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RESEARCH ARTICLE

COMPARATIVE EVALUATION OF TENSILE BOND STRENGTH OF TWO COMMERCIALLY AVAILABLE LINERS FOLLOWING PRETREATMENT OF DENTURE SURFACE WITH OXYGEN PLASMA AND LASER- AN INVITRO STUDY

[1]Dr. Saquib Ahmed Shaikh, [2]Dr. Lekha, K., *,[3]Dr. Gaurav Mathur, [4]Dr. Swasti Tambi Mathur and [4]Dr. Anup, N.

[1]Department of Prosthodontics, College of Dentistry, Majmaah University, Ministry of Higher Education Zulfi, Kingdom of Saudi Arabia
[2]Department of Prosthodontics, SDM College of Dental Sciences and Hospital, Dharwad, Karnataka, India
[3]Department of Prosthodontics, Jaipur Dental College, Jaipur, Rajasthan, India
[4]Department of Public Health Dentistry, Jaipur Dental College, Jaipur, Rajasthan, India

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ABSTRACT

Debonding of the soft liner from the denture base is a major problem that plagues their longevity. Various surface modifications have been introduced to increase the bond strength. But no studies have been conducted comparing the bond strength between denture liners and acrylic resin following Plasma-oxygen and laser treatment. A total of 108 rectangular denture base resin blocks each having a cross-sectional area of 10mm × 10mm and 40 mm length were fabricated. The blocks were divided into 2 groups (n=54) each for bonding with the 2 soft liners (Group 1-Molloplast-B, Group 2-Permasoft). Sample for tensile bond testing was made by packing a soft liner of 3mm thickness between the 2 blocks. Each group was further divided into 3 subgroups based on the surface treatment of the bonding surfaces of the resin blocks i.e. Group A- control (untreated, n=9) Group B-laser treated (n=9) and Group C-Plasma-oxygen treated (n=9). The samples were subjected to tensile stress in universal testing machine at a crosshead speed of 5mm/min. The data was tabulated and subjected to statistical analysis using One way-ANOVA test. Results of this study showed that Plasma-oxygen treatment was more effective in increasing the bond strength as compared to laser pre treatment.

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INTRODUCTION

Complete denture prosthesis has been used for rehabilitation of edentulous mouth since the time when prosthodontics was still in its infancy. Due to severe alveolar ridge resorption and presence of thin overlying mucosa, many complete denture wearers suffer prolonged discomfort under their dentures despite all possible prosthetic adjustments. (Makila, 1976; Murata *et al*., 2002) Resilient denture lining materials are viscoelastic materials that are designed to act as a cushion between the hard denture base and soft tissues in order to reduce the masticatory forces transmitted by prosthesis to the underlying tissues. (Wright, 1980) The viscoelastic properties of these materials are important for their cushioning effect, which allows a more even pressure distribution and maintains shape of the materials. (Kawano *et al*., 1991) These materials are mainly used for the patients who cannot tolerate hard acrylic bases and it helps in distributing the pressure uniformly over the supporting tissue. (Wright, 1976) Wright had stated that successful construction of a denture using two different materials relies partly on a satisfactory bond between the materials. (Wright, 1980) One of the serious problems that are associated with the use of these materials is the adhesion failure between soft denture liner and the denture base. (Sinobad *et al*., 1992) Any favourable property of denture liner is useless in the absence of a good bond to the denture base materials. Several surface modification methods eg. mechanical roughening by sandblasting or lasers, chemical treatment, mechano-chemical treatment etc. have been investigated to modify the acrylic resin surface before applying soft liner in an attempt to increase the bond strength between liner and denture base surface. (Jacobsen *et al*., 1997; Sarac *et al*., 2006) Lasers have

Corresponding author: Dr. Gaurav Mathur,
Department of Prosthodontics, Jaipur Dental College, Jaipur, Rajasthan, India.

numerous applications in medical and dental sciences. Recently, they have been used successfully for increasing the bond strength between liner and resin surface. Er:YAG laser pre treatment of denture base with specific parameters is quite effective in increasing bond strength with less undesirable effects. (Akin *et al*., 2011; Tugut *et al*., 2012) Recently, surface plasma treatment of polymer surfaces has been shown to be a practical method to enhance the adhesion properties without altering the bulk characteristics which directly impact their longevity and function. Recent studies even indicated that plasma treatment could increase the bond strength between soft liner and denture base material. (Zhang *et al*., 2010) Several studies have been done in past on comparison of the tensile bond strength between different types of liners after different types of surface modifications. But no information is available in literature regarding comparison of laser and oxygen-plasma treatment on bond strength between denture liner and denture base material. Hence the purpose of this study was to evaluate and compare the effect of oxygen-plasma and laser treatment on increasing the bond strength between two types of soft liners and denture base resin.

