Comparative Time-Dependent Evaluation of Dimensional Accuracy of Dies Using Different Tray Adhesives: An In Vitro Study

Ramandeep Kaur[1] Manjit Kumar[1] Shailesh Jain[1] Neha Jindal[1]

[1]Department of Prosthodontics, Bhojia Dental College and Hospital, Baddi, Distt. Solan, Himachal Pradesh, India

Address for Correspondence Manjit Kumar, MDS, Department of Prosthodontics, Bhojia Dental College, Baddi 176052, Distt. Solan, Himachal Pradesh (e-mail: manjitkiran@yahoo.co.in.com).

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Abstract

Statement of Problem The adhesion of impression material to impression tray is very important. Tray adhesive plays a major role in making accurate impression. Although manufactures recommend the use of particular tray adhesives, comparison of their affective adhesiveness has not been reported. The effect of use of tray adhesives on dimensional accuracy of dies has not been established.

Purpose The aim of this study was to compare the dimensional accuracy of dies using different tray adhesives at different time intervals.

Materials and Methods First part of study comprised 120 samples in six groups with 20 samples in each group. First group comprised samples with no tray adhesive, and in other five groups, different types of tray adhesives were applied. The dies obtained were evaluated for upper diameter, lower diameter, and occlusogingival height. In the second part, there were a total of 125 samples in five groups with 25 samples in each group. Five different types of tray adhesive were applied for five different time intervals 5, 10,15, 20, and 25 minutes, respectively. The specimens were tested in tensile mode for its debonding force at a crosshead speed of 5 mm/min, until separation failure occurred.

Results Significant difference was seen for upper and lower diameters when compared with the group without any tray adhesive. The maximum bond strength was found in the group in which tray adhesive was applied for 20 minutes.

Keywords
- tray adhesive
- upper diameter
- lower diameter

Introduction

Fabrication of any prosthesis requires a dimensionally accurate impression. Proper material selection, manipulation, and tray are important for recording of soft and hard tissues of the oral cavity. Therefore, to support the set material proper tray with proper adhesion of material to the tray is important for the accurate impression.[1] To enhance the dimensional accuracy of impression and later on accuracy of artificial prosthesis, a custom tray is fabricated, which allows uniform thickness of impression material to achieve this goal.[2]

To ensure accuracy of impression especially with elastomeric impression materials, materials must be secured in the custom tray. If material pulls away from the tray during removal from the oral cavity, there may be dimensional changes resulting in distorted wax pattern and later on castings.[3,4] Each type of elastomeric impression materials has tray adhesives.[5]

To check the adhesiveness of tray adhesive, several studies have been conducted. The exact time for drying the tray adhesives before impression making is also not known. Manufacturer recommend from 5 to 20 minutes per tray adhesives to dry completely.[6] However, controversial results are reported regarding to this recommended time.

This study was conducted to compare the bond strength of five different tray adhesives applied at different time intervals and the dimensional accuracy of dies obtained after application of these different tray adhesives.

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Materials and Methods

The following materials were used in this study:

- Autopolymerizing methylmethacrylate (DPI, Mumbai, India)
- Addition silicone impression materials, 3M ESPE vinyl polysiloxane (St paul, Minneapolis, United States)
- VPS tray adhesives—Coltene (Ascot Parkway, Cuyahoga Falls, United States), Caulk (Fort Wayne, IN, United States), 3M (United States), Universal Zhermack (Badia Polesine (RO), Italy), Universal GC (Alsip, Illinois, United States)

Methodology

This study was conducted in two parts. In the first part, 60 samples were made using different tray adhesives with drying time as per manufacturer's instructions and were poured using die stone type IV. The dies obtained were checked for dimensional accuracy. In the second part, total 125 samples were used to determine the bond strength of different tray adhesives.

1. **Checking dimensional accuracy of dies:** A machined, circular stainless-steel standard die was fabricated, and the dimensions of standard die were recorded about upper diameter (UD), lower diameter (LD), and occlusogingival (OG) height (►**Fig. 1**). Corresponding to the standard die, a stainless-steel custom tray was fabricated to make impression of the die. Samples were grouped as group I conventional impression without tray adhesive, group II with tray adhesive Coltene (United States), group III with tray adhesive Caulk (United States), group IV with tray adhesive 3M (United States), group V with tray adhesive ZHERMACK (Italy), and group VI with tray adhesive Universal GC (United States) (►**Fig. 2**).

