TENSILE BOND STRENGTH BETWEEN ELASTOMERIC IMPRESSION MATERIALS AND TRAY RESINS DEPENDING ON THE THICKNESS OF THE TRAY ADHESIVE

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Statement of problem. Elastomeric impression materials have been widely used to obtain an accurate impression. However there have not been enough studies on the influence of the thickness of the tray adhesives on the bonding strength between the trays and the elastomeric impression materials.

Purpose. In order to understand the relationship between the thickness of the tray adhesive and the tensile bond strength and to suggest the thickness at which the bonding strength is strongest, tensile bond strength related to the thickness of adhesives of 3 different elastomeric impression materials were tested.

Materials and methods. 3 impression materials, Permlastic® Regular Set(Kerr Corp., Romulus, Michigan, U.S.A.), Impregum™ Penta™(3M ESPE, Seefeld, Germany), and Aquasil Ultra Monophase Regular Set Smart Wetting®(Dentsply Caulk, Milford, Delaware, U.S.A.), were used in this study, and tray adhesives from the same manufacturers of the impression materials were used, which were Rubber Base Adhesive, Polyether Adhesive, and Silfix, respectively.

The tray specimens were prepared by autopolymerizing the tray material(Instant Tray Mix, Lang, Wheeling, Illinois, U.S.A.), and a PVC pipe was used to house the impression material. In group A, tray adhesives were applied in multiple thin layers of 1 to 5 and in group B, adhesives were applied only once, in the thickness equivalent to several applications. Lightness(L*) of the adhesion surface was measured with a spectrophotometer(CM-3500d, Konica Minolta, Sakai, Osaka, Japan). The tensile bond strength of the elastomeric impression material and the tray resin was measured with universal materials testing machines(Instron, Model 3366, Instron Corp, Nowood, Massachusetts, U.S.A.). A formula between the number of adhesive application layers and the lightness of the adhesion surface was deduced in group A, and the number of adhesive layers in group B was estimated by applying the lightness(L*) to the deduced formula.

Results.

1. In group A, a statistically significant increase in tensile bond strength appeared when the number of application layers increased from 1 to 2 and from 4 to 5, and no significant difference was present between 2, 3, and 4 layers in Permlastic. In Impregum, the tensile bond

strength was significantly increased when the number of adhesive layers increased from 1 to 3, but no significant difference after 3 layers. In Aquasil, the tensile bond strength significantly increased as the number of application layers increased up to 4 but showed no significant difference between 4 and 5.

2. In group B, the tensile bond strength was decreased when the thickness of the adhesive increased in Permlastic. Impregum showed an increased tensile bond strength when the thickness of the adhesive was increased. In Aquasil, the tensile bond strength increased as the number of adhesive application layers increased up to approximately 2.5 layers but it sharply decreased after approximately 4.5.

Conclusion. From the study, the common idea that it is better to apply a thin and single coat of tray adhesive needs correction in more detailed ways, and instructions on some of the tray adhesives should be reconsidered since there were several cases in which the tensile bond strength increased according to the increase in the thickness of the adhesives.

Key Words

Tray adhesive, Tensile bond strength, Elastomeric impression material

An accurate impression is mandatory in order to produce an accurate prosthesis, thus elastomeric impression materials have been used most often.[1,2] Three factors, which include not only a selection of an appropriate impression material, but also a rigid tray to support the impression material and the adhesion between the tray and the impression material, are required for an accurate impression.[3]

It is reported that perforating the tray or making the tray surface coarse is not sufficient to retain the impression materials, and therefore a tray adhesive is mandatory.[4]

A satisfactory adhesion between the tray and the impression material not only prevents the material from being separated from the tray when removing it from the oral cavity, but also is significant in that it directs the polymerization shrinkage of the material towards the tray.[5,6] An insufficient adhesion could lead to undetected inaccuracies which may result in an inaccurate prosthesis and waste expenses and time.[7]

The minimal bonding strength of the tray adhesive required during impression is influenced by various circumstances in the oral cavity, such as the undercut of the tooth, the clinical crown length, the number of teeth being impressed, the stiffness of the impression material, the interproximal areas, and the angulation of the tooth,[8] and it has not been suggested even approximately. To obtain the strongest bonding strength, many studies considering tray material,[3,8,9,10,11,12,13] tray surface treatment,[3,11,12,14,15] tray adhesives,[16] adhesive drying time,[5,10,14,17] saliva contamination,[18] removal velocity,[9,13] and different impression materials have been conducted, but there have not been enough studies on the relationship between the bonding strength and the thickness of the applied adhesive.

