The effect of surface treatment of polymethyl methacrylate denture base on the soft-liner bond strength

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ABSTRACT
The increased use of removable denture in elderly population are followed by the increased use of soft liner for denture reline due to bone resorption. However, soft liners are found to be bonded poorly to polymethyl methacrylate (PMMA) denture base. Thus, several methods are developed in order to improve the bonds between denture base and soft liner, i.e., mechanical methods (sandblast, sandpaper, laser), chemical methods (MMA monomer, acids, acetone, and plasma), or combination of both. This article evaluates the effectiveness of various surface treatment methods of PMMA materials in improving the bonds with silicone or acrylic-based soft liner. It is concluded that surface treatment on the PMMA in general increase the bond strength with the soft liners compared to the control group; the use of Er:YAG laser and MMA monomer show the highest bond strength between the PMMA and soft liner materials. Several factors such as the duration of treatment and the laser intensity energy may affect the bond strength between PMMA and soft liner. Acrylic-based soft liner in general shows better bond strength than silicone-based soft liner, nevertheless both materials show improvement in bond strength with PMMA after surface treatments.
Keywords: polymethyl methacrylate, soft liners, surface treatment, bond strength

INTRODUCTION

The increasing number of elderly populations correlates with the increasing use of dentures due to edentulism. Conventional removable dentures made of polymethyl methacrylate (PMMA) are still widely used because they are relatively inexpensive and the treatment procedures are less invasive than fixed denture treatments. However, the use of removable dentures is often accompanied by jaw bone resorption due to excessive load and this condition may cause the denture to become loose when worn by the patient. Furthermore, these ill-fitted dentures also cause irritation and injury to the oral mucosa. To overcome this problem, relining the denture base with a soft liner is often performformed to avoid excessive load on bones.[1,2]

A soft liner can be defined as a soft (viscoelastic) material that used as a way to distribute the functional load of a denture more evenly so that the concentration of the load at one point on the mucosa can be avoided.[3,4] Soft liners can be divided into short-term (tissue conditioner) and long-term soft liners. Several articles concluded that long-term soft liners can last for about 3-6 years.[3,5] Soft liners can also be classified as heat-polymerized or auto-polymerized soft liners; heat-polymerized material, whether silicone or acrylic, is recommended as it is more stable and has better durability.[4]

Silicone or acrylic soft liners have advantages and disadvantages; for example, silicone material has a good elasticity but bonds poorly with the denture base, causing it to easily come off. On the other hand, the acrylic soft liner easily loses its elasticity over time but this material bonds very well with the PMMA. Thus, no material is truly superior as a soft liner, namely a good resilience/flexibility, may last for a long time, and bonds optimally with the PMMA denture base.[6-9] Adequate bonding between soft liner and PMMA is very important because poor bonding may result in a space formed between the two materials, which it be a potential site for microorganism growth and overall soft liner failure.[10] In addition, the plasticizers contained in the material may be released over time from the soft liner, causing the material to become harder.[11-13]

Several methods have been developed to improve the bond between the PMMA denture base and the soft liner, especially for silicone materials.[1] Modification of the denture base surface, either mechanical or chemical, often used as a way to increase the contact surface area with the soft liner and thus improving the bond.[14] The mechanical surface treatment methods of the PMMA can be performed through sandblasting, sandpaper, or a laser.[3,12,15] Meanwhile, the chemical surface treatment may use either monomer, phosphoric acid, acetone, or modifying the PMMA structure with plasma.[6,15,17]

Science related to soft liners continues to develop, especially in the effort to increase the bond strength with a removable denture base. Several studies show that the bond of silicone material with acrylic resin is still below the acrylic soft liner material even when adhesives have been applied to

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the denture base material.[6,14] Thus several methods have been developed to improve the bond strength between soft liner and PMMA, especially for the silicone material.[6,12,19] The purpose of this review is to evaluate the effectiveness of various PMMA surface treatment methods in increasing the strength of the bond with soft liner materials. Through this scoping review, it is hoped that the clinicians will understand various methods to increase the bonding between soft liners and denture base and be able to choose the best surface treatment method.

