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RESEARCH ARTICLE

A COMPARATIVE EVALUATION OF THE TENSILE BOND STRENGTH BETWEEN ADDITION SILICONE IMPRESSION MATERIAL AND TWO DIFFERENT TRAY MATERIAL AFTER APPLICATION OF VARIOUS TRAY ADHESIVES: AN IN VITRO STUDY

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ABSTRACT

Aims: The Aim of this study was to evaluate the tensile bond strength between addition silicone medium body impression material and two different tray material (auto and light polymerizing) after application of various types of adhesives on the samples of tray materials.

Methods and Materials: Eighty flat, squares, resin plates were fabricated with auto and light polymerizing tray material & a hexagonal lock nut was reinforced with it. Tray adhesives was applied & medium body addition silicone impression material was injected into the gap of 3mm between the two plates. Ten samples were prepared for each type of tray adhesives. A total, 40 samples each of auto & light polymerizing tray material were been fabricated & were tested for tensile bond strength using universal testing machine.

Results: For auto polymerizing tray material significant difference was found in all the adhesives except for 3M and GC which showed statistically no significant difference & for light polymerizing tray material, significant difference was found in all the adhesives except for 3M and Dentsply which showed statistically no significant difference.

Conclusions: The auto & light polymerizing tray material exhibited similar bond strength values when same adhesive was used. With auto polymerizing tray material, Dentsply tray adhesive has shown highest tensile bond strength followed by 3M, GC and Coltene. With light polymerizing tray material, 3M tray adhesive has shown highest mean tensile bond strength followed by Dentsply, GC and Coltene.

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INTRODUCTION

The bonding strength of adhesive materials, to both the custom tray material and to the impression material itself, is critical for an accurate impression. Use of a universal spray adhesive provides lower retentive strength of addition silicone to the tray than use of the manufacturer- supplied paint-on adhesive delivery system. Chemical adhesive systems also contain solvents, such as isopropanol and toluene, having toxic and flammable properties. Impression retention is related to the chemistry of the adhesive agents and to the surface chemistry of the resin tray material. (Marafie *et al*., 2008) Recently developed adhesives consist of methyl acetate as the solvent and an adhesive conjoined monomer which are designed to

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react with the molecular networks in polyvinyl siloxane and to chemically bond with both the elastomeric impression and the acrylic tray materials. These reactive adhesives are purported to provide effective retention of the impression material which does not rely on mechanical retention. If these adhesives provide better impression retention to the tray than that provided by conventional adhesives, a more reliable method of retaining the impression material to the tray can be achieved. (Ona *et al*., 2010) A custom tray enhances accuracy by allowing a uniform thickness of impression material. (Ashwini *et al*., 2014) Materials used for fabricating custom trays include: auto polymerizing acrylic and light-activated resin material. Clinically significant characteristics of this material include: accuracy of fit, complete polymerization without residual compounds, ease of fabrication and manipulation, and strength. Because they are easy to use, light-activated materials are becoming more popular in clinical dentistry. In light of aforementioned factors, the purpose of this study was to assess the effect of new reactive adhesives on the bonding of elastomeric impression materials to the auto and light polymerizing tray material.

MATERIALS AND METHODS

A commercially available polyvinyl siloxane addition silicone medium body impression material (Affinis®) and four different brands of tray adhesives were evaluated with auto polymerizing tray material (Pyrex) and light polymerizing tray material (Plaque Photo®) [Table/Fig- 1]. A standardized metal die model was designed in three parts so that it consist of square metallic mould without stopper, square metallic mould with stopper, metallic mould cap and transfer jig assembly. The schematic diagram showing customized metallic mould without stopper, square metallic mould with stopper, and transfer jig assembly is shown in [Table/Fig- 2]. The lower surface of the square metal die mould was considered as the impression surface. Eighty flat, squares, resin plates of both with stopper & without stopper were fabricated from each type of tray material i.e. auto & light polymerizing tray material using a metallic mold. The resin plates fabricated by mould without stopper had dimension of (30mm length × 30mm breadth × 3 mm depth). The resin plate fabricated by mould with stopper was similar to the previous one with addition of square shaped stoppers at the four corners of the depression. The dimensions of this stopper were (5mm length × 5mm breadth × 3mm depth). The customized metallic mould cap of dimension (52mm length × 52mm breadth × 12mm depth) was designed for the fabrication of standardized samples of resin tray. The transfer jig assembly consists of a rectangular metal platform with a vertical rod moving upward. T-shaped vertical rod was attached to the upper horizontal metallic bar allowing downward movement of the rod. Between the two vertical rods, the sample plate which had been reinforced with hexagonal nut was attached to the rods. These vertical rods assisted in proper orientation and approximation of the sample plates towards each other when the medium body elastomeric impression material was injected between two plates.