Tray adhesives are being manufactured by a number of different companies including impression material manufacturers, and many of them recommend to apply a thin, single coat of adhesive(Kerr; 3M ESPE; Dentsply DeTrey). However, the round feature of the inside of a tray makes it difficult to apply a uniform thin layer without thicker parts and no studies have reported the effect of thick parts on the bonding strength between the tray and the impression material.

In this study, the thickness of tray adhesives of popular elastomeric impression materials, such as Permlastic® Regular Set(Kerr Corp., Romulus, Michigan, U.S.A.), Impregum™ Penta™(3M ESPE, Seefeld, Germany), and Aquasil Ultra Monophase Regular Set Smart Wetting®(Dentsply Caulk, Milford, Delaware, U.S.A.) have been deduced from the lightness of the adhesive in order to establish a relationship between the thickness of the tray adhesive and the tensile bond strength.

MATERIALS AND METHODS

1. Study Materials

The generic names and manufacturers of impression materials and tray adhesives used in the experiment are list in Table I.

2. Specimen preparation

A rectangular specimen, 24mm in width and length and 12mm in thickness, were prepared with autopolymerizing individual tray resin(Instant Tray Mix, Lang, Wheeling, Illinois, U.S.A.) and was impressed with a silicon material(rema®SIL, Dentaurum, Ispringen, Germany) to produce a mold. This silicon mold was used to create equal sized specimens with an autopolymerizing individual tray resin. A brass hook was embedded in the specimen in order to connect to the universal materials testing machine(Instron, model 3366, Instron Corp, Nowood, Massachusetts, U.S.A.). To complete the polymerization of the remaining monomers, the specimens were kept in room temperature for 24 hours and the surface, where the adhesive would be applied, was polished uniformally with a 220 grit sand paper under water irrigation and was dried in room temperature for an additional 24 hours.

Table I. Material used in this study

Material	Type	Product	Manufacturer
Impression material	Polysulfide	Permlastic® Regular Set	Kerr Corp., Romulus, Michigan, U.S.A.
	Polyether	Impregum™ Penta™	3M ESPE, Seefeld, Germany
	Additional silicone	Aquasil Ultra Monophase Regular Set Smart Wetting®	Dentsply Caulk, Milford, Delaware, U.S.A.
Tray adhesive		Rubber Base Adhesive	Kerr Corp., Romulus, Michigan, U.S.A.
		Polyether Adhesive	3M ESPE, Seefeld, Germany
		Silfix	Dentsply DeTrey GmbH, Konstanz, Germany

Table II. Combination of impression material and tray adhesive

Impression Material	Tray Adhesive
Permlastic® Regular Set	Rubber Base Adhesive
Impregum™ Penta™	Polyether Adhesive
Aquasil Ultra Monophase Regular Set Smart Wetting®	Silfix

Table III. Comparison of group A and B

	Group A	Group B
Number of specimens for each impression material	45	20
Adhesive application method	Coated with multiple even thin-layers	Evenly single coated in various thickness
Adhesive drying time	Over 5 hours	15 minutes
L* measurement time	Before polymerization of impression material	After polymerization of impression material
L* measurement point	Center part of specimen	Edge part of specimen

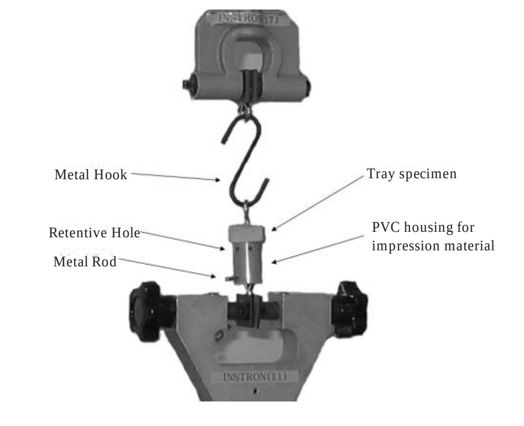

Fig. 1. Position of the test specimen for measurement of tensile bond strength.