Sixty specimens were fabricated 10 in each group. Each tray adhesive was painted on the custom-made tray and allowed to dry as per manufacturer's instructions. Impressions of the die were made using addition silicone impression material and were poured with die stone (►**Fig. 3**).

Fig. 1 Stainless steel die.

Fig. 2 Tray adhesives.

Samples were tested with the coordinate measurement machine (CMM) for UD, LD, and OG height. These measurements were compared with those obtained from standard die (►**Fig. 4**).

2. **Testing tensile bond strength of different tray adhesives at different drying time intervals:** Samples were grouped as group A in which all tray adhesives applied for 3 minutes, group B in which all tray adhesives applied for 10 minutes, group C in which all tray adhesives applied for 15 minutes, group D in which all tray adhesives applied for 20 minutes, and group E in which all tray adhesives applied for 25 minutes. For each group of 25 samples, five tray adhesives were applied on five samples of each.

A polyvinyl chloride (PVC) hollow cylinder (24 mm in diameter and 24 mm in length) was used for containing impression material (►**Fig. 5**). For fabrication of one sample, two PVC cylinders were used: one was used to retain impression material and the other one was used for housing self-cure material. To retain impression material, multiple perforations were made with acrylic burs. For additional mechanical retention, a metal screw was inserted mid portion of cylinder. The test surface of PVC cylinder

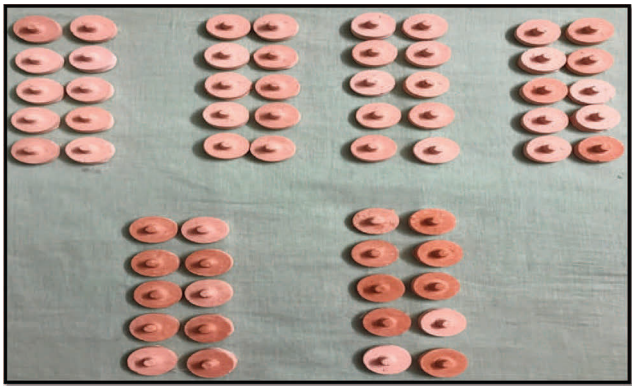

Fig. 3 Die samples fabricated.