LITERATURE STUDIES

This paper is written as a scoping review that follows the Arksey's staging framework and the *preferred reporting items for systematic review extension for scoping review* (PRISMA-ScR) guidelines.[20,21] As previously mentioned, the scope of this paper discusses the bond strength between soft liner and PMMA after surface treatment. A scoping review composition starts with determining the topic questions and establishing the *population*, *concept*, and *context* of the topic. The topic question is *How does the surface treatment of denture base material on the bonding strength of the soft liner?* The population will be denture base material that is relined by a soft liner. The concept determined is the surface treatment of the denture base material, with the bond strength between the denture base and the soft liner determined to be the context in this paper.

The literature relevant to the research questions in this scoping review was searched using the internet. Two source databases were used: PubMed and EBSCOhost. The keywords were ("*Denture*" AND "*Surface Treatment*" AND "*Soft Liner*" AND "*Bond Strength*"). The articles will follow a set of inclusion and exclusion criteria that are listed in Table 1.

The literature search was performed on PubMed and EBSCOhost databases yielded a total of 28 articles, of which 15 articles were obtained from PubMed and 13 articles from EBSCOhost. Duplicated literature from both sources was checked; 8 articles were excluded and left a total of 20 articles. Furthermore, 4 articles were irrelevant to the topic question and thus also excluded from this review. The remaining articles were then checked for the inclusion and exclusion criteria that have been set for this scoping review by reading the full-text articles; 5 articles did not meet the requirements. The final screening results gave 11 articles that will be reviewed in this scoping review.

A summary of the results of the articles used in this paper; table 2 presents the demographic data of the articles while table 3 presents the testing methods, surface treatment groups and research results. All research articles used in this scoping review are in vitro studies, of which 9 studies are designed as cross-sectional studies and 2 studies are designed as prospective studies. All studies used a universal testing machine (UTM) for testing the bond strength between PMMA material and soft-liner material.

DISCUSSION

This scoping review aims to summarize the results of existing studies regarding the comparison of various methods of surface treatment of acrylic resin base material on the bond strength of soft liners. The articles shown in this paper are all in vitro studies using heat-cured PMMA specimen blocks as research samples. Of 11 articles discussed in this paper, 9 articles are cross-sectional studies and 2 articles are prospective studies with a follow-up period of 24 hours, 1 week, or 1 month.[11,12]

Based on the 11 articles, several variations exist, namely the surface treatment methods, soft liner types, and the testing machine speed. Different types of soft-liner were used in the studies: seven studies used silicone, three studies used silicone and acrylic soft liner[3,6,14], and one study used acrylic soft liner.[12] Various surface treatments were also observed: particle sandblasting, MMA monomer, laser, plasma, acid etching, sandpaper, or combination method. Furthermore, the Universal Testing Machine (UTM) used in the studies performed with varying speed; 8 studies used 5 mm/min, 2 studies used 20 mm/min[3,14], while 1 study used 10 mm/min.[15] Those differences may have caused a variety in the results shown above.

The sandblasting method was the most studied method among all surface treatment methods (10 studies). All studies used aluminum oxide (alumina)

Table 1 Inclusion and exclusion criteria

Inclusion Criteria	Exclusion Criteria
Articles published from January-September 2021	Published before January 2011, languages other than English.
English articles	Case reports, finite element analysis (FEA) studies, systematic reviews, meta-analyses, clinical trials, or literature reviews articles.
Articles that are available as full text	
Articles in the form of in vitro studies	Articles that do not have a full-text version
Articles that discuss the bond strength between soft liners and PMMA denture bases that have been surface treated.	

