicability. An inherent limitation in the methodological approach of all the scrutinized studies was the exclusive evaluation of the surface roughness on planar specimen surfaces. Such flat morphologies do not effectively replicate the intricate contours and curvatures emblematic of actual dentures.

Each study incorporated a control group and adhered to manufacturer-provided instructions for solution preparation, thus offering a robust representation of analogous interventions. However, overall the methodology remains notably divergent. There is a need for further investigations to enhance data interpretability. As the use and adoption of 3D-printed resin bases become more widespread, it is imperative to discern if routine procedures like the use of denture cleansers remain apt.

Quality of the evidence

The body of evidence gathered from the five included studies, employing various methodologies, does not allow for a robust conclusion. Although a consistent outcome was observed across studies—the amplification of surface roughness in 3D-printed resins post-immersion—the heterogeneity in methods, particularly immersion cycles, undermines the generalizability of the findings. A predominant number of studies exhibited a high risk of bias. The major sources of this bias emerged from methodological shortcomings which we accounted for by downgrading the certainty of evidence to low in the GRADE assessment. Consequently, this low-quality evidence precludes drawing definitive and robust conclusions.

This review used an exhaustive search protocol, meticulously designed to pinpoint pertinent studies. To mitigate potential bias, multiple authors independently undertook both the selection of studies and the quality appraisal. However, this review is not without limitations. Our search was circumscribed to only papers in the English language, thereby introducing the possibility of a linguistic bias. The studies included were *in-vitro* in design and are therefore comparatively limited in scope, potentially constraining the extensibility of the outcomes to broader contexts.

Conclusions

Within the limitations of this systematic review, we found low-quality evidence that the employment of denture cleansers may induce an increase in surface roughness in 3D-printed resin bases. The most marked modification in surface morphology was in additively fabricated denture base resin, followed by heat-polymerized resin. The escalation in surface roughness of denture base resins appeared to be intricately linked to the duration of immersion. Further *in vivo* investigations with more expansive datasets are required to substantiate and replicate these preliminary findings.

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Conflicts of Interest

The authors declare no conflicts of interest.

Institutional Review Board Statement

None

Data Availability Statement

Not Applicable.

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References

1. Assunção, W.G.; Barão, V.A.R.; Delben, J.A.; Gomes, E.A.; Tabata, L.F. A comparison of patient satisfaction between treatment with conventional complete dentures and overdentures in the elderly: a literature review. *Gerodontology* **2010**, *27*, 154–162.
2. Valentini, F.; Luz, M.S.; Boscato, N.; Pereira-Cenci, T. Surface Roughness Changes in Denture Liners in Denture Stomatitis Patients. *Int. J. Prosthodont.* **2017**, *30*.
3. Gendreau, L.; Loewy, Z.G. Epidemiology and Etiology of Denture Stomatitis. *J. Prosthodont.* **2011**, *20*, 251–260, doi:10.1111/j.1532-849X.2011.00698.x.
4. Glass, R.T.; Bullard, J.W.; Hadley, C.S.; Mix, E.W.; Conrad, R.S. Partial spectrum of microorganisms found in dentures and possible disease implications. *J. Am. Osteopath. Assoc.* **2001**, *101*, 92–4.
5. ARENDORF, T.M.; WALKER, D.M. Denture stomatitis: a review. *J. Oral Rehabil.* **1987**, *14*, 217–227, doi:10.1111/j.1365-2842.1987.tb00713.x.
6. de Lucena-Ferreira, S.C.; Ricomini-Filho, A.P.; Da Silva, W.J.; Cury, J.A.; Del Bel Cury, A.A. Influence of daily immersion in denture cleanser on multispecies biofilm. *Clin. Oral Investig.* **2014**, *18*, 2179–2185.
7. Gajwani-Jain, S.; Magdum, D.; Karagir, A.; Pharane, P. Denture Cleansers: A Review. *IOSR J. Dent. Med. Sci. Ver. IV* **2015**, *14*, 2279–861, doi:10.9790/0853-14249496.
8. Paranhos, H. de F.O.; Peracini, A.; Pisani, M.X.; Oliveira, V. de C.; Souza, R.F. de; Silva-Lovato, C.H. Color Stability, Surface Roughness and Flexural Strength of an Acrylic Resin Submitted to Simulated Overnight Immersion in Denture Cleansers. *Braz. Dent. J.* **2013**, *24*, 152–156, doi:10.1590/0103-6440201302151.
9. Carvalho, C.F.; Vanderlei, A.D.; Marocho, S.M.S.;