MATERIALS AND METHODS

This in-vitro study was conducted in the department of Prosthodontics, SDM college of dental sciences and hospital, Dharwad, Karnataka, India in association with Dr DY Patil dental college and hospital, Pune; Poornima engineering college, Poornima university, Jaipur and BVB engineering college, Hubli in 2015 with the objective of comparing the effect of laser treatment and oxygen plasma treatment on tensile bond strength between two different permanent denture liners and a denture base resin.

Denture liners used in this study were:

1. Molloplast-B - Silicone based permanent denture liner. (Detax GmbH & Co. KG, Ettlingen, Germany)
2. Permasoft - Acrylic resin based permanent denture liner. (Dentsply India Pvt Ltd.)

For the purpose of the study a total of 108 acrylic resin blocks i.e. 54 specimens as were fabricated. The specimens were divided in two groups based on the two different permanent soft liners that were used. These groups were:
Group 1 – Samples lined with Molloplast soft liner
Group 2 – Samples lined with Permasoft soft liner
Each group was then divided in three subgroups based on surface treatment they received. (Table I)
Subgroup A – No treatment (control).
Subgroup B – Laser treated
Subgroup C – Oxygen plasma treated.

Table I. Group distribution of samples

Group	Soft liner	Subgroup	Pretreatment	Sample size(n)
		1A	Control	9
Group 1	Molloplast-B	1B	Laser	9
		1C	Oxygen-Plasma	9
		2A	Control	9
Group 2	Permasoft	2B	Laser	9
		2C	Oxygen-Plasma	9

Preparation of the acrylic resin blocks

A customized two piece die maker was fabricated which consisted of an upper and lower member. The upper member contained four mould spaces of dimensions 40mm length and $10x10mm^2$ cross sectional area. This was placed over the lower member which in turn formed the base (Figure 1). A brass die of dimensions 3mm length and $10x10mm^2$ cross sectional area was fabricated to be used as a spacer between the two acrylic blocks prior to the packing of the soft liner (Figure 2). Petroleum jelly was applied onto the mold, following which molten wax was flown into the mold spaces. The wax blocks obtained were invested in dental stone using the conventional flasking technique. After boil out and elimination of wax was complete, separating media was applied, heat processed polymethyl methacrylate denture resin (DPI heat cure, Dental Products of India Ltd, Mumbai) was then mixed, packed and processed according to manufacturer's instructions (Figure 3). After the curing cycle was over, the flask was bench cooled at room temperature for around two hours before deflasking. After bench cooling the test specimens were carefully retrieved and trimmed. The surfaces to be bonded were smoothened using 120 grit aluminium oxide paper, cleaned and dried. In this manner 108 acrylic resin blocks were obtained to prepare 54 specimens for tensile bond strength testing.