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Table 2 Demographic data of the included studies

No	Author (Year)	Research Purpose	Samples
1	Swapna (2016)[3]	To evaluate the effect of various surface treatments of the PMMA on the soft liner bond strength (silicone and acrylic).	120 PMMA specimens divided into control group and 3 treatment groups. Soft liners (@ 40 specimens): Heat-polymerized silicone soft liner & Auto-polymerized acrylic soft liner 1 & 2
2	Surapaneni (2013)[7]	To compare and evaluate the bond strength between silicone soft liners and PMMA surfaces that have been mechanically or chemically treated.	80 PMMA specimens divided into control group and 3 treatment groups. Soft liners (@40 specimens): Auto-polymerized silicone soft liner 1 & 2
3	Haghi (2019)[6]	To compare the bond strength between 3 types of soft liners against PMMA materials and the comparison between the control group and the treatment group.	165 PMMA specimens for the control group and 4 treatment groups. Soft liners (@ 55 specimens): Heat-polymerized silicone soft liner 1 & 2 & Heat-polymerized acrylic soft liner
4	Atsu, Keskin (2013)[1]	To investigate the effect of alumina and silica sandblasting, silanization, and adhesives on the bond strength between soft liners and acrylic resin.	50 PMMA specimens divided into control group and 4 treatment groups. Soft liner: auto-polymerized silicone soft liner (@ 10 specimens).
5	Nakhaei (2016)[19]	To evaluate the effect of surface treatment of PMMA materials on the bond strength of silicone soft liner.	96 PMMA specimens divided into control group and 3 treatment groups. Soft liner: auto-polymerized silicone soft liner (@ 24 specimens).
6	Mempally (2018)[12]	To evaluate the mechanical, chemical, and mechanochemical surface treatment of PMMA on the bond strength of acrylic-based soft liners.	320 PMMA specimens divided into control group and 3 treatment groups. Soft liners (@ 160 specimens): Heat-polymerized acrylic soft liner 1 & 2
7	Gundogdu (2014)[17]	To evaluate the effect of different surface treatments on the bond strength of 2 different soft liners to acrylic resin material.	96 PMMA specimens divided into control group and 5 treatment groups. Soft liners (@ 48 specimens): Heat-polymerized silicone soft liner & Auto-polymerized silicone soft liner
8	Yildirim (2020)[15]	To evaluate the effect of argon plasma and Er:YAG laser treatment on PMMA surface on the bond strength between silicone soft liners and PMMA.	60 PMMA specimens divided into control group and 2 treatment groups. Soft liners (@ 30 specimens): Heat-polymerized silicone soft liner & Auto-polymerized silicone soft liner
9	Akin (2011)[16]	To investigate the effect of various surface treatments of PMMA material on the bond strength of the soft liner.	120 PMMA specimens divided into control group and 7 treatment groups. Soft liner: heat-polymerized silicone soft liner (@ 15 specimens).
10	Khanna (2015)[14]	To evaluate the bond strength between 2 types of soft liners with PMMA surfaces that have been treated with various methods.	60 acrylic resin specimens divided into control group and 2 treatment groups. Soft liners (@ 30 specimens): Auto-polymerized silicone soft liner & Heat-polymerized acrylic soft liner
11	Philip (2012)[11]	To evaluate the effect of various surface treatments of the PMMA materials on the bond strength of the soft liner	49 PMMA specimens were divided into control group and 6 treatment groups. Soft liner: auto-polymerized silicone soft liner (@ 7 specimens).

Table 3. Evaluation of bond strength based on various surface treatments

No	Author & Year	Testing Method	Treatment Method (number of samples)	Results & Summaries
1	Swapna (2016)[3]	UTM at 20 mm/min	1. Control group (30) 2. Alumina particles sandblasting 30s: ● 50μ (30) ● 150μ (30) ● 250μ (30)	1. 4.37, 6.89, 8.37 (kg/cm^2) 2. 3.07-**3.36**, 4.81-**5.20**, 5.13-**5.84** (kg/cm^2) All treatment groups showed lower bond strength than the control group. Heat-polymerized silicone soft liner showed the highest bond strength
2	Surapaneni (2013)[7]	UTM at 5 mm/min	1. Control group (20) 2. 250μ alumina particles sandblast (20) 3. MMA Monomer 180s (20) 4. Acetone 30s (20)	1) 0.480; 2) 0.435; 3) 0.853; 4) 0.541 (N/mm^2) MMA monomer significantly increased the bond strength of the soft liner than the control group and other treatment groups. Sandblasting decreased the bond strength between 2 materials.
3	Haghi (2019)[6]	UTM at 5 mm/min	1. Control group (33) 2. Er:YAG laser (200 mJ, 10 Hz, 10 sec) (33)	1) 2.5-**7.0**; 2) 1.9-**6.0**; 3) 0.7-**4.8**; 4) 3.1-**8.1**; 5) 1.2-**7.9** (MPa)