i) Fabrication of samples by auto polymerizing tray material: According to the manufacturer's instruction, powder and liquid were mixed in 2:1 proportion & when the material had came to dough stage it was packed into metallic moulds with and without stopper which were coated earlier with thin film of vaseline, white petroleum jelly (Hindustan Unilever Ltd). The metallic mould cap was then placed over the metallic mould so that it would flush out the excess material. Once the material has been set, the plates were removed after 15 minutes. In this manner total 40 samples were fabricated by using auto polymerizing tray material.

ii. Fabrication of samples by light polymerizing tray material: The sheets of light polymerizing tray material were approximately cut off with required dimensions and were packed into metallic moulds with and without stopper. The metallic mould cap was then placed over the mould such that it would flush out the excess material. Then according to the manufacturer's instruction the outer surface of the plates were light polymerized into Light curing unit, (Polymat, Delta) for 3-5 minutes followed by the inner surface of the plate for 3-5 minutes. Once the material has been completely light polymerized, the plates were removed. The fabricated tray plate's inner surface were abraded with a 600-grit & the outer surfaces with a 250-grit silicon carbide abrasive paper (Norton Saint-Gobain, Mumbai) and later on cleaned with liquid ethanol (Changshu Yangyuan Chemicals, China) of both auto & light polymerizing tray material. The retention of the hexagonal lock nut (9.90 mm outer diameter and 5.0 mm inner diameter) to the plate was then enhanced by making grooves on the lateral surface of the hexagonal lock nut, which aided in mechanical retention of the plate to the nut. The hexagonal lock nut was then glued to the outer surface of plate using a cyanoacrylate adhesive. Then the plate and the hexagonal lock nut were reinforced with the respective tray material. The two plates one with stopper and another without stopper were fixed on a linearly movable stage of jig assembly by means of a threaded rod screwed into a nut on each plate so that the inner surfaces of both the plates faced each other with a gap of 3 mm between them with the help of stoppers. A thin layer of tray adhesive was then coated on each abraded surface and allowed to dry for 1–5 min according to the recommendations of manufacturers. The medium body addition silicone impression material was then being auto mixed and injected by using a mechanical gun (3M & ESPE, Bangalore) with mixing tip into the gap of 3mm between the two plates which were aligned between jig assembly [Table/ Fig- 3]. The movable stage with plates was activated immediately after injecting addition silicone material until the gap had reduced to 3 mm and the impression material was allowed to polymerize according to the manufactures instruction. Ten samples were prepared for each type of tray adhesives. A total, 40 samples each of auto & light polymerizing tray material were been fabricated.

All the fabricated samples were tested for tensile bond strength using universal testing machine (Instron, STS-248 Star testing machine, India). The samples were attached to the universal testing machine with the help of the hexagonal lock nut attached to the sample plates. The universal testing machine moving at a crosshead speed of 5mm/min using 500kg load debonded the sample plates apart. The readings were recorded and the obtained data was tabulated and statistically analyzed. A total 80 samples were fabricated which were grouped as shown in [Table/Fig- 4, 5].

Statistical analysis

The statistical tests used for the analysis of the result were: Students unpaired t test, One way ANOVA, Tukey Multiple Comparison Test.
Tensile bond strength was then calculated using the formula,