 10.59987/ads/2025.2. 98-108

Pereira, S.M.B.; Nogueira, L.; Paes-Júnior, T.J.A. Effect of disinfectant solutions on a denture base acrylic resin. *Acta Odontol. Latinoam.* **2012**, *25*, 255–60.

10. Davi, L.R.; Peracini, A.; de Queiroz Ribeiro, N.; Soares, R.B.; da Silva, C.H.L.; de Freitas Oliveira Paranhos, H.; de Souza, R.F. Effect of the physical properties of acrylic resin of overnight immersion in sodium hypochlorite solution. *Gerodontology* **2010**, *27*, 297–302, doi:10.1111/j.1741-2358.2009.00336.x.
11. Porwal, A.; Khandelwal, M.; Punia, V.; Sharma, V. Effect of denture cleansers on color stability, surface roughness, and hardness of different denture base resins. *J. Indian Prosthodont. Soc.* **2017**, *17*, 61, doi:10.4103/0972-4052.197940.
12. Silva, A.M.J.D.; Guerrero, J.G.; Pinto, L.D.R.; Carvalho, R.M.; Porto, V.C. Evaluation of surface roughness and color change of a light-cured and a heat-cured acrylic resin employed for fabrication of prosthetic bases after exposure to different types of disinfectants. *J. Res. Dent.* **2013**, *1*, 199, doi:10.19177/jrd.v1e32013199-209.
13. Bitencourt, S.B.; Catanoze, I.A.; da Silva, E.V.F.; dos Santos, P.H.; dos Santos, D.M.; Turcio, K.H.L.; Guiotti, A.M. Effect of acidic beverages on surface roughness and color stability of artificial teeth and acrylic resin. *J. Adv. Prosthodont.* **2020**, *12*, 55, doi:10.4047/jap.2020.12.2.55.
14. Yannikakis, S.; Zissis, A.; Polyzois, G.; Andreopoulos, A. Evaluation of porosity in microwave-processed acrylic resin using a photographic method. *J. Prosthet. Dent.* **2002**, *87*, 613–619, doi:10.1067/mpr.2002.124490.
15. Ferro, A.C.; Spavieri, J.H.P.; Ribas, B.R.; Scabelo, L.; Jorge, J.H. Do denture cleansers influence the surface roughness and adhesion and biofilm formation of Candida albicans on acrylic resin? Systematic review and meta-analysis. *J. Prosthodont. Res.* **2023**, *67*, 164–172.
16. Bidra, A.S.; Taylor, T.D.; Agar, J.R. Computer-aided technology for fabricating complete dentures: systematic review of historical background, current status, and future perspectives. *J. Prosthet. Dent.* **2013**, *109*, 361–6, doi:10.1016/S0022-3913(13)60318-2.
17. Kattadiyil, M.T.; Jekki, R.; Goodacre, C.J.; Baba, N.Z. Comparison of treatment outcomes in digital and conventional complete removable dental prosthesis fabrications in a predoctoral setting. *J. Prosthet. Dent.* **2015**, *114*, 818–825, doi:10.1016/j.prosdent.2015.08.001.
18. Srinivasan, M.; Kalberer, N.; Naharro, M.; Marchand, L.; Lee, H.; Müller, F. CAD-CAM milled dentures: The Geneva protocols for digital dentures. *J. Prosthet. Dent.* **2020**, *123*, 27–37, doi:10.1016/j.prosdent.2018.12.008.