Each experiment paired the elastomeric impression material and the tray adhesive from the same manufacturers(Table II), and were carried out in two groups, A and B(Table III).

A polyvinylchloride(PVC) pipe was used as a housing to fix the impression material. A 16mm caliber PVC pipe was used for Permlastic and Impregum and a 12.5 mm one for Aquasil. A metal rod was penetrated on one side of the PVC pipe to connect a hook and on the other side, 12 holes were made using a No. 8 round bur and tray adhesive was applied to retain the impression material(Fig. 1).

3. Group A Specimen preparation and experiment

The number of tray adhesive applications were 1, 2, 3, 4, and 5 times, with 9 specimens for each group, resulting in a total of 135 speciemens for the 3 different kinds of impression materials. One trained person applied the adhesive to the tray in thin, even layers, using the brush provided by the manufacturer. 20 minutes of drying time was given between each application. An additional 3 hours of drying time was given after completing the application and the lightness of the center portion of the specimens(L* value) were measured with a spectrophotometer(CM-3500d, Konica Minolta, Sakai, Osaka, Japan) using a 8mm target mask(CM-A122). Colors were calibrated before lightness measurement, using black and white targets and were measured under a D65/10° setting.

Permlastic was mixed by hand using a spatula and Impregum and Aquasil were mixed by automatic mixing tips. The PVC pipe housing was placed in the center of the tray resin and the specimen was fixed by hand while the impression material was being applied and was polymerized under room temperature.

The cross head speed of the universal materials testing machine(Instron, model 3366, Instron Corp, Nowood, Massachusetts, U.S.A.) was set to 300mm / min, and the tensile bond strength was obtained by dividing the maximum force of tensile strength at which attachment loss occurred by the cross section area(Fig. 1).

4. Group B Specimen preparation and experiment

20 specimens were prepared for each impression material, resulting in a total of 60. An even layer of adhesive was applied in the thickness between one to five layers of adhesives in group A approximately.

After 15 minutes of drying, the impression material was applied to the specimens in the same way as group A, polymerized under room temperature for 15 minutes, and the tensile bonding strength was measured using the universal materials testing machine.

After an additional 24 hours drying, the lightness of the three edges of the tray specimen, which did not contact the impression material, were measured using a spectrophotometer and the average was calculated.

5. Statistical Analysis

Statistical programs SAS 9.1 and SAS Enterprise Miner 4.3 were used. In order to determine the difference in lightness and bonding strength according to the number of adhesive application in each material of group A, ANOVA was performed and among the multiple comparison methods, the least significant difference(LSD) method was used afterwards(α=0.05). The estimation formula between the application number and the lightness in each material of group A was established using the general regression analysis and the lightness data of group B was applied to the formula to obtain the estimated application number in group B. In order to establish a relationship between the application number and the bonding strength in each material of group B, the general regression analysis was used and K-means clustering analysis using the Euclidean distance was used. The cluster number was decided under 5 with the cubic clustering criterion.

RESULTS

1. L* value (Group A)

The L* values according to the application number of tray adhesives were recorded and the average and standard deviation were calculated(Fig. 2).

When ANOVA was performed and LSD afterwards, the L* value decreased with a statistical significance as the number of application increased in all 3 impression materials. Based on this fact, it was concluded that tray adhesives were applied uniformly in the experiment, but also by obtaining the relationship between application number and the L* value, the application number of the adhesive layers can be estimated with L* value.