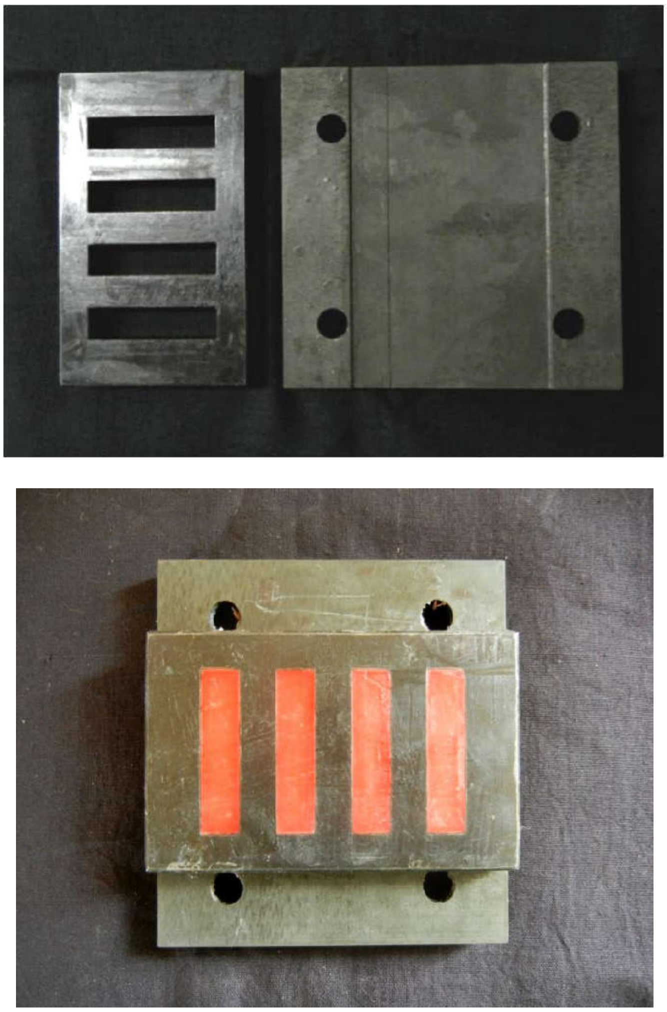

Figure 1. Customized two piece mould

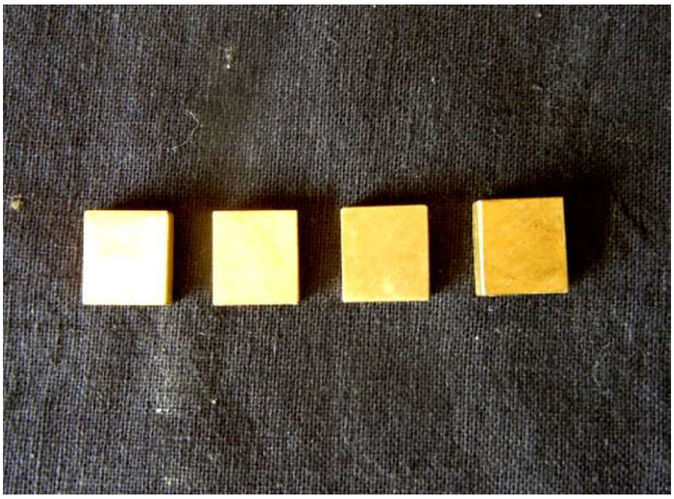

Figure 2. Brass spacers

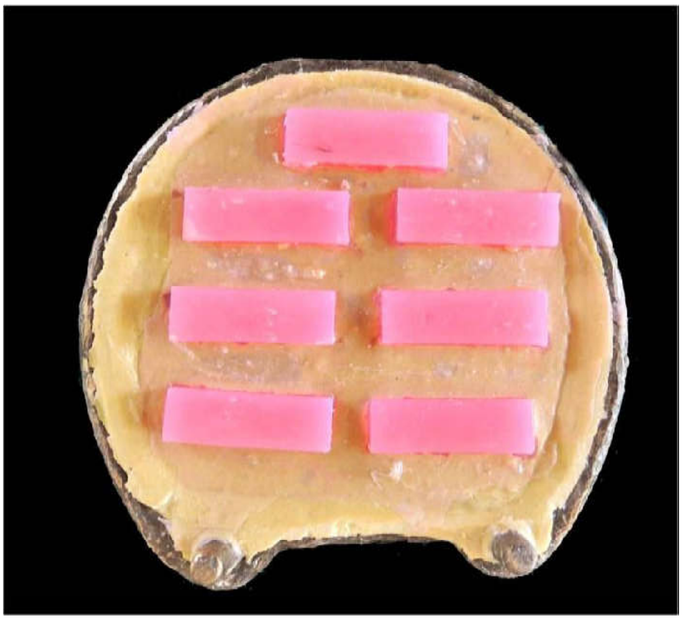

Figure 3. Processed specimens

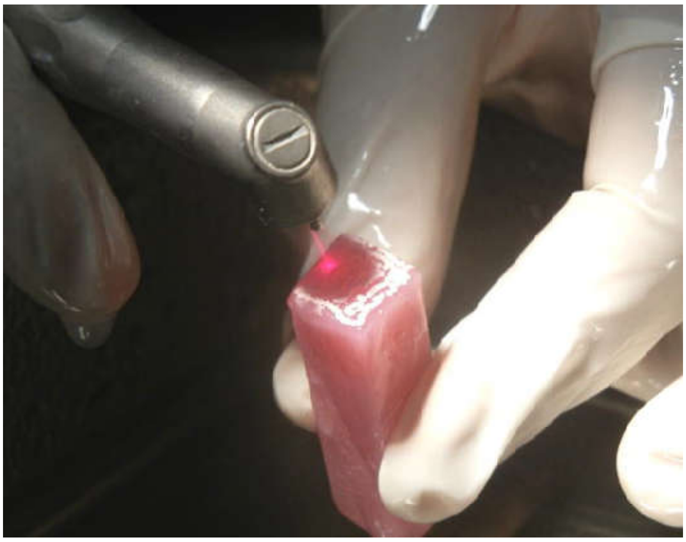

Figure 4. Laser treatment of bonding surfaces of specimens

Figure 5. Investment of two rectangular blocks with spacer

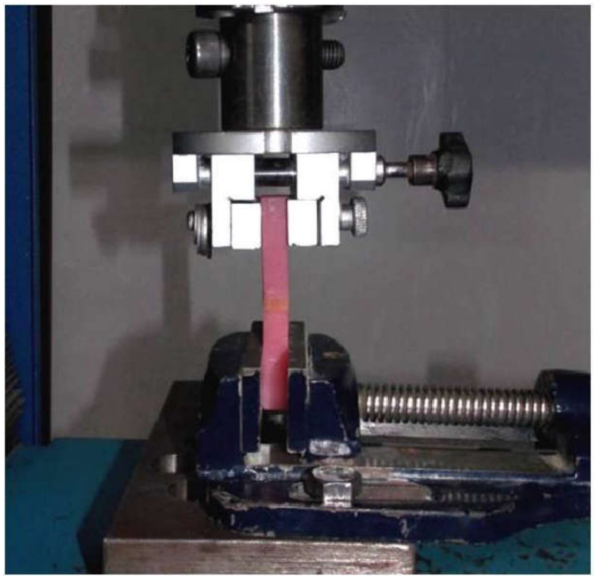

Figure 6. Tensile bond strength testing in universal testing machine

Laser Pre-treatment

Erbium:Yttrium-Aluminum-Garnet(Er:YAG) laser was used for the purpose of this study. 36 Rectangular resin blocks were subjected to laser treatment. Bonding surfaces were thoroughly cleaned to remove all debris and were positioned at 90 degrees to the laser tip. R02-C: Non-contact Er:YAG handpiece with integrated spray nozzle was used to treat the bonding surface of the specimens with the Er:YAG laser (AT Fidelis Laser unit, Fotona, Slovenia) in pulse mode with settings of 10 Hz, 3 W, and 300 mJ with a long pulse duration for 20 seconds from a fixed distance of 10mm. Water irrigation was used during lasing of the samples to prevent heat build up (Figure 4).

Oxygen-Plasma treatment

The plasma treatment system used in the study was Electron Cyclotron Resonance (ECR) plasma. 36 Rectangular resin blocks were subjected to oxygen plasma treatment. Specimens were positioned in the substrate holder. Bonding surfaces were positioned at 90 degrees to the gas flow. First, the system was evacuated using a rotary vacuum pump until it reached a pressure