			3. 150µ alumina sandblasting 10s (33) 4. MMA Monomer 180s (33) 5. Phosphoric acid 30s (33)	MMA monomer showed the highest bond strength compared to control or other treatment groups. All other treatments lowered the bond strength. Acrylic soft liner showed the highest bond strength.
4	Atsu, Keskin (2013)[1]	UTM at 5 mm/min	1. Control group (10) 2. 50µ alumina sandblasting 15s (10) 3. 30µ silica sandblasting & silanization (10) 4. Silica sandblasting & adhesives (10) 5. Silica sandblasting w/ silanization & adhesives (10)	1) 1.35; 2) 0.28; 3) 0.34; 4) 0.91; 5) 1.01 (MPa) Surface treatment of the acrylic resin with silica-modified sandblasting and silanization showed lower bond strength compared to the control group (default adhesive).
5	Nakhaei (2016)[19]	UTM at 5 mm/min	1. Control group (24) 2. 110µ alumina sandblasting 10s (24) 3. Er:YAG laser (300 mJ, 10 Hz, 20s) (24) 4. Combination of laser and sandblast (24)	1) 0.9; 2) 1.29; 3) 1.24; 4) 1.36 (MPa) All treatment groups showed higher bond strength than the control group. Combination of laser and sandblast showed the highest bond strength.
6	Mempally (2018)[12]	UTM at 5 mm/min	1. Control group (80) 2. MMA monomer 10s (80) 3. 250µ alumina sandblasting 30s (80) 4. MMA monomer and sandblasting (80)	1) 0.41-0.51; 2) 0.84-0.89; 3) 2.81-3.50; 4) 2.03-2.39 (MPa) All treatment groups showed significantly higher bond strength than the control group. The mechanical treatment group showed the highest bond strength.
7	Gundogdu (2014)[17]	UTM at 5 mm/min	1. Control group (16) 2. 36% Phosphoric acid 30s (16) 3. Er:YAG laser (150 mJ, 10 Hz, 60s) (16) 4. 50µ alumina sandblasting 10s (16) 5. Combination of acid and laser (16) 6. Combination of acid and sandblast (16)	1) 0.2-**1.32**; 2) 0.36-**1.39**; 3) 0.21-**1.29**; 4) 0.09-**0.98**; 5) 0.32-**1.08**; 6) 0.22-**1.08** (MPa) Only phosphoric acid treatment increased the bond strength of the soft liner compared to the control group. All other groups showed lower bond strength. Heat-polymerized silicone soft liner showed higher bond strength than auto-polymerized liner.
8	Yildirim (2020)[15]	UTM at 10 mm/min	1. Control group (20) 2. Argon plasma (13.56 MHz, 1 min) (20) 3. Laser Er:YAG (300 mJ, 10 Hz, 20s) (20)	1) 0.38-**0.81**; 2) 0.60-**1.15**; 3) 0.69-**1.33** (MPa) Argon plasma and Er:YAG laser showed higher bond strength between the soft liner and PMMA than the control group. Heat-polymerized silicone soft liner showed higher bond strength than auto-polymerized soft liner.
9	Akin (2011)[16]	UTM at 5 mm/min	1. Control group (15) 2. 50µ alumina sandblasting 10s (15) 3. Er:YAG laser (200 mJ, 10 Hz, 20s) (15) 4. Nd:YAG laser (100 mJ, 15 Hz, 30s) (15) 5. KTP laser (100 mJ, 10 Hz, 60s) (15) 6. Sandblasting and Er:YAG laser 7. Sandblasting and Nd:YAG laser 8. Sandblasting and KTP laser	1) 25.25; 2) 21.04; 3) 32.73; 4) 23.43; 5) 23.53; 6) 23.82; 7) 17.66; 8) 18.26 (N/mm^2) Er:YAG laser treatment showed the highest bond strength compared to the control or other treatment groups. Other laser mediums and sandblasting method lowered the bond strength.
10	Khanna (2015)[14]	UTM at 20 mm/min	1. Control group (20) 2. 250µ alumina sandblasting (20) 3. MMA Monomer 180s (20)	1) 18.27-**18.82**; 2) 18.76-**27.42**); 3) 23.82-**32.74** (MPa) All treatment groups showed higher bond strength than control group. MMA monomer provided the highest bond strength. Acrylic soft liner showed higher bond strength than silicone soft liner.
11	Philip (2012)[11]	UTM at 5 mm/min	1. Control group (7) 2. Acetone 30s (7) 3. MMA Monomer 180s (7) 4. 1000 grit silicone-carbide sandpaper 5s (7) 5. 50µ alumina sandblasting 5s (7) 6. Sandpaper and MMA monomer (7) 7. Sandblasting and MMA monomer (7)	1) 0.1; 2) 0.12; 3) 0.11; 4) 0.12; 5) 0.12; 6) 0.11; 7) 0.14 (MPa) All treatment groups showed higher bond strength than the control group. The combination of sandblasting and MMA monomer treatment showed significantly higher bond strength than other surface treatment methods.

