Review Article

Denture Liners: A Systematic Review Relative to Adhesion and Mechanical Properties

Simone Kreve and Andréa C. Dos Reis

Department of Dental Materials and Prosthodontics, Ribeirão Preto Dental School, University of São Paulo (USP), Ribeirão Preto, SP, Brazil

Correspondence should be addressed to Andréa C. Dos Reis; andreare73@yahoo.com.br

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Purpose. The objective of this systematic review is to compare results concerning the properties of adhesion, roughness, and hardness of dental liners obtained in the last ten years.

Methods. Searches on the databases LILACS, PubMed/Medline, Web of Science, and Cochrane Database of Systematic Reviews were supplemented with manual searches conducted between February and April of 2018. The inclusion criteria included experimental in vitro and in vivo, clinical, and laboratory studies on resilient and/or hard liners, assessment of hardness, roughness, and/or adhesion to the denture base, and physical/mechanical changes resulting from the disinfection process and changes in liners’ composition or application.

Results. A total of 406 articles were identified and, from those, 44 are discussed. Twenty-four studies examined the bond strength, 13 surface roughness, and 19 the hardness. Of these 44 studies, 12 evaluated more than one property. Different substances were used in the attempt to improve adhesion. Considering roughness and hardness, the benefits of sealants have been tested, and the changes resulting from antimicrobial agents’ incorporation have been assessed.

Conclusion. Adhesion to the prosthesis base is improved with surface treatments. Rough surfaces and changes in hardness compromise the material’s serviceability.

1. Introduction

Liners have been widely used in dentistry to reshape prostheses surfaces in contact with soft tissues of the oral cavity [1]. Failure in adhesion, rough surfaces, and changes in hardness are favorable factors for microbial accumulation and compromise the liner’s durability and the oral health condition such as denture stomatitis [2], implant loss [3, 4], peri-implantitis [4], and osseointegration delay, as well as respiratory problems [5] that can interfere with the rehabilitation treatment success and quality of life.

Liners are also used for prostheses fractures, remodeling of bone crests [6–8], and cleft palate [9], in cases of excessive resorption of the alveolus and occurrence of lesions on the mucosa [9, 10], and in tissue conditioning during implant healing [11], among others, acting to dissipate part of the impact of mastication [8, 12]. They are processed in laboratories (heat-polymerized) [13] and/or dentist offices (self-polymerized) because of their easy and quick application [14–17]. The term “soft liners” refers to a class of resilient materials used to reline denture base surfaces in contact with the occlusal stress-bearing oral mucosa [18].

Liners can be either hard [6, 16], usually made of polymethylmethacrylate [9, 10, 19, 20], or resilient [20–24], when plasticizers are added to the resin and the silicone elastomers [22, 24, 25]. Resilient liners are intended to be elastic, absorb energy, and act on the cushion effect [24]. Resilient reline materials are also classified as short- or long-term products. Long-term resilient denture liner materials maintain their resilience for more than 30 days and can be used for up to 1 year, while short-term liners are recommended for use for up to 30 days [26].

Liners are noninvasive and relatively more economical if compared to make a new denture [23, 27, 28]. Patients prefer resilient liners over the hard ones, because they improve comfort [14, 21, 28, 29].

However, they have some disadvantages, like presence of surface defects and porosity, residual taste after use, tendency
to pick up odors [14, 30], water uptake [14, 24, 31], poor adhesion to acrylic resin [9, 31], proneness to change of color [7, 23], difficulty to clean [32], and premature hardening due to plasticizers' solubilization [10, 31].

A successful relining depends on the bond strength between the liner and the resin base [1, 6, 33, 34]. The lack of bonding leads to debonding, diminishing the procedure's longevity, and may occur due to an inefficient bond to the denture, or low cohesive strength [31]. According to Ahmad et al. [1], better adhesion is obtained when the materials' chemical properties are similar. Adhesion of liners to base polymers depends on the chemical composition of materials involved [19] and is influenced by the resin type, thermal cycle, and surface treatment [19, 31]. Excessive roughness results in microbial colonization and difficult hygiene. Liners are unstable in aqueous solutions; the hardness increases after water, saliva, and cleaning agents' absorption. Denture relining can be a factor of predisposition for prosthetic stomatitis.

