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"Comparative Evaluation of the Effect of Adhesive Material on the Tensile Bond Strength of Three Different Elastomeric Impression Materials to an Acrylic Tray Material: an in Vitro Study"

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ABSTRACT

Background & Objectives: Incomplete adhesion between the impression material and the tray can result in enduring deformity. Particularly, when the impression is removed with force, it can result in disengagement between the impression and the tray material. This can cause distortion of the final impression which ultimately leads to an inurate working model and poor fitting prosthesis. The objective of this in-vitro study was to compare and evaluate the tensile bond strength of three different elastomeric impression materials to an acrylic tray material using two different tray adhesive systems and their compatibility with each other by testing for tensile bond strength.

Materials and Methodology: Three medium body elastomeric impression materials are PVS (poly vinyl siloxane) PE (poly ether), and VXSE (vinyl polysiloxane ether) and an auto polymerizing acrylic tray material (PMMA), and paint on and spray on tray adhesives were used in this study. Seventy-eight pair of rectangular blocks measuring 40x20x10 mm were fabricated by using master die-metallic mold with tray material. A two layer of tray adhesive was applied by paint-on method and 3 seconds of spray on method adhesive was sprayed for each sample, and were allowed to dry according to manufacturer's recommendation. Impression material was mixed according to the manufacturer's specifications and loaded into the gap between two the samples. Tensile bond strength was tested using a Universal Testing Machine (INSTRON) at a cross-head speed of 5mm/minute.

Results:A one-way ANOVA test revealed that significant difference between the three groups of Poly vinyl siloxane, Polyether and Vinyl poly siloxane ether with paint on adhesive ($P<0.05$, $F= 43.55$). Post hoc Tukey HSD comparison shows the tensile bond strength of Poly vinyl siloxane impression material with paint on adhesive was greater compared to Poly ether and Vinyl poly siloxane ether and was statistically significant. On comparison of all 3 groups, results were statistically significant in which tensile bond strength of all impression materials with paint on and spray on tray adhesive was greater with Poly vinyl siloxane than Vinyl poly siloxane ether and Poly ether respectively. Tensile bond strength of Poly vinyl siloxane impression material with Paint on adhesive was greater (SD= 261.753) than spray on adhesive (SD=222.09). Tensile bond strength of Poly ether impression material with paint on adhesive was greater (SD=257.49) than spray on adhesive (SD=217.065). Vinyl poly siloxane ether impression material with paint on adhesive was greater tensile bond strength (SD=259.50) than with spray on adhesive (SD=220.57).

Conclusion:The adhesive bond strength of paint on tray adhesive was greater than that of spray on tray adhesive regardless of the impression material used with the auto polymerizing acrylic resin and was statistically significant. Adhesive strength of paint on tray adhesive with poly vinyl siloxane impression material was greater compared to all other groups. Adhesive strength of sprayon tray adhesive with polyether impression material was the least compared to all other groups.

Key words: Tensile bond strength; Poly vinyl siloxane; Poly ether; Vinyl poly siloxane ether; Paint on tray adhesive; Spray on tray adhesive; Poly methyl methacrylate; Universal testing machine

I. INTRODUCTION

An impression is an imprint of hard and/or soft tissues, formed with specific types of impression materials that is used in different areas of dentistry including prosthetics (such as making dentures, inlays, onlays and models) restorative, diagnosis and oral and maxillofacial prosthesis for both intra oral and/or extra oral uses.

According to GPT 10- Impression is defined as the negative likeness or copy in reverse of the surface of an object; an imprint of the teeth and adjacent structures for use in dentistry. Impression material is defined as any substance or combination of substances used for making an impression or negative reproduction.

An impression should be dimensionally accurate for the fabrication of prosthesis because inaccurate impressions can compromise the function, fit and aesthetics of the restoration.[1] An accurate impression is mandatory to produce prosthesis. Therefore, elastomeric impression materials have been used more often.[2]

Elastomeric impression materials have always been the choice of material in fixed prosthodontics due to inherent qualities such as reduced marginal voids and distortion resulting in improved quality of gypsum dies. Among available elastomeric materials, the vinyl poly siloxanes (VPS) and poly ethers (PEs) are used most frequently. Advances in elastomeric chemistries have led to the invention of a new generation of impression materials which is a combination of polyvinyl and poly ether called “polyvinyl ether silicone (PVES).[9]

During removal of impression material from the mouth, the bond between the impression material and the tray is highly stressed in both tension and shear. Therefore, the tray adhesive must have sufficient cohesive and adhesive strength to resist these stresses.[2]

Tensile strength is the maximum tensile stress applied in stretching a sample to rupture. The bond strength of impression material to a tray is essential and is achieved with the use of various means of mechanical retention or chemical adhesion or both. Therefore, impression retention has an important role in the accuracy of the cast and the resulting definitive prosthesis.