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particles in the sandblasting process and one study[1] mixed silica particles with the alumina particles. Only 4 studies found that the sandblasting method increased the bond strength between the soft liner and PMMA[11,12,14,19] and one study[19] even showed that there was no significant difference with another treatment group. Mempally et al showed that the surface treatment of the acrylic resin using the 250 µ particle sandblasting showed a significantly higher bond strength than the control group and other treatment methods; it was also showed that the PMMA surface with this treatment method gave the highest roughness.[12] This result is similar to the study by Khanna et al and Usumez et al; they demonstrated that the use of 250 µ alumina particle sandblasting showed greater bond strength than the control group, although the difference was not significant.[14,23]

In contrast, other studies showed contradicting results[3,6,17], which can be explained by how the sandblasting method worked on the PMMA surface. Sandblasting create microporosities on the surface, increasing the contact surface area between the PMMA and the soft-liner material, and thus increasing the bond strength. However, it is also known that this may also cause surface irregularities that lead to the failure of penetration of the soft liner material, causing air voids to form between the two materials and decreasing the bond strength, increasing the risk of failure.[6,16,17] The results is supported by Sarac et al, stating that sandblasting showed greater microleakage than the control group.[22] In addition, the sandblasting method may create stress at the interface junction between the PMMA and soft liner material, which is predicted to weaken the bond strength between the two materials.[1,16] Modifying the particles also did not improve the bond; Atsu and Keskin found that silica modification and silanization process was not effective in increasing the bond strength between PMMA and soft liner.[1]

Thus, the sandblasting results remain inconcclusive. It may be because this method is unpredictable in modifying the PMMA surface as the process cannot be fully controlled aside from determining the particle size and the treatment duration. It is nearly impossible to accurately control how deep the microcavity formed by the particles and thus increasing the possibility of uneven contacts between the soft liner and PMMA.[1,6,16]

Mechanical treatment can also be done by using sandpaper. Only one study discussed the use of sandpaper as a surface treatment method, showing that sandpaper significantly increase the bond strength of PMMA with soft liner compared to the control group, albeit still under the sandblasting method.[11] Due to this, it is difficult to conclude about the effectiveness of using sandpaper in increasing the bond strength.