The sealants' application [28, 29], surface treatments [35, 36], and physical-mechanical changes resulting from disinfection [17, 32, 37], among others, improve adhesiveness, reduce roughness, and maintain the liners' initial hardness.

Based on what has been presented, preserving the liners' physical-mechanical properties is a challenge. Considering its immediacy, simplified process, and economy, since the relining allows the use of the same prosthesis, it could be expected to grow demand especially more in dependent elderly care. This subject approach through a systematic review allows analyzing many studies' outcomes that have been carried out in attempt to improve these materials' limitations, such as debonding of denture base and changes in roughness and hardness that compromise its elasticity, assisting the clinicians in choosing the best product or technique. This systematic review covers studies published in the past 10 years aiming to assess the state of the art of liners, properties of adhesion, roughness, and hardness.

2. Materials and Methods

The question posed was as follows: Do the denture liners' modifications alter the adhesion, roughness, and hardness properties?

This systematic review was conducted according to the PRISMA (Preferred Reporting Items for Systematic Reviews and Meta-Analyses) report [38, 39] and registered on the PROSPERO database: CRD42018108821.

The review question, objectives of the study, eligibility criteria, and search and data analysis strategy were clearly stated in advance and incorporated in the protocol's content.

2.1. Defining Eligibility Criteria

2.1.1. Search Methods. Studies reporting the properties of adhesion, roughness, and hardness of dental liners were identified by searching electronic databases and scanning reference lists of articles. Four databases were searched, LILACS, PubMed/Medline, Web of Science, and Cochrane Database of Systematic Reviews, using the following keywords: “denture liner” OR “reline” AND “soft liner” OR “surface roughness” OR “bond strength” OR “hardness” OR “hard liner.”

The literature survey was conducted from February to April of 2018 and included articles published between 2008 and 2018, in the Journal Citation Reports (JCR) indexed journals. This period was chosen for the review since the articles within that time interval depict the results of the main findings previously. Supplemental searches were conducted; the reference and citations' lists of the selected papers were reviewed in order to select potential inclusions.

2.1.2. Types of Interventions. This systematic review was performed to answer the following questions: In patients wearing removable prostheses fitted with denture liners, does the bond strength of those materials alter? What has been used in the past 10 years to improve adhesion of denture liners to denture base? Do the modifications in the denture liners to improve the adhesion to the base of the prosthesis impair hardness and roughness values?

2.1.3. Comparison. This study compares with the standard treatment, which in this case is applying the liner according to the manufacturer's instructions.

2.1.4. Outcome Measures. The outcome measures were the effect of the intervention (denture liner) with some modification, as well as comparison between the effects of surface treatments with different substances on the properties of adhesion, roughness, and hardness. The main outcomes were defined when the article included in this review presented some adhesion, surface roughness, or/and hardness evaluation and showed a substantial result.

2.1.5. Types of Studies. We selected and assessed papers published in English that met the inclusion criteria: experimental in vitro and in vivo, clinical, and laboratory studies on resilient and/or hard liners, assessment of hardness, roughness, and/or adhesion to the denture base, and physical/mechanical changes resulting from the disinfection process and changes in liners' composition or application.

Studies based exclusively on materials for denture base, unpublished data, critiques, case reports, and expert opinion papers should be excluded due to their high risk of bias [38]. Systematic reviews should also not be included.

2.1.6. Study Selection. The study selection was carried out independently by two authors who adhered to the predefined eligibility criteria. Any disagreements between the two reviewers regarding the inclusion of studies were resolved by discussion.

2.1.7. Assessment of Bias in Individual Studies. Risks were minimized by strictly following the keywords, the coherence of the selected abstracts, and analysis of articles published in selective editorial policy journals; this guarantees the quality of the individual studies.
Each of the included studies was then assessed for potential internal methodological bias such as the adequacy of randomization, incomplete outcome, and appropriate method of blinding.

3. Results

A total of 406 studies were identified on the initial screening. All abstracts were analyzed according to the PRISMA statement [38, 39]. Publications were identified as being relevant through the initial screening of titles and abstracts followed by screening of the full text. After exclusion of duplicates, 151 articles were selected for a complete assessment and, from these, 44 are discussed (Figure 1, Tables 1, 2, 3, and 4). Twenty-four studies examined the bond strength, 13 surface roughness, and 19 the hardness. Of these 44 studies, 12 evaluated more than one property. Most studies comprised in vitro evaluations, and only 3 were in vivo studies [25, 41, 42].