19. Schweiger, J.; Stumbaum, J.; Edelhoff, D.; Güth, J.-F. Systematics and concepts for the digital production of complete dentures: risks and opportunities. *Int. J. Comput. Dent.* **2018**, *21*, 41–56.
20. Millet, C.; Virard, F.; Dougnac-Galant, T.; Ducret, M. CAD-CAM immediate to definitive complete denture transition: A digital dental technique. *J. Prosthet. Dent.* **2020**, *124*, 642–646, doi:10.1016/j.prosdent.2019.10.025.
21. Chen, J.; Ahmad, R.; Suenaga, H.; Li, W.; Sasaki, K.; Swain, M.; Li, Q. Shape Optimization for Additive Manufacturing of Removable Partial Dentures - A New Paradigm for Prosthetic CAD/CAM. *PLoS One* **2015**, *10*, e0132552, doi:10.1371/journal.pone.0132552.
22. Takahashi, Y.; Yoshida, K.; Shimizu, H. Fracture resistance of maxillary complete dentures subjected to long-term water immersion. *Gerodontology* **2012**, *29*, e1086–e1091, doi:10.1111/j.1741-2358.2012.00616.x.
23. AL-Dwairi, Z.N.; AL-Quran, F.A.; AL-Omari, O.Y. The effect of antifungal agents on surface properties of poly(methyl methacrylate) and its relation to adherence of Candida albicans. *J. Prosthodont. Res.* **2012**, *56*, 272–280, doi:10.1016/j.jpor.2012.02.006.
24. Alp, G.; Johnston, W.M.; Yilmaz, B. Optical properties and surface roughness of prepolymerized poly(methyl methacrylate) denture base materials. *J. Prosthet. Dent.* **2019**, *121*, 347–352, doi:10.1016/j.prosdent.2018.03.001.
25. Quirynen, M.; Bollen, C.M.L. The influence of surface roughness and surface-free energy on supra- and subgingival plaque formation in man. *J. Clin. Periodontol.* **2005**, *22*, 1–14, doi:10.1111/j.1600-051X.1995.tb01765.x.
26. Hong, G.; Murata, H.; Li, Y.; Sadamori, S.; Hamada, T. Influence of denture cleansers on the color stability of three types of denture base acrylic resin. *J. Prosthet. Dent.* **2009**, *101*, 205–213, doi:10.1016/S0022-3913(09)60032-9.
27. Ouzzani, M.; Hammady, H.; Fedorowicz, Z.; Elmagarmid, A. Rayyan—a web and mobile app for systematic reviews. *Syst. Rev.* **2016**, *5*, doi:10.1186/s13643-016-0384-4.
28. Deeks, J.J.; Higgins, J.P.; Altman, D.G. *Cochrane Handbook for Systematic Reviews of Interventions. 2nd Edition*; 2019; Vol. 4; ISBN 9781119536628.
29. U.S. Departement of Health and Human Services Handbook for Conducting a Literature-Based Health Assessment Using OHAT Approach for Systematic Review and Evidence Integration; March 4, 2019. **2019**.
30. Jain, S.; Adawi, H. Effect of Effervescent Denture Cleansers on 3D Surface Roughness of Conventional Heat Polymerized, Subtractively, and Additively Manufactured Denture Base Resins: An In Vitro Study. *J. Prosthodont.* **2023**, *32*, 244–252, doi:10.1111/jopr.13525.
31. Alqanas, S.S.; Alfuhaid, R.A.; Alghamdi, S.F.; al-Qarni, F.D.; Gad, M.M. Effect of denture cleansers on the surface properties and color stability of 3D printed denture base materials. *J. Dent.* **2022**, *120*, 104089, doi:10.1016/j.jdent.2022.104089.