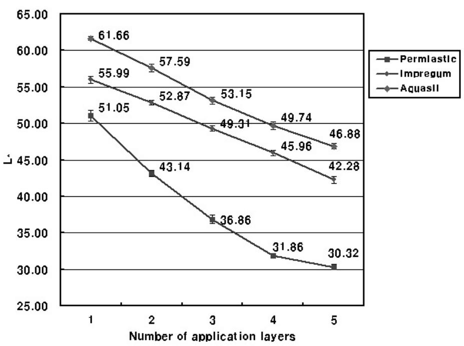

Fig. 2. Comparison of mean L* value in group A.

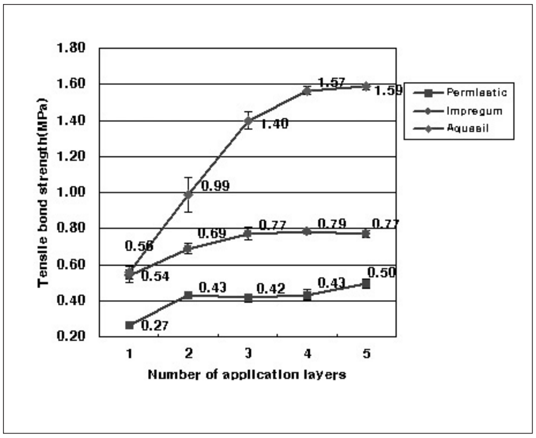

Fig. 3. Comparison of mean tensile bond strength in group A.

2. Tensile bond strength(Group A)

The tensile bond strength according to the number of tray adhesive application was recorded and the average and standard deviation were calculated(Fig. 3).

ANOVA was used and LSD afterwards to determine the difference in tensile bond strength of each impression material according to the number of tray adhesive application(Table IV, V, VI). In Permlastic, the tensile bond strength increased with a statistical significance when the application number increased from 1 to 2, no

Table IV. Results of analysis through LSD method at the $\alpha=0.05$ for L^* by the number of application layers in Permlastic, group A

	1	2	3	4	5
1	·	+	+	+	+
2	+	·	+	+	+
3	+	+	·	+	+
4	+	+	+	·	+
5	+	+	+	+	·

+; Significantly different, -; Not significantly different

Table V. Results of analysis through LSD method at the $\alpha=0.05$ for L^* by the number of application layers in Impregum, group A

	1	2	3	4	5
1	·	+	+	+	+
2	+	·	+	+	+
3	+	+	·	+	+
4	+	+	+	·	+
5	+	+	+	+	·

+; Significantly different, -; Not significantly different

Table VI. Results of analysis through LSD method at the $\alpha=0.05$ for L^* by the number of application layers in Aquasil, group A

	1	2	3	4	5
1	·	+	+	+	+
2	+	·	+	+	+
3	+	+	·	+	+
4	+	+	+	·	+
5	+	+	+	+	·

+; Significantly different, -; Not significantly different statistical difference is showed between 2, 3 and 4 and it showed a statistical increase with 5 applications. In Impregum, the tensile bond strength showed statistically significant increase up to 3 applications but no statistical difference afterwards. In Aquasil, tensile bond strength showed statistically significant increase up to 4 applications and showed no difference between 4 and 5 applications.

3. Estimating the application number from L* value (Group A)

Using the general regression analysis, the estimation formula between the application number and L* value for each impression material was calculated and applied to group B(Fig. 4).

4. Tensile Bond strength(Group B)

Using the estimation formula between the application number and L* value obtained from the group A data, the estimated application number for the given L* value from group B was calculated and was used to analyze the relationship between the estimated application number and the tensile bonding strength in group B. General regression analysis and K-means clustering analysis were used for result analysis.

1) Permlastic® Regular Set

The results of the general regression analysis and K-means clustering analysis are listed in Fig. 5 and Table VII.

As the estimated application number rose, it showed a quadratic curve, where the negativity

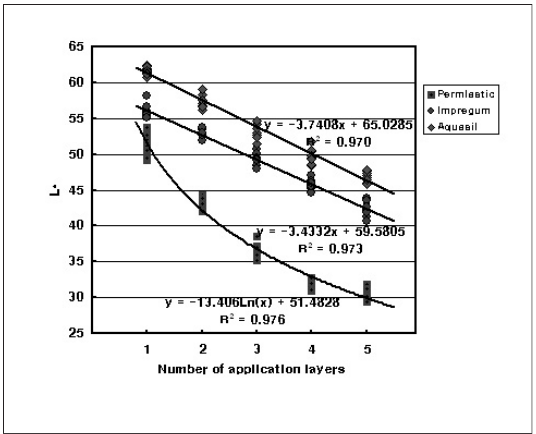

Fig. 4. General regression analysis of the number of adhesive application layers and L* value in group A.