The articles were subdivided into categories since each article could address more than one property [8, 17, 19, 27, 29, 34, 35, 41, 43–45].

Considering the different commercial brands, Ufi Gel (VOCO) was the most commonly employed silicone-based liner, and Trusoft (BOSWORTH) was the most commonly employed resilient resin-base liner. Tokuyama Rebase II (Tokuyama) was the most used chairside hard liner.

Other materials such as Kooliner (GC America), Reline Soft (GC America), COE-SOFT (GC America), Sofreliner (Tokuyama), Mucopren Soft (Kettenbach), Elite Soft (Zhermack), and New Truliner (BOSWORTH) were also assessed often [1, 6, 12, 23, 25, 27, 37, 40, 41, 43, 46–48].

Types of intervention were as follows: comparison between the effects of surface treatments with different substances [12, 20, 35, 36, 49], bond tests between liners and different prosthetic materials [1, 10, 31], and assessment of the initial roughness of materials and that resulting from disinfection methods [17, 32, 44].

4. Discussion

Denture liners’ materials have been widely used despite their substantial shortcomings. The use of solvents seems to improve the adhesion of the reliner to the PMMA base. Most cleansing agents compromise the hardness and elastic modulus. In addition, changes in roughness can lead to microbial colonization, increase the risk of oral and systemic infections, and decrease quality of life. Among the various disinfection methods, minor changes in the hardness and
Table 1: Included studies related to the bond strength.

| Author/year | Method | Study objectives | Outcomes |
|------------|--------|-----------------|----------|
| Ahmad et al./2009 | Shear bond strength | Bond strength, denture to reline materials | Higher bond strengths with similar compositions. PMMA (Meliodent), highest bond strength with (Meliodent RR), and UDMA (Eclipse) with Eclipse reline |
| Lassila et al./2010 | Tensile bond strength | Bond strength, liners to fiber-reinforced and unreinforced PMMA | Sofreliner Tough, highest bond strength, and Eversoft, lowest |
| Więckiewicz et al./2014 | Tensile and shear bond strength | Adhesion of silicone lining to denture base | A-Soft Line 30, the best adhesive properties |
| Mese and Guzel/2008 | Tensile bond strength | Effect of storage on bond strength and hardness, resilient liners | Bond strength, lower as storage time increased. Greater changes, acrylic resilient liner |
| Atsü and Keskin/2013 | Tensile bond strength | Bond strength, silicone denture liner, effects of surface treatment after thermocycling | Highest bond strength with adhesive. Surface treatment did not improve bond strength |
| Santawisuk et al./2013 | Tensile bond strength | Comparing experimental silicone with lining materials | Silastic® MDX-44210 silicone, greater mechanical properties |
| Ohkubo et al./2009 | Shear bond strength | Bond strength immersing denture in methylmercaptan | Methylmercaptan causes liner detachment |
| Takahashi et al./2011 | Tensile bond strength | Accelerated aging times on bond strength of soft liners | Mucopren Soft, higher tensile bond strength than Trusoft |
| Hamanaka et al./2016 | Shear bond strength test | Bond strength of reline resin to injection-molded thermoplastic denture | Bond strengths’ values varied. Bond improved, tribochemical silica coating and 4-META/MMA-TBB resin |
| Cavalcanti et al./2014 | Tensile bond strength | Surface treatments on adhesion of silicone denture liners | Methylmethacrylate and ethyl acetate improved the adhesion of a silicone denture liner to PMMA |
| Kim et al./2014 [33] | Tensile bond strength | Bond strength, long-term soft denture lining | GC Reline Soft, highest bond strength. GC Reline Ultrasoft and Mucopren Soft, the lowest |
| Kanie et al./2009 | Tensile bond strength and adhesive strength | Physical/mechanical properties, experimental light-curing soft lining | Tensile strength of UV-37, the lowest. No difference in adhesive strength between UV-35 and UV-37 at 1 day and 12 months |
| Dayrell et al./2012 | Tensile bond strength | Bond strength and surface roughness of soft liners, sealer coating | Without surface sealer Mucopren Soft and Dentuflx, highest bond strength; Ufi Gel, intermediate; and Comfort Denso, the lowest |
| Takahashi et al./2009 | Flexural strength test | Microwave postpolymerization (PP) on strength, acrylic resin intact and relined | New Truliner, smaller strength with PP microwave and effective only for Kooliner |
| Kim et al./2014 [40] | Tensile bond strength and transverse bond strength | Bond strength, relining resins, Acrytone, comparison, heat-polymerized acrylic and polyamide | Bond strength, relines resins and thermoplastic denture similar to acrylic resin. Polyamide, lowest |
| Maeda et al./2012 | Peel bond strength | Bond of resilient denture liners to denture | All, adequate bond strength, used clinically for three years |
| Tanimoto et al./2009 | Peel bond strength | Adhesive denture and denture liner | GC Reline Ultrasoft, lower adhesion |
| Koodaryan and Hafezeqoran/2016 | Shear bond strength test | Bond strength, reline resin, polyamide and surface modification, acetic acid | Acetic acid, the greatest bond strength of MMA |
4.1. Denture Liner Adhesion Mechanism. Aging [1] alters the adhesive properties of denture base polymers and liners [49] leading to flaws on the materials interface [41, 49, 50].

