Influence of Tray Rigidity and Impression Technique on Accuracy of Polyvinyl Siloxane Impressions

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Purpose: The aim of this study was to determine how tray rigidity and impression technique affect the accuracy of polyvinyl siloxane impressions. ***Materials and Methods:*** Disposable plastic trays and metallic Rim-Lock trays were used in combination with a heavy/light body technique or with two different putty-wash techniques. For each technique-tray combination, 10 impressions were made of a master cast with two steel abutments representing the mandibular right first premolar and second molar, between which a steel rod was placed at the ridge level. Each steel abutment had five marks, while the steel rod in between the two abutments had only one mark, which served as a reference point. With a universal measuring microscope, the x-, y-, and z-coordinates were recorded for each mark on the master cast and impressions. The distances between the different marks and the reference point on the impressions were calculated and compared with those of the master cast. ***Results:*** All techniques used with the plastic trays had distances that were significantly different from the master cast ($P < .05$), while for the metal trays, it was only the heavy/light body technique that resulted in distances that were significantly different from the master cast ($P < .05$). ***Conclusion:*** Plastic trays produced less accurate impressions than metal trays. When metal trays were used, putty-based impressions were dimensionally better than heavy/light body impressions. *Int J Prosthodont 2011;24:49–54.*

Accurate impressions are influenced by the impression material selection,[1–3] impression material manipulation and impression technique,[4] impression tray material,[5] impression tray design,[6–10] tray deformation potential,[11–13] impression retention to the impression tray surface,[14] impression thickness,[15] impression removal,[16] thermal changes after removal,[17] storage condition after removal,[1] and material used for making the dies and its compatibility with the impression material. In addition, by eliminating the mobility of teeth resulting from the thickness of the periodontal ligament[18] the demand for accuracy of impressions will increase in areas. That is true for those with minimal to no abutment mobility, such as those with implant-retained fixed partial dentures.[19] Considering all of these variables and their interactions, it can be inferred that high impression accuracy is not easily achieved.

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Impression trays used for polyvinyl siloxane (PVS) impressions are either custom made or bought as stock trays. The advantage of using a custom-made tray is that the impression material forms a uniform thickness inside the tray, while the advantage of using a stock tray is the convenience and cost, but uneven impression material thickness could be a problem. All impression materials shrink during polymerization, suggesting that variations in impression material thicknesses could result in different shrinkage at different locations.[3,20,21]

Because of differences in the viscosities of different impression materials, different forces are needed to seat the tray during impression taking. Consequently, a rigid impression tray should suffer less distortion during impression taking with heavy viscous materials, such as putties.

Today, some of the most popular impression techniques include *(1)* injecting a low viscous impression material around the prepared teeth and seating a tray loaded with a high viscous impression material over the still unset low viscous material[22]; *(2)* taking an impression in a very high viscous material (putty), and after the impression has set and been removed, injecting a light body impression material around the teeth and in the set putty impression, whereupon the set putty impression is placed back again over the teeth[23]; and *(3)* using a spacer (often a

Fig 1 Frontal view of the master cast. Note the stainless steel rods between the abutment replicas.

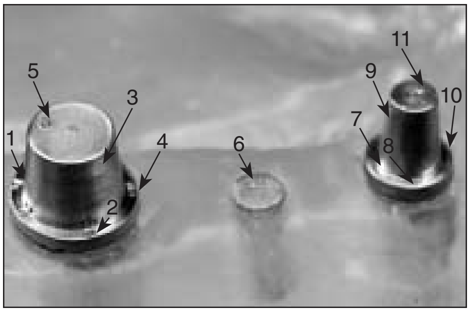


Fig 2 Simulated preparations and the marks used as measuring points.

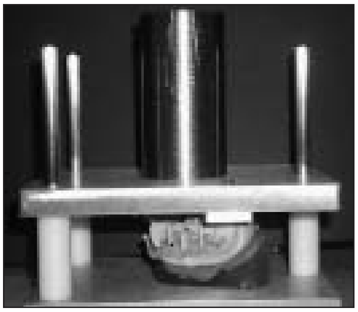


Fig 3 Lateral view of the impression device with a 3-lb weight on top while taking an impression (IT3).

vacuum-processed tray) that is placed over the teeth before an impression is taken in a putty material. After the putty has set, the spacer is removed and a low viscous material is placed around the teeth, as well as in the spacer region of the putty impression, whereupon a final impression is made.