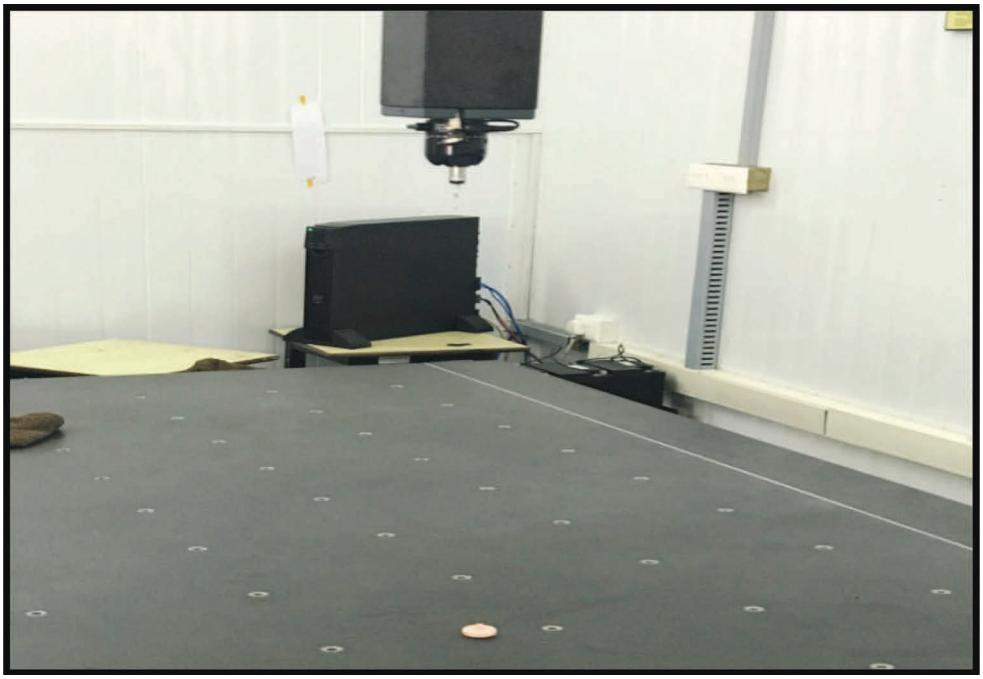

Fig. 4 Die sample on coordinate measurement machine.

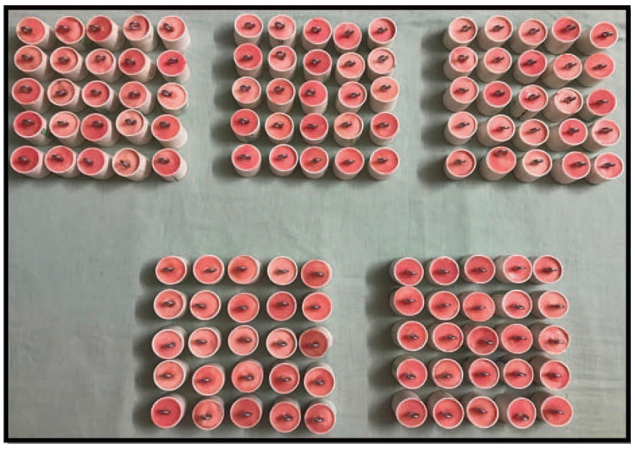

Fig. 5 Resin samples fabricated.

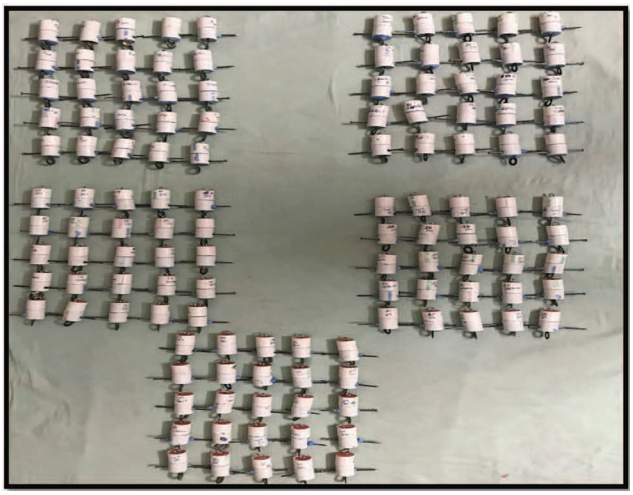

Fig. 6 Bonded samples.

containing self-cure was polished with silicone carbide paper 80 grit before application of tray adhesive. The eye hook was inserted in both the PVC cylinders to act as an attachment to Instron (Norwood, Massachusetts, United States). The testing surface of the samples was painted with different tray adhesives and was allowed to dry according to different time intervals to be tested. The impression material was dispensed onto the testing surface of specimen and held in position till the impression material sets (►**Fig. 6**).

The testing specimens were attached to Instron with the two S-shaped holders in their respective position (►**Fig. 7**). The specimens were tested in tensile mode for its debonding force at a crosshead speed of 5 mm/min, until separation failure occurred. The maximum force at which separation occurred was recorded in kgF and divided by area of adhesion and recorded as tensile adhesive bond strength for each of the specimens tested. Data obtained were subjected to statistical analysis.

