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A comparison of two universal tray adhesives with different drying time on the tensile bond strength of polyvinyl siloxane impression material to stock metal trays -an in vitro study

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Abstract

Background and Objectives: There is limited information available regarding effect of tray adhesives on stock metal trays using a lesser drying time.

Aims and Objectives: To evaluate and compare the tensile bond strength of two commercially available universal tray adhesives of different drying time, to different stock metal trays when Polyvinyl siloxane impression material was used.

Method: A total of 40 metal test assemblies were used, wherein 10 samples of perforated metal test assemblies, Detaseal tray adhesive was applied (GROUP 1) and the remaining 10 samples of non-perforated metal test assemblies were also coated with Detaseal tray adhesive (GROUP 3) and both groups were subjected to a drying time of 2 minutes. In 10 samples, Zhermack tray adhesive was applied to perforated metal test plate specimens (GROUP 2) and the remaining 10 non-perforated metal test assemblies were coated with Zhermack tray adhesive (GROUP 4). Kruskal-Wallis one-way ANOVA test, followed by Tukey's Post Hoc test was used for the results.

Results: The mean tensile bond strength of Polyvinyl siloxane impression material from lowest to highest among the groups studied were: 0.07MPa (Group 3) followed by 0.24MPa (Group 1), 0.70 MPa (Group 4), and 0.73MPa (Group 2) respectively.

Conclusion: There is significant increase of mean adhesive tensile bond strength of Zhermack tray adhesive than Detaseal tray adhesive which suggests a minimal drying time of 5 minutes is adequate while using Zhermack tray adhesive.

Keywords: Polyvinyl siloxane, stock metal trays, Universal tray adhesive, Drying time, Tensile bond strength.

Introduction

In the specialty of prosthodontics, accurate impressions are essential for a successful treatment outcome. Impression materials vary in the properties of accuracy, dimensional stability, flow, flexibility, patient comfort and economy out of which elastomers are a group of rubbery polymers which can replicate intraoral and extraoral structures with sufficient accuracy for fabrication of fixed and removable prostheses.[1]

Polyvinyl siloxanes have applications in fixed prosthodontics, operative dentistry, removable prosthodontics and implant dentistry.[2] Polyvinyl siloxanes (PVS) are available in four viscosities such as light body, medium body, heavy body and very heavy body(putty) used for making impressions in both edentulous and dentulous arches, duplication of casts and bite registrations.[3]

Impressions can be made either with stock trays or custom trays.[4] Stock trays are prefabricated trays which maybe perforated or non-perforated. Although custom trays are believed to produce a uniform thickness of 2-4mm of the impression material, the value of clinician's time and cost factor leads us to use stock trays. It is also popular due to its ready availability and ease of use but also avoids unwanted exposure of dental personnel to acrylic resin monomer. The putty-wash technique advocates the use of stock trays and is accurate as those impression techniques which uses custom trays. [5]

The impression material needs adequate adhesion to stock or custom trays either mechanically or chemically or by both and should not detach from the tray during removal from the oral cavity. The bond between the impression material and the tray is affected by both tensile and shear stresses acting on the base of the tray and side of the trays, respectively. Mechanical retention is achieved in perforated trays whereas chemical retention is achieved by application of tray adhesives which can be either universal adhesive or manufacturer supplied adhesive.[4]

Previous studies[7,8,9,10] reveals that universal tray adhesives showed higher bond strength in comparison to manufacturer supplied tray adhesives. Specific tray adhesive is applied for each class of elastomeric impression material. The different methods used for applying the tray adhesive include- Liquid paint on method, Spray on method, and Self-stick adhesive system out of which the liquid paint on adhesive is the most preferred type. Since, using mechanical retention alone may compromise the accuracy of an impression, a combination of both mechanical and chemical retention methods has been suggested.[4]

Both manufacturer recommended and universal tray adhesives are available but there are not many studies supporting the use of manufacturer recommended tray adhesives with any brand of Polyvinyl siloxane impression material. Also, clinicians tend to use universal tray adhesive when the adhesive given by the manufacturer gets exhausted.[10]

Several studies[4,7,8,10,11] have been done to test the bond strength between elastomers and custom tray materials using tray adhesives at different drying time. But very few studies are available regarding the bond strength of tray adhesives to different stock trays with different drying time.[9]

Hence, the aim of this study is to evaluate the tensile bond strength of two universal tray adhesives of different drying time, to different stock metal trays used in elastomeric impression making. Also, this study will enable us to find out the influence of lesser drying time on the bond strength of Polyvinyl siloxane impression material to metal stock trays with universal tray adhesives.