32. Jain, S.; Sayed, M.; Ahmed, W.M.; Halawi, A.H.A.; Najmi, N.M.A.; Aggarwal, A.; Bhandi, S.; Patil, S. Correction: Jain et al. An in-vitro study to evaluate the effect of denture cleansing agents on color stability of denture bases fabricated using cad/cam milling, 3d-printing and conventional techniques. Coatings 2021, 11, 962. *Coatings* **2021**, *11*, doi:10.3390/coatings11101177.
33. Gehan El-Olimy, A.S. Effect of two cleansing materials on hardness and surface roughness of conventional and three-dimensional printed denture base materials. *Tanta Dent J* **2022**, *3*, 125–31, doi:10.4103/tdj.tdj_17_22.
34. Alfouzan, A.F.; Tuwaym, M.; Aldaghri, E.N.; Alojaymi, T.; Alotiabi, H.M.; Taweel, S.M.A.; Al-Otaibi, H.N.; Ali, R.; Alshehri, H.; Labban, N. Efficacy of Denture Cleansers on Microbial Adherence and Surface Topography of Conventional and CAD/CAM-Processed Denture Base Resins. *Polymers (Basel).* **2023**, *15*, 1–13, doi:10.3390/polym15020460.
35. Alfouzan, A.F.; Alotiabi, H.M.; Labban, N.; Al-Otaibi, H.N.; Al Taweel, S.M.; AlShehri, H.A. Effect of aging and mechanical brushing on surface roughness of 3D printed denture resins: A profilometer and scanning electron microscopy analysis. *Technol. Heal. Care* **2021**, *30*, 161–173, doi:10.3233/THC-212974.
36. Bollen, C.M.; Lambrechts, P.; Quirynen, M. Comparison of surface roughness of oral hard materials to the threshold surface roughness for bacterial plaque retention: a review of the literature. *Dent. Mater.* **1997**, *13*, 258–269, doi:10.1016/S0109-5641(97)80038-3.
37. Morgan, T.D.; Wilson, M. The effects of surface roughness and type of denture acrylic on biofilm formation by Streptococcus oralis in a constant depth film fermentor. *J. Appl. Microbiol.* **2001**, *91*, 47–53, doi:10.1046/j.1365-2672.2001.01338.x.
38. An, Y.H.; Friedman, R.J. Concise Review of Mechanisms of Bacterial Adhesion. *J. Biomed. Mater. Res.* **1998**, *43*, 338–348.
39. Buergers, R.; Rosentritt, M.; Handel, G. Bacterial adhesion of Streptococcus mutans to provisional fixed prosthodontic material. *J. Prosthet. Dent.* **2007**, *98*, 461–9, doi:10.1016/S0022-3913(07)60146-2.
40. Gligorijević, N.; Mihajlov-Krstev, T.; Kostić, M.; Nikolić, L.; Stanković, N.; Nikolić, V.; Dinić, A.; Igić, M.; Bernstein, N. Antimicrobial Properties of Silver-Modified Denture Base Resins. *Nanomaterials* **2022**, *12*, 2453, doi:10.3390/nano12142453.
41. Coulthwaite, L.; Verran, J. Potential pathogenic aspects of denture plaque. *Br. J. Biomed. Sci.* **2007**, *64*, 180–189, doi:10.1080/09674845.2007.11732784.
42. R, R.; Robin*, P.; Raj, J.D. A Survey of Denture Hygiene in Older Patients. *J. Med. Sci. Clin. Res.* **2015**,