$$\text{Tensile strength} = \frac{(F)}{(A)}$$

Where F - Applied Peak load.
A- Cross sectional area

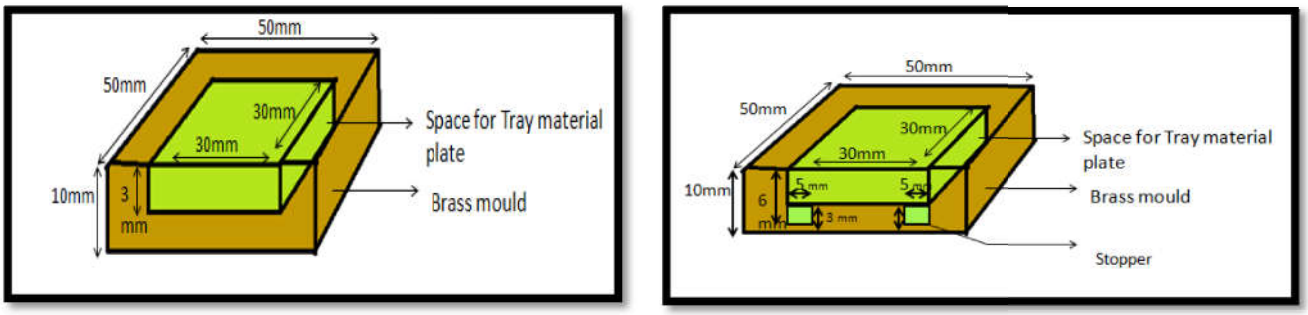
After tensile bond strength testing the entire specimen were analyzed for failure analysis on the basis of the failed surface topography. The failure modes of the adhesion were classified as follows on the basis of the failed surface topography of each specimen: (a) adhesive failure characterized by complete separation of the impression material from the acrylic, (b) cohesive failure characterized by only tearing of impression material without tray surface exposure, and (c) mixed failure characterized by mixed areas of the impression material and exposed acrylic.

RESULTS

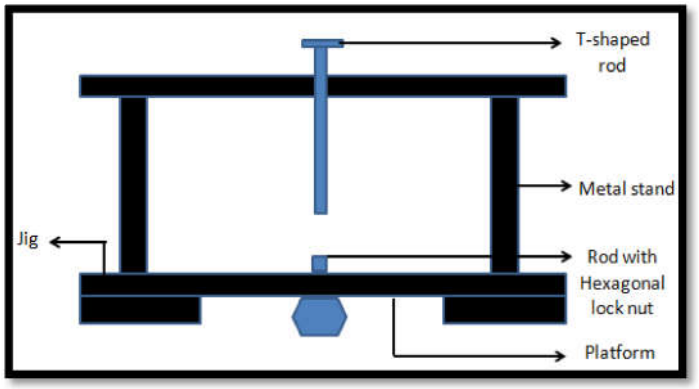
In auto polymerized tray material mean tensile bond strength for adhesive 3M was 0.23±0.100, in Coltene it was 0.06±0.031, in Denstply it was 0.31±0.063 and in GC adhesive it was 0.18±0.0437. In light polymerized tray material group mean tensile bond strength for adhesive 3M was 0.27±0.04, in Coltene it was 0.07±0.042, in Dentsply it was 0.27 and in GC adhesive it was 0.19 [Table/Fig- 6]. A graph showing comparison of Tensile Bond Strength of auto (Group A) and light polymerized (Group B) tray material with four different tray adhesive subgroups is shown in Table/Graph- 7. Statistically for auto polymerizing tray material significant value (p-value=0.000) were obtained between and within groups in tensile bond strength (MPa) using four adhesives. For light polymerizing tray material significant value (p-value=0.000) were obtained between and within groups in tensile bond strength (MPa) using four adhesives.

[Table/ Fig- 1]: Materials used in the study

S. No.	Material	Commercial name	Manufacturer	Lot number
A	Polyvinyl siloxane addition silicone medium body impression material	Affinis® Precious Perfect impressions	Coltene Whaledent AG, Altstatten, Switzerland	G15904 G30674
B. 1	Tray adhesive	VPS tray adhesive	3M ESPE Dental Products, Neuss, Germany	582247
B. 2	Tray adhesive	Caulk tray adhesive	Dentsply DeTrey GmbH Konstanz Germany	140528
B. 3	Tray adhesive	Coltene® tray Adhesive	Coltene Whaledent AG, Altstatten, Switzerland	F51345
B. 4	Tray adhesive	Universal VPS adhesive	GC America inc. ALSIP, Japan	1204261
C	Light polymerizing tray material	Plaque Photo®	Willmann & Pein GmbH Schusterring Barmstedt/ Hamburg Germany	131396
D	Auto polymerizing tray material Powder Liquid	Pyrex special instant tray material	Pyrex polykem Roorkee	 ITM-001 ITM-001
E. 1	Vaseline	Vaseline pure skin jelly	Hindustan Unilever Ltd, Assam	B619
E. 2	Cyanoacrylate	Feviquick®	Pidilite Industries Ltd. Mumbai	H4
E. 3	Ethanol	Ethanol,® absolute	Changshu Yangyuan Chemical China	20150125