Mechanical retention is achieved by the presence of undercuts and perforations into which the unset impression material flows, sets, and becomes locked[7]. The adhesive chemical method uses an adhesive material delivered in a volatile solvent. Upon application of the adhesive, the carrier solvent swells the outermost surface of the tray, allowing the adhesive to penetrate and interact intimately with the tray 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 of the tray material.

Impression retention is related to the chemistry of the adhesive agents and to the surface chemistry of the resin tray material.[6] Thus, solvent evaporation is considered as the setting of theadhesive, and is dependent on time, temperature, and relative humidity.

Enhanced retention of impression material to the tray occurs after surface abrasion is performed, before tray adhesive is applied, regardless of tray adhesive and impression material used.[1,4] In addition, use of a custom tray with adhesive is more accurate than use of a stock tray with adhesive.

Several methods are used for application of tray adhesive such as liquid paint-on method, spray on method and self-stick adhesion system. The conventional or liquid paint-on adhesive method is most commonly used.[3,4]

An impression material having high tear resistance requires an adhesive that is effective, so that ease of application of tray adhesive and time reduction matters.[5]

II. AIMS AND OBJECTIVES OF THE STUDY

Aim of the study:

The present study was planned to evaluate and compare the tensile bond strength of three different elastomeric impression materials to an acrylic tray material using two different tray adhesive systems and their compatibility with each other by testing for tensile bond strength.

The Objectives are:

- The primary objective of the study was to evaluate the tensile bond strength of adhesive material on the three different elastomeric impression materials to an acrylic tray material.

- The secondary objective of the study was to compare the bond strength between tray material/ adhesive and adhesive/elastomeric impression material.

Null hypothesis was formulated as there is no difference in tensile bond strength of adhesive material on the three different elastomeric impression materials to an acrylic tray material.

III. METHODOLOGY:

PREPARATION OF TEST SAMPLES:

The study was carried out in the following manner:
1. Preparation of master die
2. Preparation of test samples: Auto polymerizing acrylic resin tray material
3. Testing the samples
4. Statistical analysis of data

1. Preparation of master die:

For standardization, a stainless-steel mold (Fig.)was fabricated which had two parts. There was a lower assembly of 40x20x10mm and an upper assembly with a flat surface, to cover the lower assembly.

2. Preparation of test samples:

A total seventy-eight pair of rectangular blocks measuring 40x20x10 mm were fabricated from commercially available auto-polymerizing methyl methacrylate resin (chemical cure resin-Dental products of India DPI) (Fig.). Application of petroleum jelly on the metal mold. The custom tray resin (DPI, India) was mixed according to the manufacturer's recommendation. After the material reached dough stage (Fig.), it was packed into the mold and pressed with an upper assembly until the material flowed uniformly inside the mold till the flash flowed out (Fig.). 156 rectangular blocks (78x2=156) were fabricated using same method (Fig.).

The 156 rectangular blocks were divided into 3 groups, 26 pair in each group. 2 blocks were used to make one test sample resulting in 26 samples in each group. Therefore, there were 78 pair of samples totally. The sample surface was polished with a 320-grit Silicone carbide paper to standardize surface roughness.

Two acrylic blocks were fixed on a linearly movable stage by means of a grip and wedge mechanism already present in UTM (Universal Testing Machine, Micro Mach Technologies S1300 model) (Fig.). Acrylic blocks were placed with a gap of approximately 5mm between them, such that the impression material was sandwiched between the blocks to fill the gap (Fig.).

A two layer of tray adhesive was applied by paint-on method on each smooth surface for 39 samples and spray-on adhesive was sprayed for 3 seconds, at a distance of 3cm on other 39 samples of each smooth surfaceand they were allowed to dry for 10 minutes at room temperature (32°±2°C and 50°±10% relative humidity) according to manufacturer's specifications.

The impression material was mixed as per manufacturer's instructions and loaded into the gap between two blocks (Fig). The movable stage was then actuated 10 seconds after loading the impression material until the gap is reduced to 2mm and the impression was allowed to polymerize in accordance with manufacturer's recommendation (Fig). Both blocks with sandwiched impression material was removed from the machine and the excess impression material overhanging the blocks was trimmed off.

Specimen were stored at 32°±2°C and 50°±10% relative humidity 24 hours before testing procedure.

Grouping the samples:

The samples were divided into 3 groups of 26 pair of samples. Each group were further divided into 2 subgroups each containing 13 pair of samples.

Group 1:

Group 1A:

- (DPI chemical cure)- Addition silicone impression material (Aquasil Monophase Dentsply)- Paint-on (3M ESPE VPS) tray adhesive was used.

Group 1B:

- (DPI chemical cure)- Addition silicone impression material (Aquasil Monophase Dentsply)- Spray-on tray adhesive was used.