The bond between the prosthesis and liner begins with the dissolution of the resin by the solvent, swelling of surface layers, and evaporation of the solvent. The liner monomers diffuse, penetrate the resin pores, and form an interpenetrating polymeric network [51]. The larger the surface swelling, the deeper the porous layer and, as a consequence, the better the adhesion between the liner and denture base.

The bond strength between the liner and denture base was assessed [12, 15, 31, 49, 50] through primer application, where the layer of the GC resin primer was applied on the polyamide surfaces [52], through an adhesive such as a bonding agent that is a reline material partner [12], through sandblasting of the acrylic base resin surfaces with 50 μm Al₂O₃ particles [20], through organic solvents, such as the application of an acetone solution and ethyl acetate solution [35], through application of a mixture of methyl formate and methyl acetate solution [51], and with changes in the prosthesis material like PMMA, preimpregnated with unidirectional glass fiber [12].

According to Ohkubo et al. [30], dentures used for an extended period of time are difficult to reline because microorganisms produce methyl mercaptan, which causes liner detachment even after the primer dissolution. Since bacteria penetrate to approximately 3 mm deep [30], more efficacy is obtained by reducing the base thickness and applying a high penetration primer, such as those based on dichloromethane.

4.1.1. Silicone Liners. Silicone liners are mechanically superior and more durable than resin liners [35, 43]. However, they lack chemical adhesion [19, 31, 35], and adhesive flaws can be associated with the bonding agent [12]. Adhesive failures between the liner (silicone-type resilient denture liners) and prosthesis (heat-polymerized polymethylmethacrylate (PMMA)) increased from 13.8% to 60% after 30 days of storage in water [49], suggesting that their bonding gradually weakens over time.

Air abrasion with silica and silanization failed to improve bond strength of silicone resilient lining to the prosthesis (heat-cure acrylic), and the defects produced by the 30 μm particles were not sufficient for the liner material penetration [20].

Organic solvents such as MMA (methylmethacrylate) and ethyl acetate improve silicone liners’ adhesion to PMMA because they lead to softening and porosities that enhance adhesive penetration [33, 35]. Lassila et al. [12] found enhanced adhesion using ethyl acetate as bonding agent; Kim et al. [40] found better results using a primer or adhesive to adhere silicone liners to PMMA surfaces since they reduce the bubbles’ formation during relining.

4.1.2. Treatments to Improve Denture Liners’ Adhesion to the Prosthesis. Treatment with acetic acid was comparable to that with trichochemical silica coating [52]. On the other hand, polymethylmethacrylate (PMMA) surfaces showed better adhesion with methyl formate-methyl acetate (MF-MA) than with resin liner bonding agents [51], composed of acetone and 2-HEMA, which is not volatile and obstructs the polymeric chains’ interlocking, thus reducing bonding. There is no residual solution for MF-MA.