(a) (b)



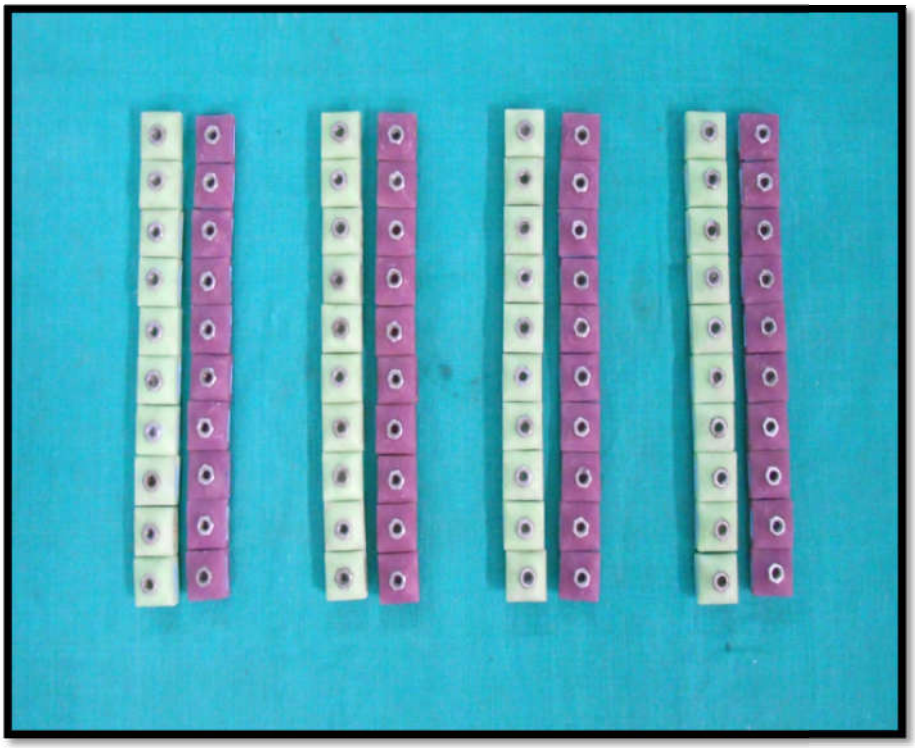
(c)

[Table/ Fig- 2]: Standardized schematic diagram showing customized die model. (a) Square mould without stopper, (b) Square mould with stopper and (c) Transfer jig assembly

[Table/Fig- 3]: The medium body addition silicone impression material being auto mixed in a mechanical gun and injected into the gap between the two plates

[Table/Fig- 4]. Grouping of samples in accordance to the tray material (Auto and Light polymerizing) and subgrouped as per type of the tray adhesive used (3M, GC, Coltene and Dentsply)

80 Samples							
Group A 40 Samples (Auto-polymerizing tray material)				Group B 40 Samples(Light-polymerizing tray material)			
A_1 10 Samples applied with 3M Tray adhesive	A_2 10 Samples applied with GC Tray adhesive	A_3 10 Samples applied with Coltene Tray adhesive	A_4 10 Samples applied with Dentsply Tray adhesive	B_1 10 Samples applied with 3M Tray adhesive	B_2 10 Samples applied with GC Tray adhesive	B_3 10 Samples applied with Coltene Tray adhesive	B_4 10 Samples applied with Dentsply Tray adhesive



[Table/Fig- 5]. Showing total 80 samples of tray material injected with medium body addition silicone which were grouped as auto polymerizing (Group A) and light polymerizing tray material (Group B). They were subgrouped as 10 samples each coated with 3M (A_1, B_1), GC (A_2, B_2), Coltene (A_3, B_3) and Dentsply(A_4, B_4) tray adhesive respectively

[Table /Fig- 6]: Comparison of tensile bond strength for both the groups that is auto & light polymerized tray material and subgroups that is with four different tray adhesives