Chemical surface treatment is another method to increase the bond strength between soft liner and PMMA. Chemicals such as MMA monomers, phosphoric acid, or acetone were discussed in several studies. Among these three materials, the use of MMA monomer is the most surface treatment method discussed in the studies. All studies on MMA monomer showed an increase in the bond strength between PMMA and soft liner. They also showed that MMA monomer was the treatment method that provided the greatest bond strength increase compared to other chemical methods.[6,7,14] This increase was thanks to the formation of surface microporosity through the etching process, increasing the surface area of contact between soft liner and PMMA.[7] Haghi, et al also found that the PMMA surface was cleaner and smoother than the control group and the treatment groups through *scanning electron microscopy* analysis, reducing any probability of air voids formed between the two materials.[6] Sarac et al also showed that MMA monomer provided the least microleakage compared to the mechanical (sandblasting) and chemical (acetone) treatment groups and increased the bond strength between acrylic resin and soft liner compared to the control group.[22,24]

Chemical surface treatment can also be done with phosphoric acid or acetone. There are only 2 articles reviewed that discussed the use of phosphoric acid[6,17] and acetone[7,11] for the treatment of PMMA surfaces, respectively. Phosphoric acid or acetone has the same mechanism as the MMA monomer mentioned above. Nevertheless, phosphoric acid and acetone were not very effective in improving the bond strength between the PMMA and the soft liner compared to the MMA monomer. Especially for phosphoric acid, the bond strength between the PMMA and the soft liner were lower than the control group.[6] However, Gundogdu et al showed slight difference in result; phosphoric acid etching showed a slight increase in the bond strength compared to the control group.[17] The result differences between two studies could be due to differences in the method of specimen preparation before the test was conducted as the former carried out a thermocycling process on the specimens, changing the physical properties of the two materials before the test was performed.[6]

The use of a laser can also modify the PMMA surface. In this scoping review, the mediums used in the studies were Er:YAG (erbium-doped yttrium aluminum garnet), Nd:YAG (neodymium-doped yttrium aluminum garnet), and KTP (potassium-titanyl-phosphate), although of the three mediums used, Nd:YAG and KTP mediums were only discussed in one article.[16] Different results were observed from all article regarding the bond strength between PMMA and soft liners. Three studies[15,16,19] showed that significantly higher bond strength was observed in the Er:YAG laser treatment group compared to the control group, although one study[19] also noted that the laser treatment bond strength was not significantly different from the other treatment methods.

In contrast, two studies[6,17] found that the use of Er:YAG laser decreased the bond strength between the two materials when compared to the control group, although it was also noted that this decrease was not significant.[17] Also, one study that used Nd:YAG and KTP medium showed that they were not effective in increasing the bond strength.[16]

Laser treatment modifies the PMMA surface by forming microcavities that will increase the contact surface area with the soft liner. The cavities size is influenced by the laser energy intensity, treatment duration, frequency, and the medium used.[15,16] One study[6] that found a decreased bond strength with laser treatment used a lower energy intensity and shorter time (200 mJ, 10s) than the other studies[15,16,19] that showed a higher bond strength with the use of laser (200-300 mJ, 20s). It is predicted that higher laser energy intensity and/or longer duration of time could result in better bond strength between PMMA and soft liner. It would also explain why Nd:YAG and KTP laser showed a lower bond strength than the control group as only 100 mJ of energy intensity was used.[16]

Yildirim et al also discussed the use of plasma argon as a surface treatment method aside from the use of laser. They found that although not as effective as laser, plasma argon significantly increased the bond strength compared to the control group.[15] Plasma is claimed to increase the PMMA surface wettability, meaning that it increases the hydrophilic properties of the polymer surface without disturbing its mechanical properties, thus improving the adhesion.[15,25] However, it should be noted that as there is only 1 article that discuscusses the use of plasma in this review, so it may be inadequate to conclude whether the use of plasma is truly effective in increasing the bond strength between acrylic resins and soft liner.

Combination of two different surface treatment methods were also discussed in several studies. Combination of laser and sandblasting[16,19] and combination of chemical (MMA monomer) and mechanical (sandblasting or sandpaper) surface treatment on the bond strength between PMMA and soft liner were discussed.[11,12] This combination method gave varying results. Laser and sandblasting combination showed the highest increase in bond strength compared to the control or other treatment groups in one study.[19] However, other study[16] showed a lower bond strength compared to the control group although the difference was considered insignificant. This difference in results is possibly due to the difference in the sandblast particle size and the laser energy intensity used between the two studies. The combined use of laser and sandblasting may be effective in increasing the bond strength between acrylic resin and soft liner as long as the particle size, laser energy intensity, and duration of treatment are taken into account.