of 0.013 mbar. A 2.45 Ghz microwave was then introduced into the plasma chamber through a quartz window, and magnetic field of 875 gauss was created. Oxygen gas was then introduced into the reactor to displace residual gases. This process was repeated three times to ensure complete removal of impurities. Finally, pressure was stabilized at 0.4 mbar by appropriate opening of the inlet valve. Plasma treatment was carried out for 20 minutes for each sample.

Packing of liners

Specimens for each tensile bond strength test were made by processing the soft liner against two rectangular resin blocks. The brass die of 3mm thickness and 10mm x 10mm^2 surface area was used as a spacer prior to the packing of the soft liner (Figure 5). Two rectangular resin blocks with the metal spacer sealed to them were invested in the dental flasks dental stone as described above. Once the dental stone had completely set, the flasks were opened and the metal spacer was removed. Soft liner was packed into the space between the two resin blocks and processed as per the manufacturer's instructions. All specimens were subjected to tensile stress in a universal testing machine at a crosshead speed of 5mm per minute (Figure 6). The tensile bond strength values obtained were then subjected to statistical analysis using one way Anova test.

RESULTS

Maximum mean tensile bond strength (TBS) was observed with Group 1C (1.39 Mpa) and the lowest TBS value was seen with Group 2A (0.56 Mpa). Significant differences were found in the tensile bond strength values of Group1 and Group 2.