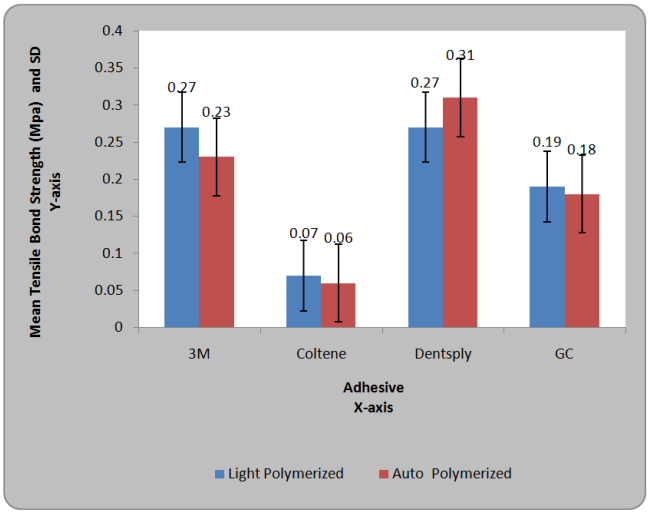
Descriptive Statistics

Auto polymerized

Adhesives	N	Mean	Std. Deviation	Std. Error	95% Confidence Interval for Mean		Minimum	Maximum
					Lower Bound	Upper Bound		
3M	10	0.23	0.100	0.03	0.16	0.30	0.06	0.37
Coltene	10	0.06	0.031	0.01	0.04	0.08	0.02	0.12
Dentsply	10	0.31	0.063	0.01	0.27	0.36	0.21	0.42
GC	10	0.18	0.043	0.01	0.15	0.22	0.13	0.28

Light polymerized

Adhesives	N	Mean	Std. Deviation	Std. Error	95% Confidence Interval for Mean		Minimum	Maximum
					Lower Bound	Upper Bound		
3M	10	0.27	0.04	0.01	0.24	0.30	0.21	0.33
Coltene	10	0.07	0.042	0.01	0.04	0.10	0.01	0.17
Dentsply	10	0.27	C	0.02	0.22	0.32	0.13	0.37
GC	10	0.19	0.06	0.02	0.14	0.24	0.07	0.31



[Table/Graph- 7]: Comparison of Tensile Bond Strength of auto (Group A) and light polymerized (Group B) tray material with four different tray adhesive subgroups

[Table/Graph- 8]. Multiple Comparison: Turkey Test of Tensile Bond Strength for auto & light polymerizing tray material with four different tray adhesives subgroups

Auto polymerized

Adhesives		Mean Difference (I-J)	Std. Error	p-value	95% Confidence Interval	
					Lower Bound	Upper Bound
3M	Coltene	0.16	0.02	0.000 S,p<0.05	0.09	0.24
	Dentsply	-0.08	0.02	0.043 S,p<0.05	-0.15	-0.001
	GC	0.04	0.02	0.403 NS,p>0.05	-0.03	0.12
Coltene	Dentsply	-0.24	0.02	0.000 S,p<0.05	-0.32	-0.17
	GC	-0.12	0.02	0.001 S,p<0.05	-0.20	-0.04
Dentsply	GC	0.12	0.02	0.001 S,p<0.05	0.04	0.20

Light polymerized

Adhesives		Mean Difference (I-J)	Std. Error	p-value	95% Confidence Interval	
					Lower Bound	Upper Bound
3M	Coltene	0.20	0.02	0.000 S,p<0.05	0.13	0.26
	Dentsply	0.002	0.02	1.000 NS,p>0.05	-0.06	0.07
	GC	0.08	0.02	0.008 S,p<0.05	0.01	0.15
Coltene	Dentsply	-0.19	0.02	0.000 S,p<0.05	-0.26	-0.13
	GC	-0.11	0.02	0.000 S,p<0.05	-0.18	-0.04
Dentsply	GC	0.08	0.02	0.010 S,p<0.05	0.01	0.15

[Table/Graph- 9]: Comparison of Tensile Bond Strength of auto & light polymerized tray material in four tray adhesive groups

Student's unpaired t test

Adhesive	Polymerized	N	Mean	Std. Deviation	Std. Error Mean	t-value	p-value
3M	Auto Polymerized	10	0.23	0.10	0.03	1.23	0.23 NS,p>0.05
	Light Polymerized	10	0.27	0.04	0.01		
Coltene	Auto Polymerized	10	0.06	0.03	0.01	0.57	0.57
	Light Polymerized	10	0.07	0 .04	0.01		NS,p>0.05
Dentsply	Auto Polymerized	10	0.31	0.06	0.01	1.36	0.18 NS,p>0.05
	Light Polymerized	10	0.27	0.06	0.02		
GC	Auto Polymerized	10	0.18	0.04	0.01	0.06	0.95 NS,p>0.05
	Light Polymerized	10	0.19	0.06	0.02		