Methods

This prospective, in vitro study was conducted in the department of Prosthodontics, Bapuji Dental College and Hospital, Davangere, Karnataka, India. and Department of Mechanical engineering, Gowdara Mallikarjun Appa Institute of Technology, Davangere, Karnataka, India.

Fabrication of test specimen (figure 1)

Stock metal trays (perforated and non-perforated) which are commercially available in the market were used to fabricate the test plate specimens. Test plate specimens, both perforated and non-perforated were sectioned from stock metal trays in the dimensions of 0.5mm thickness and 3cm x 3cm in length using heavy duty handpiece with a carborundum disc. The thickness of the impression material will be regulated in 5mm by placing a customized metal spacer frame. Perforations were of 2mm diameter at 2mm intervals in the perforated test plate specimens. For both perforated and non-perforated test plate specimens, perpendicular handles were made using austenitic stainless-steel wire of 1.5mm diameter which was soldered onto the outer surface margins of test plates for tensile testing purpose.

In this manner, 80 metal test plate specimens were made and divided into 4 groups of 20 each. In each group, 2 metal test plate specimens were used to make one test sample thus resulting in 10 test samples in each group. Therefore, there were 40 test assemblies totally.[13]

Preparation of the test assembly (Figure 2 and 3)

The inner surface of each perforated and non-perforated metal test plate specimen was cleaned and uniformly coated with a single application of the adhesive solution over a period of 1 minute and was allowed to dry at room temperature (23 K). The manufacturer recommended drying time of 2 minutes was allowed for Detaseal tray adhesive and a drying time of 5 minutes was followed after the application of Zhermack tray adhesive.

Ten grams of each base and catalyst pastes were weighed for Polyvinyl siloxane impression material. The proportioned base and catalyst pastes were mixed according to the manufacturer's instructions. After the test plates dried, a mix of impression material of 5mm thickness will be loaded and pressed uniformly in between the two test plates until the metal spacer frame comes in contact with both the plates. After centering, the plates were held under pressure undisturbed for about 7 minutes allowing the impression material to set. Excess material beyond the borders of the plates was then trimmed away with a sharp knife.[9]

Grouping of the finished samples (Figure 4)

A total of 40 test assemblies were fabricated and out of these 20 test assemblies were perforated metal test plate specimens and the remaining 20 test assemblies were nonperforated metal test plate specimens. All the test samples were grouped as the follows: GROUP 1: Perforated stock metal tray with universal tray adhesive

Detaseal (2minutes). GROUP 2: Perforated stock metal tray with universal tray adhesive Zhermack (5minutes). GROUP 3: Non-perforated stock metal tray with universal tray adhesive Detaseal (2minutes).

GROUP 4: Non-perforated stock metal tray with universal tray adhesive Zhermack (5minutes)

Measurement of tensile bond strength in universal testing machine (Figure 5)

Once impression material sets according to the manufacturer's recommended time, each specimen test assembly was attached to the Universal testing machine by means of metal hook attached on either ends and was tested for tensile bond strength. Tensile bond strength was determined by recording the force required to deboned the Polyvinyl siloxane impression material and test plate specimen having the tray adhesive in between them. The universal testing machine (UTM), also known as the universal tester, materials testing machine or materials test frame, is used to test the tensile strength and compressive strength of materials. The "universal" part of the name reflects that it can perform many standard tensile and compression tests on materials, components, and structures.

The machine used in this study was universal testing machine (TEC-SOL, GMIT, Davangere, Karnataka, India) which like any other universal testing machine was capable of recording tension, compression, bend, flexure, peel, shear, stress relaxation, and creep and provided a range of cross head speeds which could be set from 0.001 to 500mm/min along with an accuracy of 1% within the test speed. As the machine was started it began to apply an increasing load on the specimen at cross head speed of 5mm/min.31 Once, the debonding of each sample was accomplished, the maximum load and the bond strengths (recorded via computerized, software based) were noted carefully for each of the samples respectively in each group.

The tensile bond strength was calculated by the formula:

Tensile bond strength= F/A

Where, F - maximum force at which separation failure occurred in KgF.