Group 2:

Group 2A:

- (DPI chemical cure)- Polyether impression material (3M ESPE Monophase)- Paint-on (3M ESPE VPS) tray adhesive was used.

Group 2B:

- (DPI chemical cure)- Polyether impression material (3M ESPE Monophase)- Spray-on tray adhesive was used.

Group 3:

Group 3A:

- (DPI chemical cure)- Vinyl polyether siloxane impression material (EXA'lence' GC America)- Paint-on (3M ESPE VPS) tray adhesive was used.

Group 3B:

- (DPI chemical cure)- Vinyl polyether siloxane impression material (EXA'lence' GC America)- Spray-on tray adhesive was be used.

3. Testing the samples:

The samples were attached to the universal testing machine (Model S1300). The tensile bond test was conducted for each sample at a cross-head speed of 5mm/minute using a 1000 N load cell set at full scale load and slowly but gradually pulled apart till the separation of the impression material from the testing surface of the sample occurs. The bond strength was calculated as

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the maximum force at which separation failure occurred and is divided by the area of adhesion, recorded as the adhesive strength in MPa.

IV. DISCUSSION

An impression should be dimensionally accurate for the fabrication of prosthesis because inaccurate impressions can compromise the function, fit and aesthetics of the restoration.[1] An accurate impression is mandatory to produce prosthesis. Therefore, elastomeric impression materials have been used more often.[2]

Elastomeric impression materials have always been the choice of material in fixed prosthodontics due to inherent qualities such as reduced marginal voids and distortion resulting in improved quality of gypsum dies.[3,4] Among available elastomeric materials, the vinyl poly siloxanes (VPS) and poly ethers (PEs) are used most frequently. Advances in elastomeric chemistries have led to the invention of a new generation of impression materials which is a combination of polyvinyl and poly ether called "polyvinyl ether silicone" (PVES).[4]

The aim of the study was to evaluate and compare the tensile bond strength of three different elastomeric impression materials to an acrylic tray material using two different tray adhesive systems and their compatibility with each other by testing for tensile bond strength.

The impression tray is a device used to carry, confine and control the impression material, while the impression is made. The choice of materials and techniques for fabricating custom trays is extensive, ranging from auto polymerizing, heat-activated acrylic resins, visible light-curable resins to thermoplastic resins, in this study auto polymerizing polymethyl methacrylate acrylic was used as a tray material.[5]

According to Mohd. Zainal Abidin, Mohd Sulong et al roughening the acrylic resin tray enhances the retentive properties of tray adhesive. This procedure was accomplished with Sic paper or sandpaper during the finishing of a custom acrylic resin tray. In the present study the sample surface were polished with a 320-grit Silicone carbide paper to standardize surface roughness.[5,6]

Impressions are fundamental and play an essential role in dentistry. Accurate duplication of oral tissues and teeth is essential for a successful treatment outcome. Making an impression is the first step toward any treatment modality.[7] Impression materials have also evolved from the most popular being irreversible hydrocolloid to the latest combination of elastomers (Vinyl siloxane ether).[7]

Accurate and consistent impressions can be obtained only when adhesives are used. Clinical experience has demonstrated that a strong bond is desired to prevent undetected micro separation and inaccuracies in the impressions that contributes to non-fitting restorations. Adhesives are especially indicated when the impression material has a high tear resistance, so that it can be effectively retrieved from the undercuts. Studies have shown that bond strength can be significantly increased, when adhesives are allowed to dry for 15 minutes before making the impression.[8,9]

In this present study, retention of the impression material to the tray was achieved by chemical method as tray adhesive application, tray adhesives were applied as two strokes by paint on method and spray on method by same operator for standardization and were dried for about 15 min before loading the impression material onto the tray.

Phillips and Skinner reported that the base used for adhesives for silicone elastomer 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 and Powers reported maximum tear force/ length values for VPS impression materials ranging from 1500 to 4300 N/m. Given this range, the adhesive appears to be the weak link, which is consistent with the clinical observation that failure is periodically observed at the adhesive/tray or adhesive/impression material interface.[8,9]

Evaporation of the solvent in the adhesive is known as setting of the adhesive. It is dependent on temperature, humidity, and time. Therefore, in this present study, the better adhesive bond strength of caulk dentsply universal tray adhesive in comparison with that of Coltene tray adhesive may be attributed to the difference in the solubility of the tray material by the solvent present in the tray adhesive.[8,9,10]

Peregrina et al. stated that using paint on universal tray adhesive provided higher adhesive bond strength values for the VPS impression materials when compared to the manufacturer recommended adhesive to the auto polymerizing acrylic tray material tested. Study that was 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 in the range of 0.13–1.09 MPa.[5,6]

In the present study paint on tray adhesive and coltene spray on adhesive were used to compare the tensile bond strength of different elastomeric impression materials.