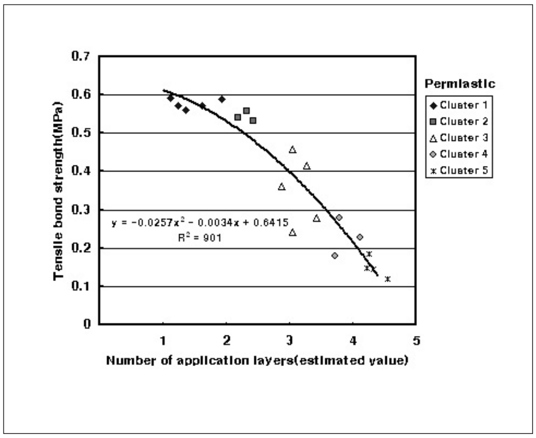

Fig. 5. Tensile bond strength of Permlastic in group B.

Table VII. Clustering analysis of Permlastic in group B

		Cluster 1	Cluster 2	Cluster 3	Cluster 4	Cluster 5
Number of application layers (estimated value)	Minimum	1.11	2.18	2.87	3.73	4.22
	Maximum	1.92	2.44	3.43	4.13	4.54
	Average	1.46	2.32	3.14	3.88	4.34
Tensile bond strength(MPa)	Average	0.58	0.54	0.35	0.23	0.15

of the slope increased and the tensile strength decreased. The bonding strength was greatest in cluster 1, with an average of 0.58MPa and cluster 5 showed the lowest average, 0.15MPa. Cluster 1 and 2 bordered when the estimated application number was approximately 2.

2) Impregum™ Penta™

The results of the general regression analysis and K-means clustering analysis are listed in Fig. 6 and Table VIII.

As the estimated application number increased, it displayed a linear line, showing an increase in bonding strength. The bonding strength was lowest in cluster 1 with an average of 0.49MPa and highest in cluster 5, with an average of 0.87MPa.

3) Aquasil Ultra Monophase Regular Set Smart Wetting®

The results of the general regression analysis and K-means clustering analysis are listed in Fig. 7 and Table IX.

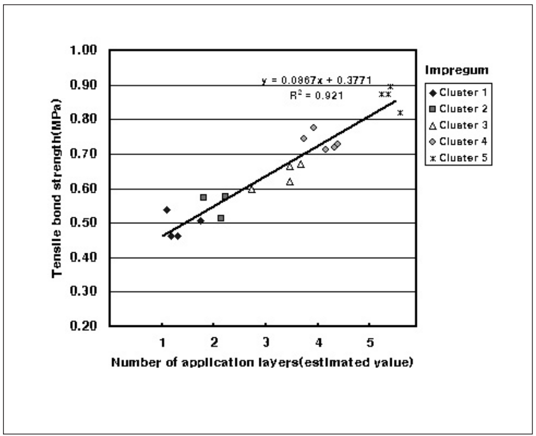

Fig. 6. Tensile bond strength of Impregum in group B.

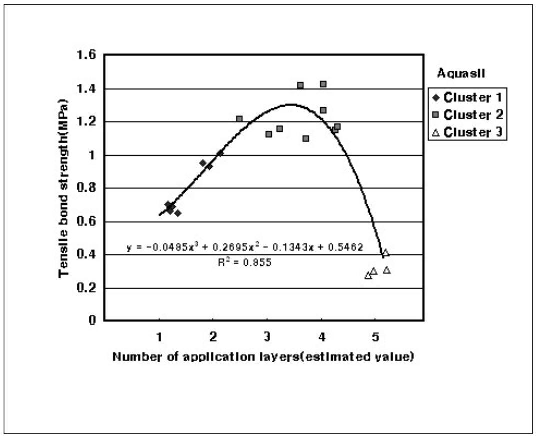

Fig. 7. Tensile bond strength of Aquasil in group B.