Multiple Comparison: Tukey test for auto polymerizing tray material showed significant difference in all the adhesives except for 3M and GC which showed statistically no significant difference (p>0.05). For light polymerizing tray material, significant difference was found in all the adhesives except for 3M and Dentsply which showed statistically no significant difference (p>0.05) [Table/Fig-8]. On comparison of Tensile Bond Strength of auto & light polymerized tray material in four tray adhesive groups using Student's unpaired t test, statistically no significant difference was found between auto & light polymerized tray material [Table/Fig-9]. Analysis of failure type in auto and light polymerized tray material groups with four different tray adhesives showed that adhesive failures were observed in all the light and auto polymerized tray material specimens. No specimen exhibited cohesive or mixed failure.

DISCUSSION

Importance of bonding of impression material to tray is a critical factor in obtaining an accurate impression. Literature has stated variability in the bonding properties of the adhesive agents supplied with the various elastomeric impression materials. Otherwise excellent elastomeric impression materials can be compromised by weak adhesive bonds. Therefore, attachment of the impression material is essential and is achieved by the application of a dental adhesive. The mechanisms governing the chemical reactions between conventional adhesives and tray materials are not fully understood. Upon application of the adhesive, the carrier solvent may cause swelling of the outermost surface of the tray, thereby allowing the adhesive to penetrate and interact intimately with the material. The solvent then evaporates, leaving the entire tray surface covered with the adhesive, which is retained within the molecular network of the superficial layer. (Philips and Skinner, 1982) Dental manufacturer previously used toluene (methyl benzene) as the solvent for various dental adhesives, but subsequently stopped using this material because of its toxic properties and potential to cause severe neurological harm. As an alternative, recently manufactured adhesives, including those used in the present study, contain methyl acetate —a clear, flammable liquid used as a solvent in glues and paints—as an active ingredient to dissolve the acrylic surface. The enhanced adhesion of the reactive adhesives is probably achieved because of chemical adhesion between the impression material and methyl methacrylate. The base used for the adhesives may contain a reactive silicone such as ethylsilicate that creates a physical bond with methyl methacrylate and a conjoined monomer that links with the molecular networks of the polyvinyl siloxane. Unfortunately, the manufacturers have not fully disclosed the mechanism(s) involved in these adhesive reactions. (Ona *et al*., 2010) Phillips and Skinner reported that the base used for adhesives for silicone elastomeric impression materials may contain a reactive silicone such as polydimethylsiloxane and ethyl silicate, the latter creating a physical bond with the impression tray resin. (Craig *et al*., 1992; Craig and Powers, 2001; Payne and Pereira, 1992) Since due to recent advancement in the composition of the adhesives shown by different dental adhesive manufacturers, a need was felt to determine the bond strength shown by these recently introduced tray adhesives.

The primary objective of the present study was to assess the effect of the recent adhesives on the bond strength and to determine the material used for tray fabrication affects the bond strength. Payne JA and Pereria BP had stated that by roughening the tray material with a carbide bur prior to the application of the adhesive materials, increases the adhesion of the impression material to auto and light polymerizing resin.[4] In the present study the fabricated specimen surface was abraded with silicone carbide paper and cleaned with the ethanol. In the present study, the values of tensile bond strength between polyvinyl siloxane impression material and auto & light polymerized tray material were in agreement with the range of 0.13 to 1.09 (MPa) found in other studies, except for Coltene impression material. (Ona *et al*., 2010; Bindra and Heath, 1997; Peregrina *et al*., 2005) The result showed that for auto and light polymerizing tray material, significant value were obtained between and within groups in tensile bond strength (MPa) using four adhesives. On comparing tensile bond strength in four adhesives for auto polymerizing tray material significant difference was found in all the adhesives except for 3M and GC which shows statistically no significant difference. For light polymerizing tray material, significant difference was found in all the adhesives except for 3M and Dentsply which shows statistically no significant difference. The result showed that the mean tensile bond strength (MPa) in auto polymerized tray material using 3M tray adhesive was 0.23±0.10 (MPa) and in light polymerized tray material it was 0.27±0.04 (MPa). Statistically no significant difference was found between auto and light polymerized tray material. Mean tensile bond strength in auto polymerized tray material using Coltene tray adhesive was 0.06±0.03 (MPa) and in light polymerized tray material it

was 0.07±0.04 (MPa). Statistically no significant difference was found between light and auto polymerized tray material.