doi:10.18535/jmscr/v3i9.01.
43. Costa, R.T.F.; Pellizzer, E.P.; Vasconcelos, B.C. do E.; Gomes, J.M.L.; Lemos, C.A.A.; de Moraes, S.L.D. Surface roughness of acrylic resins used for denture base after chemical disinfection: A systematic review and meta-analysis. *Gerodontology* **2021**, *38*, 242–251, doi:10.1111/ger.12529.
44. Peracini, A.; Davi, L.R.; de Queiroz Ribeiro, N.; de Souza, R.F.; Lovato da Silva, C.H.; de Freitas Oliveira Paranhos, H. Effect of denture cleansers on physical properties of heat-polymerized acrylic resin. *J. Prosthodont. Res.* **2010**, *54*, 78–83, doi:10.1016/j.jpor.2009.11.004.
45. Savabi, O.; Attar, K.; Nejatidanesh, F.; Goroohi, H.; Badrian, H. Effect of different chemical disinfectants on the flexural strength of heat-polymerized acrylic resins. *Eur. J. Prosthodont. Restor. Dent.* **2013**, *21*, 105–8.
46. Alkaltham, N.S.; Aldhafiri, R.A.; Al-Thobity, A.M.; Alramadan, H.; Aljubran, H.; Ateeq, I.S.; Khan, S.Q.; Akhtar, S.; Gad, M.M. Effect of Denture Disinfectants on the Mechanical Performance of 3D-Printed Denture Base Materials. *Polymers (Basel).* **2023**, *15*, 1175, doi:10.3390/polym15051175.
47. Gad, M.M.; Fouda, S.M.; Abualsaud, R.; Alshahrani, F.A.; Al-Thobity, A.M.; Khan, S.Q.; Akhtar, S.; Ateeq, I.S.; Helal, M.A.; Al-Harbi, F.A. Strength and Surface Properties of a 3D-Printed Denture Base Polymer. *J. Prosthodont.* **2022**, *31*, 412–418, doi:10.1111/jopr.13413.
48. Nikawa, H.; Iwanaga, H.; Hamada, T.; Yuhta, S. Effects of denture cleansers on direct soft denture lining materials. *J. Prosthet. Dent.* **1994**, *72*, 657–62, doi:10.1016/0022-3913(94)90300-x.
49. Coimbra, F.C.T.; Rocha, M.M.; Oliveira, V.C.; Macedo, A.P.; Pagnano, V.O.; Silva-Lovato, C.H.; Paranhos, H. de F.O. Antimicrobial activity of effervescent denture tablets on multispecies biofilms. *Gerodontology* **2021**, *38*, 87–94, doi:10.1111/ger.12500.
50. Yatabe, M.; Seki, H.; Shirasu, N.; Sone, M. Effect of the reducing agent on the oxygen-inhibited layer of the cross-linked reline material. *J. Oral Rehabil.* **2001**, *28*, 180–5, doi:10.1046/j.1365-2842.2001.00634.x.
51. Al-Thobity, A.M.; Gad, M.; ArRejaie, A.; Alnassar, T.; Al-Khalifa, K.S. Impact of Denture Cleansing Solution Immersion on Some Properties of Different Denture Base Materials: An In Vitro Study. *J. Prosthodont.* **2019**, *28*, 913–919, doi:10.1111/jopr.12649.
52. Sharma, P.; Garg, S.; Kalra, N.M. Effect of Denture Cleansers on Surface Roughness and Flexural Strength of Heat Cure Denture Base Resin-An In vitro Study. *J. Clin. Diagn. Res.* **2017**, *11*, ZC94–ZC97, doi:10.7860/JCDR/2017/27307.10483.
53. da Silva, F.C.; Kimpara, E.T.; Mancini, M.N.G.; Balducci, I.; Jorge, A.O.C.; Koga-Ito, C.Y. Effectiveness of six different disinfectants on removing five microbial species and effects on the topographic characteristics of acrylic resin. *J. Prosthodont.* **2008**, *17*, 627–33, doi:10.1111/j.1532-849X.2008.00358.x.
54. Cevik, P.; Yildirim-Bicer, A.Z. The Effect of Silica and Prepolymer Nanoparticles on the Mechanical Properties of Denture Base Acrylic Resin. *J. Prosthodont.* **2018**, *27*, 763–770, doi:10.1111/JOPR.12573.
55. Could Dental Material Reuse Play a Significant Role in Preservation of Raw Materials, Water, Energy, and Costs? Microbiological Analysis of New versus Reused Healing Abutments: An In Vitro Study Burioni R.; Silvestrini L.; D'Orto B.; Tetè G.; Nagni M.; Polizzi E.; Gherlone E.F. Bioengineering 2024, 11(4), 387; https://doi.org/10.3390/bioengineering11040387

10.59987/ads/2025.2. 98-108