A - area of adhesion, i.e., area of the square plate.

All values were measured in mega pascals (MPa).

Statistical analysis

Collected data was entered in excel software and was analysed using R software version 3.2.3. Tensile Bond Strength was presented as mean and standard deviation. Oneway ANOVA test was performed, followed by Tukey's Post Hoc test which was used as a test of significance. $p < 0.05$ was considered as statistically significant.[12]

Results

The values of the tensile bond strength (MPa) of the samples of all four groups was tabulated (Graph 1). It was observed that the samples with mechanical retention showed higher tensile bond strength as compared to chemical retention alone.

The results obtained were tabulated and statistical analysis was performed by Kruskal-Wallis one-way ANOVA test for quantitative analysis among the groups and Post hoc Tukey's test to compare the significant differences between the individual groups. SPSS version 25 was used to analyze the data. A p value of < 0.05 was considered significant for the analysis.

The individual tensile bond strength between perforated and non-perforated stock metal tray and Polyvinyl siloxane impression material at different adhesive drying time intervals of 2 minutes and 5 minutes gave the maximum value was obtained in Group 2 which was 0.85MPa and the minimum value was obtained in Group 3 which was 0.05MPa.

It is evident from the values that perforated stock metal trays shows higher tensile bond strength when compared to non-perforated stock metal trays, and the bond strength was found Manuscript 8 to be higher when the universal tray adhesive of 5 minutes was used when compared to that of 2 minutes.

The mean of the tensile bond strength values obtained were considered and compared.

The individual tensile bond strength between perforated and non-perforated stock metal tray and Polyvinyl siloxane impression material at different adhesive drying time intervals of 2 minutes and 5 minutes.

Mean tensile bond strength in megapascals and standard deviation values being 0.24MPa (0.06) in Group 1, 0.73MPa (0.09) in Group 2, 0.07MPa (0.01) in Group 3 and 0.70MPa (0.10) in Group 4 respectively. The mean tensile bond strength from highest to lowest among the groups studied are: 0.73 (Group 2) followed by 0.70 (Group 4), 0.24(Group 1), and 0.07 (Group 3) respectively. The Kruskal-Wallis one way ANOVA test value 33.02 was found to be significant at 0.000 level.

Graph 1 shows the comparison of two universal tray adhesives with different drying time on the tensile bond strength of Polyvinyl siloxane impression material to stock metal trays.

A highly significant difference ($p<0.01$) in tensile strength was noted between each of the four groups (except between 2nd and 4th groups) with the greatest strength in the second group followed by the fourth, first and the third groups.

There was a statistically significant difference in the tensile bond strength among the different groups and even the Post hoc Tukey's test results displayed significant differences between the different individual groups. The tensile bond strength was highest in Group 2 and it was least in Group 3.

Discussion

To obtain the most accurate impression, it is essential to use a tray adhesive in order to direct the shrinkage of the body of the elastomeric impression material towards the tray. [24,29, 34] An undistorted impression is that the impression material should adhere firmly to the tray either mechanically or chemically or by both. The adhesive providing chemical retention can be a conventional, universal adhesive or a manufacturer supplied adhesive. It has been observed in routine clinical practice that most of the practitioners do not use tray adhesives and rely on mechanical retention alone, which may compromise the accuracy of impression.[4]

Several studies have been performed to identify the optimum drying time and also on accuracy of custom versus stock trays. [6,43,49,50] It is generally recommended to wait for ten to fifteen minutes after application of the adhesive before making the impression. 26This allows time for the solvent to react with the tray material. Studies conducted previously revealed 10 minutes drying time[8] or 7–15 minutes,19prior to making impressions achieved adequate tensile bond strength. 48 hours drying time was shown to give significantly higher bond strength than 10 minutes. However, in many dental practices, the tray is tried in the patient's mouth, dried and adhesive is applied and impression is made immediately.[11,41.]

Previous literature reported that the impression material adhesive combination supplied by the manufacturer might not necessarily be the best.[18] Universal adhesives have now started to replace the manufacturer's adhesive and paint on adhesive is found to be effective.[10] Also, there have been limited studies evaluating the bond strength of these adhesives on stock metal trays which is more popular among clinicians.[9] Considering these facts, this study is done to test the effectiveness of the two

brands of universal paint on adhesives (Detaseal and Zhermack) with drying times of 2 minutes and 5 minutes respectively on very heavy consistency Polyvinyl siloxane when perforated and non-perforated metal stock trays were used.