Another way to enhance the liners’ adhesion to the prostheses is application of laser Er: YAG that alters prostheses surfaces, creating defects. Akin et al. [53] showed an increase in the silicone-based liners’ bond strength to a UDMA base following laser application.
| Author/year | Method used | Study objectives | Outcomes |
|-------------|-------------|------------------|----------|
| Kasuga et al./2011 | Hardness values in Shore A durometer | Compare fluorinated monomer soft lining materials, conventional | No hardness difference, experimental fluorinated soft lining materials, Molloplast B |
| Mese and Guzel/2008 | Hardness values in Shore A durometer | Storage duration on tensile bond strength and hardness, acrylic resin and silicone liners | Hardness, higher with increased duration of immersion |
| Santawisuk et al./2013 | Hardness values in Shore A durometer | Tensile strength, tear resistance, and hardness of experimental silicone elastomers (ESE) | Hardness, ESE increased with amount of silica filler (from 6 to 10 phr) |
| Kutlu et al./2016 | Surface roughness tester | Sealer coating, roughness of soft lining | Roughness, methacrylate-based liners increased, denture cleanser. Sealer coating, no effect, roughness |
| Mante et al./2008 | Hardness values in Shore A durometer | PermaSeal, hardness of soft reline | Sealer reduced saliva softening effect, methacrylate-based soft reline |
| Kim et al./2014 [33] | Hardness values in Shore A durometer | Hardness and bond strength of long-term soft denture lining | Hardness, 28-day decreased compared to 24-hour |
| Kanie et al./2009 | Hardness values in Shore A durometer | Evaluate experimental light-curing soft lining materials (ESLMs) | Hardness, UA-16, UV-32, and UV-35 similar to commercial denture liner |
| Badaró et al./2017 | Hardness values in Shore A durometer and surface roughness tester | R. communis dentifrice (10%) on abrasiveness, hardness, and color change of a denture liner | Weight loss, roughness similar to Corega. Colgate, Corega Brite, roughness from 0.26 to 0.34 μm. Brushing, no effect, hardness |
| Dayrell et al./2012 | Surface roughness tester | Sealer coating, bond strength and roughness of liners | Palaselle coating, no effect, liners roughness. Without sealer coating, no difference observed on roughness |
| Machado et al./2012 | Surface roughness tester | Roughness of denture resin, hard and resilient lining materials | No differences, initial roughness, Lucitone, Sofreliner, Tokuyama Rebase II, and New Truliner. Immersion 4%, chlorhexidine increased roughness. Ufi Gel Hard and Sofreliner, after 1 and 2 disinfection cycles |
| Cazacu et al./2009 | Hardness values in Shore A durometer | Heat curable silicone, tested as a liner | Hardness, 59 ShA |
| Mainieri et al./2011 | Surface roughness tester | Roughness, soft liners with and without surface sealer after brushing | Roughness, sealed COE-SOFT increased baseline, 1 month. Ui-Gel with and without sealer coating, after 6 months |
| Machado et al./2011 | Surface roughness tester | Roughness denture, hard and resilient lining materials | Roughness, Tokuyama Rebase II and Ufi Gel Hard similar or > New Truliner. Lucitone and Tokuyama Rebase II, no affected immersion disinfection |
| Mancuso et al./2012 | Hardness values in Shore A durometer | Ageing effect, hardness, absorption, solubility, and color denture liners | Thermocycling influenced hardness |
| Leite et al./2010 | Hardness values in Shore A durometer | Hardness values | Thermal cycling increased hardness, Elite Soft. Decrease for Kooliner |
| Pisani et al./2012 | Hardness values in Shore A durometer and surface roughness tester | Color stability, hardness and roughness, denture liners cleansers’ immersion | Hardness increased. Hypochlorite altered hardness. Elite Soft, highest roughness |
| Bertolini et al./2014 | Hardness values in Shore A durometer | Hardness, chlorhexidine diacetate or chlorhexidine hydrochloride soft lining | Hardness, no changes, antimicrobial agents |
| Chladek et al./2013 | Hardness values in Shore A durometer | Mechanical changes denture liners, silver nanoparticle | Softone roughness increased, miconazole and chlorhexidine. Trusoft did not increase. Hardness and roughness, little changes |
| Urban et al./2014 | Hardness values in Shore A durometer and surface roughness tester | Hardness and roughness, liners with antimicrobial | Thermo-cycling influenced hardness |
Table 3: Included studies related to the hardness and roughness for hard denture liners.