On the other hand, the combination of chemical and mechanical surface treatment methods was discussed in two studies.[11,12] Both showed that the method was effective to increase the bond strength between PMMA and soft liner. It worked through the combination of microporosity formation and also depolymerization of the PMMA surface, thus more optimal bonding between the two materials is achieved.[11] However, it was also noted that this mechanochemical method still showed a lower bond strength compared to the sandblasting method, possibly due to uncontrolled pressure appled during MMA monomer application, damaging the PMMA porous surface.[12]

Different soft liners also affect the bond with PMMA. Generally, the bond of acrylic soft liners with PMMA better than silicone soft liners regardless of the surface treatment method used.[6,14] Despite better elasticity and longer duration of use, silicone bonds with acrylic resin through weaker adhesion forces (with the help of adhesives). In contrast, acrylic soft-liner bonds with PMMA through cohesive forces and is thus more resistant to shear forces that cause the detachment of soft liner from the acrylic resin.[12,19] Nevertheless, both materials generally had higher bond strength after the PMMA surface treatment than the control group. Also, heat-polymerized silicone soft liner bonded better with PMMA than the auto-polymerized ones.[6,15,17] These results are also in agreement with the study by Kulak-Ozkan et al, stating that auto-polymerized material tends to have greater shrinkage and shorter duration of use.[26]

As additional information, while it was not shown in the results summary, two studies[11,12] also observed the effect of immersion on the specimens' bond strength. It was conducted to simulate a real-life situation, where a soft liner may lose its elasticity and undergo dimensional changes due to water/saliva absorption, thus affecting the bond with PMMA.[6,12,17] Specimens immersion after 1 week gave the highest bond strength in one study. It may occur due to the latent polymerization of the soft liner during the immersion period and thus the improving the bond between the liner and PMMA. Also, it was observed that the bond strength decreased after immersion for 1 month.[11] This is also supported by Mempally et al that showed 24 hours of immersion provided higher bond strength than the 1-month immersion period. However, they use acrylic soft liner in the study and these different properties may also affect the process.[12]

The limitations of this scoping review are related to the variations in the details of the treatment used as mentioned above. This lack of uniformity in the treatment methods and materials used in the studies reviewed in this paper, exact conclusions are quite difficult to make. Several treatment methods, namely the use of sandpaper[11] and plasma[15] were also only discussed in one article and thus no conclusions could be drawn regarding the effectiveness of these methods on the bond strength improvement between soft liners and acrylic resin. Finally, all studies reviewed are in vitro studies, most of which are cross-sectional studies. The results may not be fully applicable to real clinical situations. Perhaps, using more article databases could provide more articles to review and create more uniform data for further review.

It is concluded that surface treatment of the PMMA generally increase the bond strength between PMMA and soft liner when compared to the control group.
Several surface treatment methods, namely Er:YAG laser, MMA monomer, plasma argon, and combination of mechanical and chemical treatment show a higher bond strength between PMMA and soft liner than the control group. Meanwhile, methods such as Nd:YAG laser, KTP laser, and particles sandblasting show a lower bond strength compared to the control group. However, several factors such as the duration of the surface treatment, the laser energy intensity, and the sandblasting particle size may affect the end results.

On the other hand, acrylic soft liner and heat-polymerized liner show higher bond strength than silicone soft liner and auto-polymerized material, respectively. Also, specimens' immersion for one week shows the highest bond strength between two materials compared to the period of 24 hours and 1 month due to latent polymerization. However, further reviews are required in order to verify this latent polymerization effect.

Considering the limitations of this scoping review, it is suggested that further investigations are needed in regards to the efficacy of Nd:YAG laser, KTP laser, and sandblasting surface treatment in improving the bond strength between PMMA and soft liner from more databases so a uniform data may be collected.

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