In accordance with the study undertaken, the highest tensile bond strength [0.73MPa] was recorded for perforated stock metal trays (Group 2), that had mechanical perforations as well as Zhermack adhesive application. The tensile bond strength of non-Manuscript 10 perforated stock metal trays coated with Zhermack tray adhesive was second best[0.70MPa] to the perforated stock metal trays coated with Zhermack tray adhesive wherein both groups were dried for 5 minutes [0.73MPa]. The non-perforated stock metal trays coated with Detaseal tray adhesive and dried for 2 minutes showed the least tensile bond strength [0.07MPa] amongst all the groups.

The present study showed that there is no statistically significant difference in tensile bond strength between the non-perforated stock metal trays and perforated stock metal trays coated with Zhermack tray adhesive. The evaporation of solvent is dependent on temperature, humidity and time.[11,31,41.]

Therefore, in this present study, the better adhesive bond strength of Zhermack universal tray adhesive in comparison with that of Detaseal universal tray adhesive may be attributed to the difference in the action of solvent as well as due to the presence of low concentration of modifiers (toluene, petroleum spirits, and benzene), on the stock metal trays used. Within limitations of this study, universal tray adhesive Zhermack with a drying time of 5 minutes showed higher bond strength than the universal tray adhesive Detaseal which had a drying time of 2 minutes. The bond strength of the adhesive agent, impression tray and impression material depend on the surface chemistry of the impression tray used and the chemical properties of the adhesive agents.[42]

Previous studies that were conducted in various experimental conditions reported that when conventional universal adhesives are used, the bond strength of Polyvinyl siloxane impression materials to acrylic tray materials was in the range of 0.13MPa–1.09 MPa.[8,15,17,37,42,45] Samman and fletcher42 had conducted adhesion tests using Polyvinyl siloxane to metal test plates and recorded mean values of 0.55MPa whereas Bindra and Heath9 (1997) reported a mean value of 0.37MPa, both of which are similar to results obtained in this study. The results obtained in this study were compared with the other studies by Poojya et al[38], Payne et al[37], Dixon et al[44], which suggested the bond strength of 0.55MPa-0.97MPa. The range of adhesive bond strengths (0.07MPa-0.73MPa) achieved when using stock metal trays were found to be almost similar to the values obtained from previous studies done using custom acrylic trays. Studies by Peregrina et al [8], Grant & Tjan[15], Sulong&Setchell[18], Chee et al19 also showed similar results (0.20MPa- 0.21MPa) of retention of Polyvinyl siloxane using tray adhesives. In the current study, the use of a single impression material to compare the bond strengths of two different adhesives reduced the bias when different impression materials were used in the past.

In Zhermack tray adhesive, the mode of failure was cohesive where failure occurred within the body of the adhesive itself. Adhesive film patches were observed both on the tray surface and the impression surfaces. In Detaseal tray adhesive, the nature of bond strength failure was primarily adhesive where failure occurred at the adhesive-test plate interface with most of the adhesive remaining on the metal test plate.

Based on these findings, and the published work of other investigators, it is not possible to define a threshold bond strength value, but it may be assumed that a stronger bond between the impression material and tray is necessary. The force necessary to remove stiff impression materials like Polyvinyl siloxane from the mouth may be increased in the presence of severe undercuts, the shape of the clinical crown, the spacing and angulation of teeth. Instructions on drying time for the adhesive are also variable depending on the brand used. Most dentists follow the manufacturer's instructions, but problems are often encountered where clinical circumstances dictate departure from standard operating procedures. From the data presented in this study, there does not seem to be any substantial disadvantage to applying the adhesive Zhermack and Detaseal with a considerable drying time of 5 minutes and 2 minutes before making an impression.

One of the limitations of this study is that since it is an in vitro study done under experimental conditions, in vivo variables like direction and force of removal, contaminated tray surface were not considered and further research should be done for the same. The results obtained could vary if the bond strengths were tested inside the oral cavity i.e., under natural conditions where presence of saliva and temperature could have given different readings on the testing equipment. Also, there is a need for evaluating the effect of film thickness and setting of adhesives on impression materials.

Conclusion

Within the limitations of this study and from the results obtained the following conclusions can be drawn.