Table VIII. Clustering analysis of Impregum in group B

		Cluster 1	Cluster 2	Cluster 3	Cluster 4	Cluster 5
Number of application layers (estimated value)	Minimum	1.09	1.81	2.72	3.73	5.23
	Maximum	1.75	2.22	3.68	4.39	5.58
	Average	1.33	2.06	3.33	4.11	5.39
Tensile bond strength(MPa)	Average	0.49	0.55	0.64	0.74	0.87

Table IX. Clustering analysis of Aquasil in group B

		Cluster 1	Cluster 2	Cluster 3
Number of application layers (estimated value)	Minimum	1.17	2.50	4.88
	Maximum	2.14	4.31	5.22
	Average	1.55	3.64	5.07
Tensile bond strength(MPa)	Average	0.80	1.22	0.32

As the estimated application number increased, it showed a cubic curve where the bonding strength increased and dropped very suddenly. When there were 3 clustering, a cubic clustering criterion of 4.16 was obtained, which was bigger than 3. The bonding strength of cluster 2 showed the highest bonding strength, with an average of 1.22MPa. The estimated application of cluster 2 ranges from 2.5~4.5 times.

DISCUSSION

Although the bonding failure between the tray and the impression material during impression taking leads to an inaccurate prosthesis, many dentists tend to overlook the fact. Carrotte et al[19] reported that 14 out of 50 trays from a dental lab that took impressions showed unsatisfying bonding between the impression material and the tray.

Numbers of studies have been preceded on the factors that affect the bonding strength between elastomeric impressions and trays but there has not been enough studies on the thickness of the tray adhesive. This may be due to the fact that it is difficult to control the thickness of the tray adhesives in a single application as the applicant' s will. However since the tray adhesive is applied in a thin way, this study was based on the fact that the masking of background color changes according to the adhesive thickness and the thickness was calculated in an indirect way.

When color is measured with a spectrophotometer, three types of data, L*, a*, b*, which the Commission Internationale de l' Eclairage defined as the CIELAB form can be obtained for a quantitative analysis. L* represents lightness ranging from 0 to 100, and a*, b* represents the horizontal color plane and ranges from -100 to +100. In this study, only L* value was used. This is because a 3 dimensional color value is not necessary and before using the spectrophotometer, a calibration on lightness was conducted and concluded that a more definite value can be obtained from the lightness.

In all of the 3 impression materials, the lightness decreased with a statistical significance as the number of adhesive application was increased, which implies that all of the applications were applied evenly. Therefore it is considered in the study that for each impression material, the application number is proportionate with the thickness of the adhesive and the application number can be used as the standard for application thickness. Because of the different viscosity of the adhesive and the different size of the brush among manufacturers, the actual thickness of the adhesive may differ even when the same number of adhesives are applied. However this experiment provided a more effective clinical guide since it was based on application number instead of actual thickness of adhesive.

In this study, an autopolymerizing tray resin, widely used for economical efficiency, was used for the specimen, but light-cured tray resins are also abundantly supplied in the market. Bindra and Heath[13], and Dixon et al[17] report that light-cured tray resins show a higher bonding strength than an autopolymerizing tray resin, but Peregrina et al[20] reported that there is not a statistical significancant difference in bonding strength between a light-cured tray resin and an autopolymerized one. Because light-cured tray resin have advantages such as prevention of inhalation of monomers, feasible tray preparation, and instant volume stability due to light polymerization, further studies should be regarded.

In order to obtain a uniform surface on all the tray resin specimens, the surface was polished with a 220 grit sandpaper. Davis et al[14] reported that when the resin is polymerized on tinfoil, asbestos or polished with sandpaper after polymerization, the bonding strength is higher than polymerizing on wax. No statistically significant difference were shown between the tinfoil, asbestos, and sandpaper groups. Carbide bur roughening[3], sandblasting[12], carbide paper roughening[15] have been suggested to increase the bonding strength with the tray. In this study, all the specimens were polished with sandpaper and the surface maintained uniformity in all groups.