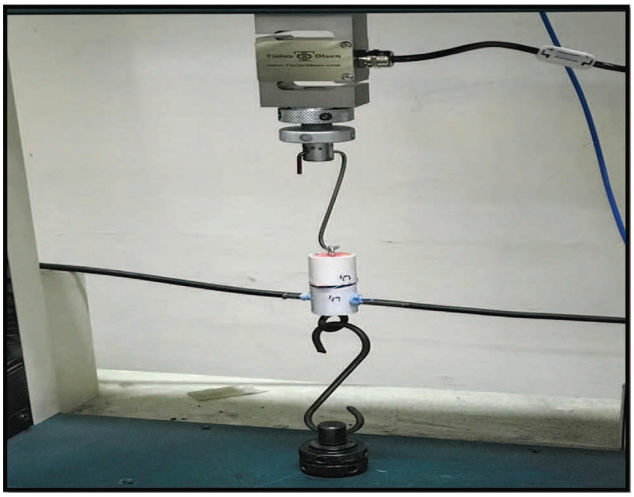

Fig. 7 Sample tested on Universal Testing Machine (Instron).

Results

Descriptive statistical analysis (mean, standard deviation) of all the studied groups for UD, LD, and OG height is given in ►**Table 1**. The overall mean for UD, LD, and OG height came out to be 0.110, 0.039, and 0.001 mm, respectively. ANOVA (analysis of variance) was applied to draw comparison, and it showed statistical difference for UD and LD.

For second part of the study, the final bond strength of 125 samples was tested. Descriptive statistical analysis of all the groups (all tray adhesives at different time intervals) is described in ►**Table 2**. Intergroup comparison by ANOVA test showed statistically significant difference between tensile strength of different tray adhesives.

Discussion

Elastomeric Impression materials are widely used in the fabrication of indirect restorations because these reversibly deform when withdrawn from the undercut. Polyvinyl siloxane impression materials, also known as *addition silicones*, exhibit exceptional dimensional stability because no by products are formed during polymerization reaction and can be poured at convenience of the operator. Whatever the accuracy of material may be, there will be dimensional changes in the die if the material detaches from the tray during removal from the oral cavity. The detachment of impression material from the tray may prevent the impression material to return to its original shape thus, resulting in distorted die, wax pattern, and casting.

This study was undertaken to evaluate dimensional accuracy of dies using different tray adhesives. Also, the tensile strength of different tray adhesives was tested at different drying time intervals. In this study, the impressions of stainless-steel die were made and poured. The samples were checked for UD, LD, and OG height, and were compared with the dimensions of standard die.

For dimensional accuracy of dies, out of 60 samples tested ($p < 0.005$), a significant difference was seen in the UD and LD. The mean of UD in all the six groups (►**Table 1**) varied between 6.54 and 7.33 mm, showing a variation of 0.79 mm. Similarly, the mean for LD varied from 7.37 to 8.30, showing a statistically significant difference of 0.93 mm. All the groups performed similarly in producing dies of nearly equal height. The mean for OG height varied from 7.46 to 7.48, producing nonsignificant results.

The dies obtained from the impressions in this study were generally smaller in two dimensions and same in the third one. In the control group in which no tray adhesive was used, the smaller dies resulted because during polymerization reaction, the impression material shrinks toward the center of mass. The use of tray adhesive would redirect this shrinkage toward the impression tray resulting in die larger in diameter but shorter in height.[7] In the absence of tray adhesive as in the control group, unrestricted polymerization of the impression material was observed.

In the other five groups in which different tray adhesives were used, also resulted in shorter in dies because of nonstandardization of tray adhesive application. A single layer of tray adhesive might not be sufficient to control polymerization shrinkage. Also, all the tray adhesives were dried according to manufacturer's instructions that might not be sufficient drying time for tray adhesive to control polymerization shrinkage.

Table 1 Descriptive statistics of all of the studied groups

	gp	N	Mean	Standard deviation	Standard error mean
Upper diameter	1	10	7.1880	0.31811	0.10060
	2	10	7.1050	0.08515	0.02693
	3	10	6.5450	0.42088	0.13309
	4	10	7.3350	0.35504	0.11227
	5	10	7.2870	0.34667	0.10963
	6	10	7.2940	0.35456	0.11212
Lower diameter	1	10	8.2000	0.13532	0.04279
	2	10	8.2360	0.09640	0.03048
	3	10	7.3270	0.35556	0.11244
	4	10	8.3000	0.23556	0.07449
	5	10	8.2040	0.11587	0.03664
	6	10	8.2290	0.09689	0.03064
Occlusogingival height	1	10	7.4840	0.05190	0.01641
	2	10	7.4770	0.04498	0.01422
	3	10	7.4850	0.04453	0.01408
	4	10	7.4600	0.05142	0.01626
	5	10	7.4880	0.04566	0.01444
	6	10	7.4790	0.01969	0.00623