• There is significant increase of mean adhesive tensile bond strength of Zhermack tray adhesive when compared to Detaseal tray adhesive which suggests a minimal drying time of 5 minutes is adequate while using Zhermack tray adhesive.

• Based on the results obtained, the study concluded that the mean adhesive bond strength was not significantly increased by the presence of perforations for Zhermack tray adhesive whereas mechanical retention augmented the effect of Detaseal tray adhesive.

• The tensile bond strength of Polyvinyl siloxane achieved using metal stock trays were within the clinically acceptable range.

Figures

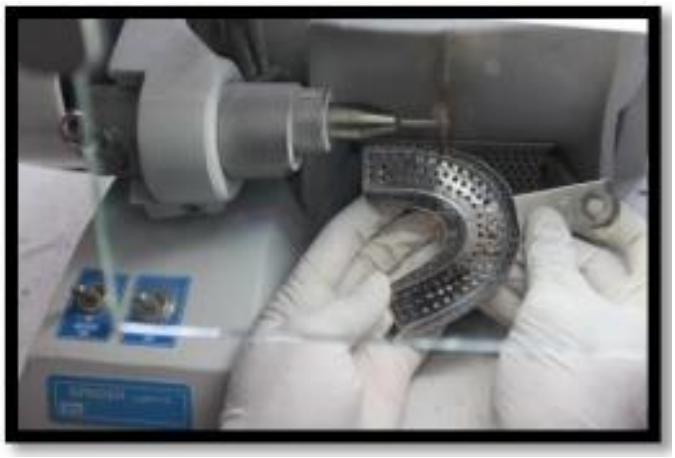


Fig 1: Fabrication of test plate specimen.

Fig 2: Universal tray adhesives for polyvinyl siloxane impression material.

Fig 3: Polyvinyl siloxane (putty consistency) impression mater.

Fig 4: Subgrouping of finished sample.

Fig 5: Test assembly loaded onto the universal testing machine.

GROUP	MEAN	STANDARD DEVIATION	H statistic	P value
1	0.24	0.06	33.02	0.000
2	0.73	0.09		
3	0.07	0.01		
4	0.70	0.10		

Tables 1: comparison of the tensile bond strength among the four groups using kruskal wallis anova.

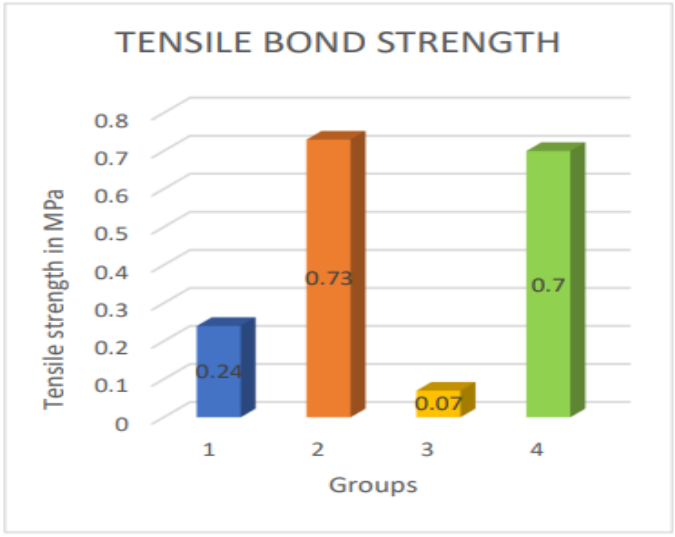
GROUPS COMPARED	MEAN DIFFERENCE	Z statistic	P value
GROUP 1 * GROUP 2	-0.48	-3.785	0.000
GROUP 1 * GROUP 3	0.17	-3.792	0.000
GROUP 1 * GROUP 4	-0.45	-3.787	0.000
GROUP 2 * GROUP 3	0.66	-3.788	0.000
GROUP 2 * GROUP 4	-0.03	-0.454	0.65
GROUP 3 * GROUP 4	-0.63	-3.788	0.000

Table 2: post hoc comparison of the tensile bond strength among each of the four individual groups.

p (probability factor) <0.05 – Statistically significant.

Post-hoc test = Z test.

Negative results indicate that the groups are inversely proportional to each other.



Graph 1: shows the comparison of two universal tray adhesives with different drying time on the tensile bond strength of polyvinyl siloxane impression material to stock metal trays.

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