The methods of the tensile bond strength experiment using the PVC housing followed the experiment conducted by Peregrina et al[20] and Yi and Chung[21] and a 16mm caliber PVC housing was used for Permlastic and Impregum. In Yi and Chung's experiment, no problems were reported using a 19mm PVC housing for Aquasil, but preliminary experiments for Aquasil in this study showed a great increase in tensile bond strength as the thickness of the adhesive increased, which separated the bonding area between the PVC housing and the impression material even with the maximum mechanical bonding structure in the 16mm PVC housing. Therefore a smaller 12.5mm PVC housing was used for Aquasil and before the impression material was polymerized, 2 additional metal rods were added by perforating the PVC pipe, maximizing the mechanical bonding strength. Even though a decrease in the PVC pipe diameter resulted in decreased area, which increased the error during bonding strength calculation and led to an increased standard deviation, a statistically significant result was obtained(Fig. 3).

Both tensile and shear strength were suggested for the force applied to the adhesive area during the removal of the impression from the oral cavity[22], and previous studies have researched the relevance between the two bonding strength, but none was discovered.[7,13,16,23] This study focused on preventing undetectable errors and therefore designed the experiment as to measure the tensile bond strength. This is because shear bond failure occurs on the lateral wall of tray and the clinician can detect it.

Many studies have been reported on the drying time of the adhesive after application and most studies reveal that when more than 15 minutes of drying time was given, the tensile bond strength showed no statistical significant difference up to 24 hours[5,10,14], and therefore it could be analyzed that the time needed for the solvent inside the adhesive to evaporate and become dry is 15 minutes. In group A, 20 minutes of drying time was given between each coating to prevent any wet adhesives, which make controlling the adhesive thickness impossible. Also, an additional 5 hours of drying was given before the lightness was measured with a spectrophotometer, because the undried adhesive could stick to the machine and impair the adhesion layer.

Many studies have been reported on the appropriate crosshead speed for the universal materials testing machine when measuring the tensile bond strength.[9,13,16] A crosshead speed of 300mm / min was used based on the report that results was more consistent with this crosshead speed, even though it is impossible to obtain the exact same speed when removing the impression from the oral cavity.

Although group A was designed to control the thickness of the tray adhesive, different results were expected due to the difference in the clinical procedures. Group B was designed additionaly because clinicians apply a certain thickness of adhesive only once and dry it for a short 15 minutes, which may leave unevaporated solvents in the adhesive or make bond with the adhesive and the impression material to form a new layer that may affect the bonding strength. Specimens from group B were manufactured in various thickness because it was impossible to control the adhesive thickness accurately. And the lightness of the adhesive layer was measured, then based on the results from group A the number of adhesive layers was determined. Because the adhesive does not dry within 15 minutes, lightness of group B was determined after an additional 24 hours drying time, in the reversed way after tensile bond strength test. During lightness measurement, the remaining area which did not contact the impression material was used and to minimize the error, three points apart from each other were used and the average was calculated.

Generally, a minimal thickness of adhesives is recommended for glue type adhesives to prevent lowering of bonding strength due to the remaining solvent.[24] The manual in all 3 of the tray adhesives used in the study(Kerr; 3M ESPE; Dentsply DeTrey) instructs a thin layer application and most previous studies related to tray adhesives applied a single, thin layer. However, unlike the generally accepted idea as above, multiple sections in the result of this study showed an increase in bonding strength as the application layer increased.