Table 2 Descriptive statistics of all of the groups

Variable	gp	Mean	Standard deviation	Standard error mean
Universal	1	0.00940	0.003130	0.001400
	2	0.05500	0.007036	0.003146
	3	0.07980	0.004025	0.001800
	4	0.10360	0.005639	0.002522
	5	0.10400	0.006000	0.002683
Zhermack	1	0.02280	0.005762	0.002577
	2	0.06980	0.002775	0.001241
	3	0.08240	0.004722	0.002112
	4	0.10500	0.006782	0.003033
	5	0.10780	0.006573	0.002939
Coltene	1	0.04060	0.000548	0.000245
	2	0.08180	0.004658	0.002083
	3	0.10180	0.005263	0.002354
	4	0.10500	0.006782	0.003033
	5	0.10860	0.005727	0.002561
Caulk	1	0.02700	0.005788	0.002588
	2	0.10200	0.005568	0.002490
	3	0.10740	0.005177	0.002315
	4	0.12620	0.008289	0.003707
	5	0.13080	0.004764	0.002131
3M	1	0.05300	0.002121	0.000949
	2	0.09660	0.001517	0.000678
	3	0.10520	0.006496	0.002905
	4	0.14380	0.005848	0.002615
	5	0.14380	0.005848	0.002615

While correlating the data to the clinical situation, it should be kept in mind that the results are applicable only in cases single tooth preparation and only to the types of tray adhesives tested. However, different impression materials, types of trays, and techniques will yield different results. In this study, neither the effects of the lips, cheek, and tongue in containing the impression material could be simulated nor the influence of the occlusal force.[8] The machined stainless-steel die used in this study has certain advantages over the prepared tooth in oral cavity.

For evaluation of tensile strength of different tray adhesives, 125 samples were fabricated and tested at variable drying times. For all the tray adhesives, the mean tensile strength increased significantly up to 15 to 20 minutes of drying time. Then up to 25 minutes, not much increase was seen. The maximum mean tensile strength achieved was 0.143 MPa that lies in the range reported by Davis et al and Samman and Fletcher.[9] However, the values as high as 0.76 and 0.37 respectively as reported by Grant and Tjan were not achieved in this study.[10] Davis et al found a gradual increase in tensile strength from 5 to 15 minutes. The largest gain in their study was from 5 to 15 minutes, and gains after that were considered minimal.[10] The study that showed very high values may be attributed to minor differences in the material, type of adhesive, size of the resin samples, and rate of force application.[11]

Based on aforementioned findings, it is not possible to value the bond strength of adhesives, which leads to interface failures between tray and impression materials that lead to inaccurate dies obtained later on.[12] Zainal also reported that roughening the acrylic resin enhances the retentive properties of tray adhesive. In this study also, all the custom-made resin samples evaluated were roughened using 320 grit silicone carbide paper.

The maximum mean bond strength achieved did not increase much after 20 minutes drying time, which is in accordance with the study done by Dixon and Breeding. They reported that adhesive tensile bond strength of elastomeric impression material to an autopolymerizing tray material has been found to stabilize after 30 minutes and remain constant during the following 72 hours. Therefore, if the patient cancels, or the office is rescheduled, the adhesive may be applied long before the impression is completed.[13]

Conclusion

This in vitro study aimed to evaluate the dimensional accuracy of dies using different tray adhesive and tensile strength of

five tray adhesives at variable drying time intervals ranging from 3, 10, 15, 20, and 25 minutes. Therefore, within the limits of this in vitro investigation, the following conclusions can be drawn:

- Tray adhesives should be applied to prevent polymerization shrinkage of impression materials and to obtain dimensionally accurate dies.
- The maximum tensile strength of all the tray adhesives was obtained when they were dried up to 20 minutes.
- After drying time of 20 minutes, no significant change in tensile strength was noticed.

Funding
None.

Conflict of Interest
None declared.

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