Table II: Mean tensile bond strength values and standard deviation of Group 1A,Group 1B, Group 1C

Type of pretreatment	N	Mean tensile strength(MPa)	Standard deviation	95% confidence interval for mean	
				Lower bound	Upper bound
Control	9	1.02	.03153	.9980	1.0465
Laser	9	1.32	.04153	1.2914	1.3553
Plasma-o_2	9	1.39	.04690	1.3539	1.4261

Table III: Mean tensile bond strength values and standard deviation of Group 2A, Group 2B and Group 2C

Type of pretreatment	N	Mean tensile strength (MPa)	Standard deviation	95% confidence interval for mean	
				Lower bound	Upper bound
Control	9	.56	.03500	.5331	.5869
Laser	9	.62	.03500	.5931	.6469
Plasma-o_2	9	.68	.03202	.6554	.7046

Table IV shows the results of one-way ANOVA for tensile strength between Group 1A, Group 1B and Group 1C. The results showed significant differences between subgroups of Group1 (p value <0.05).

Table IV: Results of Anova for tensile strength between Group 1A, Group 1B and Group 1C

	Sum of squares	Df	Mean squares	F value	Significance
Between groups	.691	2	.346		
Within groups	.039	24	.002	210.731	.001
Pair wise comparison					
Plasma treated Vs Laser treated : p value – .005 (highly significant)					
Plasma treated Vs Control : p value – .001 (highly significant)					
Laser treated Vs Control : p value – .001 (highly significant)					

Table V shows the results of one-way ANOVA for tensile bond strength between Group 2A, Group 2B and Group 2C. Highly significant differences were seen in TBS values between Group 2A and Group 2B (p value- 0.003) as well as between Group 2A and Group 2C (P value -0.001). The difference between the TBS values of Group 2B and Group 2C were also found to be highly significant.(p value-0.003)

Table V: Results of Anova for tensile bond strength between Group 2A, Group 2B and Group 2C

	Sum of squares	Df	Mean squares	F value	Significance
Between groups	.065	2	.032		
Within groups	.028	24	.001	27.971	.001
Pair wise comparison					
Plasma treated Vs Laser treated : p value – .003 (highly significant)					
Plasma treated Vs Control : p value – .001 (highly significant)					
Laser treated Vs Control : p value – .003 (highly significant)					

DISCUSSION

A resilient denture liner is a rational option adopted by the prosthodontist to protect the edentulous ridges. In the modern dentistry, they hold an important position due to their wide arena of applications. Soft liners provide comfort for patients who cannot tolerate occlusal pressures, such as in cases of alveolar ridge resorption, soreness, and knife-edge ridges. According to Wright, the most common reason for failure of a soft-lined denture was the failure of ''adhesion'' between the liner and denture base. (Wright, 1984) This bond failure between the liner and denture creates a potential interface for micro leakage, plaque and calculus (Kawano *et al*., 1992) In order to improve the bonding between soft liner and denture base resins several methods have been proposed. They may be categorized into mechanical, chemical and chemo-mechanical and more recently plasma. Researchers have reported that roughening the acrylic resin base with airborne-particle abrasion before applying a resilient lining material weakened the bond. (Akin *et al*., 2011; Kulkarni and Parkhedkar, 2011) and also use of dichloromethane is not recommended because of its carcinogenic effect. (Shimizu *et al*., 2006) Use of lasers in medical and dental sciences has recently gained widespread applications and importance. Once regarded as a complex technology with limited uses in clinical dentistry, there is a growing awareness of the usefulness of lasers in the armamentarium of the modern dental practice, where they can be used as an adjunct or alternative to traditional approaches.

(Walsh, 2003) Akin *et al*. (2011) reported that Er:YAG laser surface treatment increased tensile bond strength between resilient soft-liner and denture base. He also showed that Nd: YAG and KTP lasers were ineffective in increasing the strength of the bond. (Akin *et al*., 2011) And therefore, Er:YAG laser was used in present study. Tugut *et al* (2012) reported that Er:YAG laser treatment at 10 Hz, 3 W, and 300 mJ with a long pulse duration for 20 seconds effectively increased tensile bonding strength between resilient soft liner and denture base. He explained his findings on basis of high energy of the Er:YAG laser. The impact of the high-energy pulse causes instant vaporization of water with a massive volumetric expansion. This expansion causes the surrounding material to ablate increasing the surface area. Therefore, soft lining materials penetrate into the irregularities or pits produced by the Er: YAG laser increasing the strength of the bond. (Tugut *et al*., 2012) The same settings of laser (10 Hz, 3 W, and 300 mJ with a long pulse duration for 20seconds) which has been proved to be most effective in increasing bond strength were used in present study.