In group A, the bonding strength increased with a statistical significance for Permlastic when the application number increased from 1 to 2 and from 4 to 5, for Impregum, from 1 to 3, and for Aquasil, from 1 to 4 and none showed a statistically significant decrease in bonding strength(Fig. 3). These results conflict the common ideas and it is maybe because the adhesive is applied first and the impression material is polymerized on the adhesive later not in general bonding method. There has not been any reports on the increase of bonding strength when the thickness of the adhesive is increased and the mechanics have not been explained. Polymerization shrinkage could be a possible reason. It is reported that even materials that show excellent volume stability, such as Polyether, Additional silicone shows a 0.2% polymerization shrinkage[25], and this primarily results in transformation of the impression and possibly cause stress between the tray adhesive and the tray when the impression material chemically or mechanically binds to the tray and shrinks. If one assumes that the tray adhesive layer can work as a shock-absorber, a thin tray adhesive layer may not provide a proper absorbing effect and the stress may concentrate between the adhesive and the tray. This could cause partial debonding of the interface or stress may remain, which may lead to lowering of the tensile bond strength. In order to verify this assumption, additional studies need to be conducted.

In group B, the relationship between the estimated application number and the tensile bond strength showed contrasting results among different impression materials. In case of Permlastic, the tensile bond strength decreased as the application number increased(Fig. 5). Therefore the highest bonding strength will be obtained when the adhesive is applied as thin as possible without any clumps, and when it is not possible to apply a thin layer because of excess evaporation of the solvent in the adhesive bottle, it is suggested that an adequate amount of solvent be added or bottle be thrown away to get a new one. In case of Impregum, the bonding strength increased as the application layer increased(Fig. 6), and it can be concluded that one can improve the tensile bond strength by applying the adhesive more than 2~3 times instead of the minimal amount. For Aquasil, an estimated application number up to 2.5 continually increased the bonding strength but after 4.5, it rapidly dropped(Fig. 7). Clinicians are expected to increase the tensile bond strength by applying a sufficient amount of adhesives(3 layers) rather than the minimal amount.

To sum up, the change in the tensile bond strength according to the thickness of the adhesive can be divided into 3 types. In all the impression materials in group A and Impregum of group B showed an increase in tensile bond strength as the adhesive thickness increased(Fig. 3, 6). In Aquasil of group B, the bonding strength increased up to a certain amount as the adhesive thickness increased but beyond that point, the strength rapidly decreased(Fig. 7). Permlastic of group B showed a decrease in bonding strength as the thickness increased(Fig. 5). Applying only a thin, single layer of tray adhesive according to the manufacturer' s instructions is not the best method for some impression materials, such as Impregum, and Aquasil. Two or three layers of adhesive will result in a higher tensile bond strength.

Henceforth, it is suggested in experiments when adhesive is included that more careful attention should be paid to apply the tray adhesive uniformly, and the thickness of the adhesive to be stated since the thickness affects the bonding strength considerably. Additionally, it is suggested that studies on the shear bond strength according to the adhesive thickness and the bonding strength according to the thickness when using light-cured tray resins be conducted. Further studies also need to be conducted to enlighten on the mechanics of the change in tensile bond strength according to the change in adhesive thickness.

CONCLUSION

In order to establish the relationship between the tray adhesive thickness and the tensile bond strength when using impression materials such as Permlastic, Impregum, Aquasil, the tray adhesive provided by each manufacturer was uniformly applied in a single layer 1~5 times in one group of specimens and multiple layers at once in another and the tensile bond strength was measured. The number of adhesive application was estimated based on the lightness, and the following results were obtained from the relationship established between the application number and the tensile bond strength.

1. In all 3 impression materials, the lightness of the surface of the tray increased with a statistical significance as the application number increased.
2. When the adhesive was applied multiple times with a 20 minute interval, the tensile bond strength increased with a statistical significance when the application number increased from 1 to 2 and from 4 to 5 in Permlastic. The tensile bond strength increased up to 3 layers for Impregum, and 4 layers for Aquasil. Further layers applied did not show any statistically significant increase.
3. When the tray adhesive was applied all at once and the impression material was applied 15 minutes later, the tensile bond strength decreased as the adhesive thickness increased in Permlastic, but continually increased as the thickness increased in Impregum, and for Aquasil, the bonding strength increased up an estimated 2.5 layers but decreased rapidly after an estimated 4.5 layers.

The common idea that the highest bonding strength is obtained from applying a thin layer of adhesives does not apply to all materials and since some manufacturer' s instructions is not appropriate from the tensile bond strength' s point of view, reconsideration and further studies need to be conducted.

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