| Author/year          | Method used                                      | Study objectives                                                                 | Outcomes                                                                 |
|----------------------|--------------------------------------------------|----------------------------------------------------------------------------------|--------------------------------------------------------------------------|
| Urban et al. /2009   | Vickers hardness tester and surface roughness tester | Effect of water-bath postpolymerization (PP), degree of conversion, flexural strength, and microhardness, reline resins | Hardness increased by PP except Ufi Gel Hard                                |
| Machado et al. /2009 | Vickers hardness tester and surface roughness tester | Hardness and surface roughness, microwave and chemical disinfection, reline resins, denture resin | Hardness, Lucitone 550, not affected. Kooliner and DuraLiner II, increased, except Lucitone 550. Microwave 2 cycles, increased roughness. Tokuyama did not increase. Hardness, small decrease, 30 days |
| Izumida et al. /2014 | Surface roughness tester                         | Roughness, denture cleansers, reline resin                                       | Roughness, reduction, brushing and sodium perborate and/or chlorhexidine gluconate |
| Machado et al. /2012 | Surface roughness tester                         | Roughness, denture, hard chairside and resilient lining materials                | Initial roughness, no differences, Lucitone and Sofreliner, Tokuyama Rebase II and New Truliner. Chlorhexidine 4%, increased roughness, Ufi Gel Hard and Sofreliner, after disinfection |
| Dias Panariello et al. /2015 | Knoop hardness and surface roughness tester | Roughness (brushing, immersion). Hardness, color, Lucitone 550 (L), and reline resin | Roughness, decreased to L. Hardness, NaOCl and perborate, decreased to L. Hardness, decreased for T |
| Machado et al. /2011 | Surface roughness tester                         | Roughness denture, hard chairside and resilient lining materials                | Roughness, Tokuyama Rebase II and Ufi Gel similar or < New Truliner. Roughness, Lucitone and Tokuyama Rebase II, not affected by immersion and disinfection |

Table 4: Included studies related to in vivo studies.

| Author/year          | Observation period | Method used                                      | Study objectives                                                                 | Outcomes                                                                 |
|----------------------|--------------------|--------------------------------------------------|----------------------------------------------------------------------------------|--------------------------------------------------------------------------|
| Mutlay et al. /2008  | 3, 6, and 12 months | Evaluation criteria: physical integrity, surface detail, adhesion, color, odor, plaque accumulation, resilience, hygiene, mucosal condition, and signs of fungal colonization | Clinical performance denture liners, 12 months                                   | Roughening, posterior region                                               |
| Bail et al. /2014    | Rats used palatal plates, 14 days | A roughness tester                             | Roughness, soft liners                                                         | Roughness, Dentuflax and Dentusoft, similar. Trusoft, rougher than Dentusoft. Ufi Gel P, lowest roughness (14-day) |
| Ogawa et al. /2016   | Original and 1-month hardness, after oral exposure | Shore D hardness                             | Denture liners changes, 1-month clinical setting                                | Hardness, changes influenced, patients’ characteristics                  |

Considering experimental urethane acrylate oligomers-based photopolymerized soft liners, no significant difference in adhesion was observed after 1 day or 12 months of storage in water at 37°C [34]. This material seems to increase the liners’ durability, which is usually of a few months.

4.1.3. Liners’ Adhesion to Different Types of Prostheses. To improve bonding between polyamide prostheses and self-polymerizable resin liners, the prosthesis treatment with tribochemical silica and 4-META/MMA-TBB (4-methacryloxyethyl trimellitate anhydride in methylmethacrylate initiated by tri-n-butyl borane) resin is recommended [36]. Polyamides are chemical resistant materials due to their high degree of crystallinity [33].

Ahmad et al. [1] found flaws in the liners’ adhesion to a UDMA (photopolymerized urethane dimethacrylate) prosthesis due to its highly reticular nature that hinders the monomer penetration. In contrast, Akin et al. [53] found similar adhesion of the resilient liner to UDMA or PMMA
prostheses. Adhesion of hard liners to thermoplastic acrylic resin was similar to that of conventional thermopolymerized acrylic resin; however, results were different for polyamide since these polymers are chemically resistant [33].