In the current study, the testing for tensile bond strength was done after 30 min from the setting of the impression material. Various other authors have conducted the tensile test after the set of impression material as per the manufacturer's instructions. However, in the present study, the test was performed after 30 min of loading of impression material onto the tray surface. This was done considering the time lapse after making the impression in a clinical scenario.

As for polyether and vinyl siloxane ether, there was no statistical significance among three adhesives, when using visible light-cured trays. Possibly, this is because polyether and vinyl siloxane ether contain both polar (C=O) groups which are hydrophilic, and non-polar (CH3) groups which are hydrophobic. Hence providing a more wetting surface for the adhesives to act upon. This finding was in accordance with the study conducted by Oboudi SF et al.[9,10]

It was also observed that among the two universal tray adhesives used, GC UTA provided greater TBS compared to Coltene UTA across all elastomeric impression material. It was again a significant observation seen because of GC UTA. It is basically recommended for VPS elastomeric impression materials and not specifically for condensation silicone impression materials.[10]

The lower bond strength values obtained with the spray-on adhesive may result from differences within the adhesive layer that could result from this method of application, which appeared visually to produce a thinner coat. However, no increased failure through the adhesive layer was apparent in these groups. It should be noted that there were noticeable differences in the ease of application of the adhesives tested.[11]

The Dentsply and Coltene adhesives tend to remain tacky at the 10-minute testing time.[12] The present study examined only the tensile strength of adhesives. Further research is needed to investigate the effect of the film thickness and setting of adhesives.

The results of the present study depicted that the tensile bond strength achieved by auto-polymerizing PMMA trays, A one-way ANOVA revealed significant difference between the three Groups i.e., PVS, PE and VXSE with paint on tray adhesive (P<0.05, F= 43.55). Post hoc Tukey HSD comparison shows the tensile bond strength of PVS withpaint on adhesive was greater compared to VXSE and PE and statistically significant. This infers that polyether with paint on adhesive showed significantly least tensile bond strength which was followed by vinyl poly ether siloxane and highest with poly vinyl siloxane. On comparison of all 3 groups, results were statistically significant in which tensile bond strength of all impression materials with paint on tray adhesive was greater with PVS than VXSE and PE respectively.

Tensile bond strength of PVS withspray on adhesive was greater compared to PE and VXSE and statistically significant (P<0.03, F= 46.06). This infers that PE with spray on adhesive showed significantly least tensile bond strength which was followed by vinyl poly ether siloxane and highest with poly vinyl siloxane. On comparison of all 3 groups, results were statistically significant in which tensile bond strength of all impression materials with spray on tray adhesive was greater with PVS than VXSE and PE respectively.

An independent t-testrevealed highly significant difference between the subgroups i.e., PVS with paint on and spray on tray adhesive (P<0.01, t= 75.02). On comparison results were statistically highly significant in which tensile bond strength of PVS impression material with paint on tray adhesive was greater (SD= 261.753) than PVS impression material with spray on tray adhesive (SD=222.09).

Highly significant difference between the subgroups i.e., PE with paint on and spray on tray adhesive (P<0.01, t= 85.47) (table 4). On comparison results were statistically highly significant in which tensile bond strength of PE impression material with paint on tray adhesive was greater (SD=257.49) than PE impression material with coltene tray adhesive (SD=217.065).

Highly significant difference between the subgroups i.e., VXSE with paint on and spray on tray adhesive (P<0.01, t= 78.88). On comparison results were statistically highly significant in which tensile bond strength of VXSE impression material with paint on tray adhesive was greater (SD=259.50) than VXSE impression material with spray on tray adhesive (SD=220.57).

The results of the current study should however be considered in the light of a few experimental limitations. For example, the test protocol used in the current study employed flat 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. Saliva is one of the common contaminants of the adhesive material and this study did not include this influence.

Limitations of the study:

1.As it is an in vitro study, oral conditions could not be simulated.

2.The tray samples taken in the study had flat surfaces as opposed to multiplanar surfaces of the custom trays used in the oral cavity.

3. The samples constituted of tray surfaces opposing each other, while this is not the case in vivo, as the impression material is opposed by teeth or oral mucosa on one side.

Scope for further study:

Further research is needed to investigate the influence of in-vivo conditions influencing the parameter of the study

V. CONCLUSION

Within the limitation of this study,

1. The adhesive bond strength of paint on tray adhesive was higher than spray on tray adhesive regardless of the impression material used with the auto polymerizing acrylic resin as the tray material.
2. Adhesive strength of paint on tray adhesive with addition silicone impression material was highest compared to all other groups.
3. Adhesive strength of spray on tray adhesive with polyether impression material was the least compared to all other groups.

In the present era of precision medicine, it is necessary to have detailed information of the bond strength and reaction of various tray adhesives with the tray and impression material, as it plays a crucial role in the accuracy of the cast and the prosthesis.