Mean tensile bond strength in auto polymerized tray material using Dentsply tray adhesive was 0.31±0.06 (MPa) and in light polymerized tray material it was 0.27±0.06 (MPa). Statistically no significant difference was found between light and auto polymerized tray material. Mean tensile bond strength in auto polymerized tray material using GC tray adhesive it was 0.18±0.04 (MPa) and in light polymerized tray material it was 0.19±0.06 (MPa). Statistically no significant difference was found between light and auto polymerized tray material. The findings of the present study, in which no significant difference was found between auto and light polymerized tray material were in agreement with those reported by Hogans and Agar. (DeAraujo and Jorgensen, 1985) However other studies showed that the light polymerizing tray material showed higher bond strength than auto polymerizing tray material. (Ashwini *et al*., 2014; Philips and Skinner, 1982; Bindra and Heath, 1997; Peregrina *et al*., 2005; Abdullah and Talic, 2003; Dixon *et al*., 1993; Smith *et al*., 2002; Kumar *et al*., 2014) In other studies, the bond strength of the addition-silicone material/adhesive was significantly higher than that of the polysulfide material/adhesive. (Hogans and Agar, 1992) The GC paint-on universal adhesive provided significantly higher adhesive values than those obtained with the adhesives supplied by the manufacturers of the impression materials tested. (Ashwini *et al*., 2014; Peregrina *et al*., 2005) In other study, the self- stick adhesive system provided significantly lower retentive strength to plastic tray material than chemical adhesives for irreversible hydrocolloid, vinyl polysiloxane, and polyether. (Marafie *et al*., 2008)

In the present study, the tensile bond strength testing of all the specimens were analyzed for failure analysis on the basis of the failed surface topography. Out of the adhesive, cohesive and mixed failure, adhesive failures were observed in all the auto and light polymerized tray material specimens. In other study it was found that a combination of mixed and adhesive failure was present. (Ona *et al*., 2010) It should be noted that the strength of an impression material is strongly dependent on the viscosity and elasticity, with these rheological properties being consistent with the principal application of specific products and further studies to assess the effect of such material properties on the bond strength of impression materials are highly desirable. Combinations of elastomeric impressions and adhesives have high bond values as compared to conventional adhesives; this may result in more secure and accurate reproductions of the teeth and alveolar ridges of severe undercuts. The results of the current study should however be considered in the light of several experimental limitations. For example, it is not known whether the high bond strengths of the impression materials with reactive adhesives affect the accuracy of reproduction and the fit of the restorations. The test protocol used in the current study employed flat plate specimens and did not attempt to mimic the clinical conditions imposed by the lateral walls of an impression tray as well as those by the teeth and alveolar ridges of a severe undercut. In addition, the bond strengths measured in this study were determined for surfaces polished with 600-grid emery paper. Therefore, regardless of the adhesive and impression materials used, the bond strength could be even higher if the acrylic surface was roughened to enhance retention. Further testing should focus on examining these effects, and in vivo studies should be also conducted to confirm the in vitro findings of the current study.

Conclusion

The study was conducted to evaluate the effect on tensile bond strength between auto & light polymerizing tray materials and medium body addition silicone impression material after application of four different tray adhesives on tray materials. Within the limitations of the experimental conditions of this in vitro study, it can be concluded that:

- The auto polymerizing tray material exhibited the bond strength values similar to those observed for light curing tray material, when same adhesive was used.
- Among auto polymerizing tray material (Pyrex), the highest tensile bond strength was shown by Dentsply followed by 3M, GC and Coltene tray adhesive. However, the mean bond strength with 3M and GC tray adhesive was not significantly different.
- Among light polymerizing tray material (Plaque Photo®), the highest mean tensile bond strength was shown by 3M followed by Dentsply, GC and Coltene tray adhesive. However, the mean bond strength with 3M and Dentsply tray adhesive was not significantly different.
- The weakest bond was observed at adhesive and impression material interface for all the combination of tray material and adhesive tested.
- Hence, the custom tray, surface roughened with silicone abrasive paper and coated with the tray adhesives is advised to use to obtain a dimensionally accurate impression and master cast. Also, the clinician must have the knowledge of the use of appropriate tray adhesive along with silicone impression material which is of utmost important for the success of the prosthodontic procedure.

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