A weak adhesion between the resilient resin-base liner and prosthesis was explained by the absence of monomers associated with nonreticulated amorphous polymers [50]. Nonetheless, glass fiber-reinforced PMMA showed increased adhesion to the liner since the fibers were previously filled with nonreticulated polymers containing PMMA islands in micrometric scale [12]. These exposed fibers were better dissolved by ethyl acetate.

4.1.4. Antimicrobial Agents. It is important to assess changes in adhesion of prostheses and liners resulting from medicine incorporation. Antimicrobial additives can be a low-cost, effective alternative that does not require the patients’ cooperation [12]. Pisani et al. [54] showed no changes in resin liner bonding considering immersion time or sodium perborate use, indicating that these do not affect the materials’ dissolution. Alcântara et al. [55] showed that the addition of nystatin, miconazole, ketoconazole, or chlorhexidine diacetate in several dosages had no effect on the liner’s adhesion to the prosthesis.

4.1.5. Considerations Relative to Denture Liners’ Adhesion. Poor adhesion creates a favorable environment to microorganisms and compromises the liner’s durability. For silicone liners, the use of solvents seems to improve their adhesion to PMMA, since it favors the adhesive penetration and creates a mechanical blockage. For PMMA surfaces, the substitution of the most commonly found monomer (acetone and 2-HEMA) for a solution with better agent evaporation improves adhesion allowing the interlocking of the polymer chains.

4.2. Surface Roughness. There are several methods to remove contaminants from the liners, but it is important to assess their effects on the surface since cleaning solutions can penetrate the resin and change its morphology. In addition, immersion time and concentration can alter the polymer structure [32].

Self-polymerizable hard liners’ roughness increases after immersion in sodium perborate and radiation with microwaves due to the immersion temperature and oxygen release by the perborate [17]. Bubbling from the oxygen release is a mechanical cleaning mechanism [17]. Izumida et al. [32] found a reduction in roughness associated with brushing and disinfection with sodium perborate and/or chlorhexidine gluconate and related it to cross-linked agents that reduce the acrylic resin solubility in organic solvents.

Brushing with only toothpaste and water increased roughness of silicone liner [32, 37], since toothpaste is composed of sodium carbonate, an abrasive agent.

No changes in roughness were found in one heat-polymerized denture base acrylic resin (Lucitone 550b) and another autopolymerized reline resin (Tokuyama Rebase Fast II) with different cleaning agents and this was associated with the short immersion time (1, 3, 21, 45, and 90 cycles of 10 seconds) [56]. Machado et al. [44] found an increase in roughness of the hard liner due to porosities formed from the release of residual monomers and plasticizers and from the increase in temperature during disinfection with microwaves. The increase in roughness was observed when organic solvents such as MMA were applied on PMMA as an attempt to improve adhesiveness to silicone-based liners [35], because these solvents degrade the surface and alter its morphology.

Values found for roughness of resin and silicone liners [22] exceeded the ideal clinical parameter (0.2 𝜇m) [57]. High values were also found by other authors [27, 44, 58]. Kutlu et al. [28] prepared the specimens on glass plates and obtained values above 0.2 𝜇m. Machado et al. [58] found initial roughness of 3.54 𝜇m in a resin-base liner. Methacrylate resilient liners are rougher than silicone liners due to their chemical structure, residual monomer content, polymerization method, monomers’ volatility, and mixing technique [24, 43].

4.2.1. Sealants’ Application. Surface sealants protect liners against water absorption and damage from chemicals, saliva, food, and brushing and coating defects and reduce porosities and fissures [18, 29]. Their application reduced roughness produced by brushing in silicone and resin liners, with a more pronounced effect for siloxane-based material [18]. On the other hand, Kutlu et al. [28] showed no reduction in roughness when a sealant was applied to silicone-based and methacrylate-based liners. These findings are in agreement with another study [43]. Several situations increase liners’ roughness, a favoring factor for bacteria accumulation. There is still no consensus on whether roughness is reduced when a surface sealant is applied.

4.3. Hardness. According to the specific ISO standards, liners can be categorized as type A (soft) or type B (extra soft) for measurements taken 24 hours after the preparation of specimens (ISO 10139-2:2009) [59].