Results of present study are in accordance with findings of study conducted by Akin (2011) and Tugut (2012). However the findings of present study contradict the results of study done by Mustafa *et al* (2007). In present study, a significant difference was found between tensile bond strength values of control group and laser group for both the materials i.e. Molloplast-B and Permasoft. For Molloplast-B group, an increase of 29% in TBS as compared to control group was observed. The difference was highly significant statistically (p-.001). When Permasoft samples were evaluated, laser treatment of samples resulted in a 10.7% increase in TBS. A significant difference was found between the two groups (p- .003). Therefore it can be concluded from these results that Er:YAG laser surface pre-treatment successfully increased tensile bond strength between denture base acrylic resin and both Molloplast-B as well as Permasoft resilient denture lining materials.

Plasma-surface modification (PSM) as an economical and effective materials processing technique is gaining popularity in the biomedical field. It is possible to change chemical and biomechanical properties of polymeric surfaces without adverse effects on their physical characteristics. (Chu *et al*., 2002) Plasma surface modifications are confined only to a few nanometers below the surface. Through the oxygen plasma treatment, oxygen-containing groups of C-O and C=O are effectively introduced onto the polymer surface due to the highly reactive property of oxygen plasma. The presence of oxygen-containing groups improves the surface hydrophilicity of the plasma treated specimens which enhances the penetration of the soft liner into the irregularities on the acrylic resin surface. Consequently, the latter phenomenon is contributed to an increase in bond strength between the denture base resin and soft liner. (Zhang *et al*., 2010) Researchers such as Zhang *et al*. (2010) and Nishigawa *et al*. (2003) have reported an increase in tensile bond strength between an acrylic resin denture material and a soft liner after oxygen plasma treatment. (Nishigawa *et al*., 2003; Zhang *et al*., 2010) In the present study, for Molloplast-B group Plasma-Oxygen treatment increased mean TBS by 36% whereas for Permasoft group increase in mean TBS was found to be 21.4%. The difference between plasma oxygen group and control group for both Molloplast-B and Permasoft samples was found to be highly significant (p-.001) showing that Plasma-Oxygen treatment successfully increased TBS for both Molloplast-B and Permasoft group.

When laser group and Plasma-oxygen groups are compared, for both materials mean TBS with plasma-oxygen surface treatment was higher as compared to laser treatment. Plasma-Oxygen treated samples had 5.3% more mean TBS value for Molloplast group and 9.6% more mean TBS value for Permasoft group than their corresponding laser treated groups. The difference between laser group and plasma oxygen treated groups was found to be statistically significant with p-.005 for Molloplast-b and p-.003 for Permasoft material.

Clinical Application: During processing of these soft liners, after deflasking is done, soft liner is packed onto the intaglio surface of dentures after application of adhesive agent. Flask assembly is then closed and is processed. When laser treatment has to be done, after deflasking, intaglio surface of denture can be directly lased using Er:YAG laser unit with recommended settings. On the other hand, when Plasma-Oxygen treatment is desired, after deflasking, the part of the flask containing the denture has to be sent to a laboratory or biomedical research institute where Oxygen-Plasma unit is available and then the surface pre-treatment of denture can be carried out. Once the surface pre-treatment (laser or Plasma-Oxygen) has been done, soft liner can be then packed and processed in conventional manner.

According to present investigation, both Laser and Plasma-oxygen treatment was successful in increasing tensile bond strength values between both the denture lining materials and denture base resin. Er:YAG laser unit is more commonly used in dental applications than an ECR plasma setup. Also ECR plasma setup is quite expensive both in its installation and maintenance than the laser unit.

Conclusion

Within the limitations of the study it can be concluded that both Er:YAG laser treatment and Oxygen-Plasma treatment are effective in improving the tensile bond strength of the silicone based soft liner Molloplast-B and acrylic based soft liner Permasoft. Although bond strength values obtained after Plasma-oxygen treatment were more than laser treated samples, considering clinical feasibility and cost effectiveness, Er:YAG laser treatment is more appropriate for the purpose of increasing bond strength between denture base resin and soft liner.

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