A compilation associated with resilient liners comprises changes in hardness over time [42]. Hardness can be defined as penetration resistance [10], it increased in resin liners subjected to warm-water bath following polymerization, and it was associated with the reduction in residual monomers [6]. Mancuso et al. [60] also found an increase after aging that was associated with differences in type and content of plasticizers, leaching, and liquid absorption [17, 60]. Hardness of experimental photopolymerizable soft liners based on urethane acrylate oligomers was similar to that of silicone or acrylic resilient liners [34]. Conversely, Cazacu et al. [45] found higher hardness values for a thermostable silicone tested as liner, equivalent to that of addition silicone.

Chemical cleaning is the first choice to avoid liner damage. Immersion impacts malleability, ductility, and resistance to traction [19]. Immersion in different solutions increased the liners’ hardness [17, 44, 46]. On the other hand, Rezende-Pinto et al. [27] found a reduction in self-polymerizable hard liners’ hardness regardless of chemical solution or water immersion, before and after 30 cycles. Water diffuses through
the resin until it saturates it and this results in surface softening.

Clinically, changes in hardness can also be caused by temperature fluctuations in the oral cavity and changes in pH [29], and, in the laboratory, they may still be affected by the type and concentration, immersion time, and composition of the cleaning solution. Changes in acrylic resilient liners occurred after 1 month of use by patients; and smoking patients showed higher hardness values, probably due to heat exposure. The frequent use of cleaners kept the liners soft and delayed their hardening process. Complete maxillary prostheses users presented higher values, associated with the materials’ package. It is known that the pressure exerted by the denture during mastication accelerates the liner degradation. Complete monomaxillary prostheses exert greater occlusal strength than the bimaxillary prostheses. However, the authors showed no association between hardness and occlusal force after 1 month of the liner application. An increase in saliva acidity was associated with an increase in hardness, but this association cannot be generalized. Finally, use during sleep increased hardness, which was associated with individual and environmental factors [42].

Maintenance of materials’ hardness is critical for their longevity; its effect, with and without sealants, varied among studies [18, 29]. Sealant application on resilient methacrylate can be effective in preserving hardness, since the solvent evaporates and creates a superficial layer resistant to degradation [29].

Given that soft liners’ hardness is approximately 40 Shore hardness units (DIN 53505 and ASTM D2240/75), Santawisuk et al. [25] have enhanced the mechanical properties of an experimental silicone by adding synthetic silica. Comparing with silicone liners, it showed potential as a liner (Shore A hardness 41.3). Kasuga et al. [8] tested a fluorinated monomer of dodecafluorohexyl methacrylate as soft liner material and observed Shore A hardness, similar to that of a commercially available silicone-based liner.

According to Izumida et al. [32], materials containing reticulation agents show greater stability in hardness when stored in aqueous solutions. Pisani et al. [48], on the other hand, found a hardness increase of both liners when stored in liquids. Hypochlorite was the solution that resulted in the greatest change.

It should be noted that the hardness has a direct relation with the viscoelastic properties which are responsible for distributing and absorbing the tensions generated during its clinical function [15, 19, 20]. The higher the hardness value, the lower the material’s ability to absorb the impact of mastication [37]. Decrease in hardness values may lead to superficial changes and retention of oral pathogens. In addition, the silicone rubber-based soft lining materials enhance the growth of fungi such as Candida albicans on the presence of saliva [63, 64].

5. General Considerations

Failure of adhesion between the prosthesis and liner will compromise the procedure durability and favor microbial colonization. Adhesive failure may be associated with the bonding agent. The use of solvents in silicone-based liners seems to improve the adhesion of these to the PMMA base. A surface treatment is required to adhere liners to the polyamide denture base, either with acetic acid or with tribochemical silica. For PMMA surfaces, better adhesion is obtained with the same chemical properties of the liner and denture base. It is important to preserve the hardness values, so that the liner can maintain its elastic property.

Roughness surfaces and hardness changes favor microbial colonization and stomatitis. The selection of the liner should be based on the procedure’s objective, considering serviceability, and expected results. The diversity of methods presented the properties in a diverse manner, showing that subsequent studies are necessary to meet better utilization and indication of liners regarding hardness, roughness, and adhesion. Based on the present results, further in vivo investigations with randomized controlled trials are necessary to compare the performance and properties of these denture liners’ modifications in clinical use.

Conflicts of Interest

The authors report no conflicts of interest.

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