Considering the options mentioned previously, the authors hypothesize that the most reliable impressions are achieved with a rigid tray and a thin final impression layer (techniques 2 or 3). Of techniques 2 and 3, technique 3 is expected to perform best, despite its thicker wash layer. The reason is simply that a tighter putty fit (technique 2) will result in increased putty compression while the wash impression is being taken, which would increase the risk that the putty "springs" back when the final impression is removed. To test this hypothesis, the authors decided to compare metal and polymeric stock trays, and with each of these trays, use the three different impression techniques.

Materials and Methods

Master Cast

A mandibular master cast was fabricated from self-curing acrylic resin (Orthodontic Resin, Dentsply-Caulk) with four machined stainless steel dies simulating prepared abutment teeth in the mandibular first premolar and second molar regions. In addition, two stainless steel reference posts were located in the left and right sides between the stainless steel dies and flat to the ridge level (Fig 1).

The dies were designed to simulate circular full-crown preparations with shoulders and 6-degree total occlusal convergence (TOC). The molar preparations were 7.0-mm high, had a cervical outer diameter of 9.0 mm, and a shoulder width of 1.0 mm. The premolar preparations had the same TOC, height, and shoulder width, but an outer diameter of 7.0 mm. The dies were locked into the resin to avoid any movement. Two 3.0-mm-diameter stainless steel reference rods were inserted at the ridge level halfway between the stainless steel replicas located on each side. A diamond bur (Maxima Diamonds 801-012C-FG, Henry Schein) attached to a parallelometer (PFG 100, Cendres & Métaux) was used to make marks on the occlusal surfaces and the shoulders of the dies, as well as on the stainless steel rods between the dies (Fig 2). These marks consisted of circular scratches with a distinct dot in the center of the circles. These center dots were used as measuring points.

To standardize the impression procedure, the master cast was attached to a half inch–thick aluminum plate with two screws. On the aluminum plate, three stainless steel pins were positioned vertically to guide a second top plate with the tray attached to it (Fig 3).

Because of differences in tray designs, separate plates were used for the metallic and plastic trays. The holes in the top plate slid along the rods attached to the base plate and allowed precise positioning onto the master cast during the impression taking procedures. Three plastic stops were assembled on the pins to control the seating of the tray against the cast. Because of differences in tray designs between the metallic and plastic trays, two different sets of vertical stops were used.

Tray Materials

The two trays used were either plastic stock trays (Disposable impression trays, Henry Schein) or metallic stock trays (Rim-Lock trays, Dentsply-Caulk). Tray adhesive (V.P.S. Tray Adhesive, Kerr; lot: 5-1082) was applied to the inside of the trays 10 minutes prior to impression taking.

Impression Technique Groups

Three impression groups (IT1, IT2, and IT3) were used in this study. Group IT1 used heavy- and light-bodied PVS materials (Aquasil, Dentsply-Caulk; lots: 050618 and 050421, respectively). A tray attached to the top plate was loaded with the heavy-bodied material. Simultaneously, the light body material was injected directly onto the right side abutment replicas. The top plate was then placed on the vertical rods and guided close to their stops, whereupon a 3-lb weight was placed on the top plate to fully seat the tray to the pre-established ideal cast-tray relation. The impression was left undisturbed for 10 minutes before it was removed in one quick pulling action.

Group IT2 used a putty (Exaflex, GC; lot: 0505201) and a light body material (Aquasil). The top plate was first removed from the stand and the tray was loaded with the putty material. The top plate was then placed on the vertical rods and guided close to their stops. A 20-lb weight was then placed on top of the plate to fully seat the tray to the pre-established ideal cast-tray relation. The impression was left undisturbed for 6 minutes and afterward was removed in one quick pulling action. The light body material was then injected around the abutments and inside the already set putty impression. The top plate with the already set putty impression was once again placed on the vertical rods and guided close to their stops, and a 28-lb weight was placed on top to fully seat the tray to the pre-established ideal cast-tray relation. The impression was left undisturbed for 10 minutes and then removed in one quick pulling action.

Group IT3 used a spacer created with a 2-mm-thick plastic pressure-formed template (Great Lakes Orthodontics) placed over the abutments, on which a putty impression (Exaflex) was made, as described for group IT2. The impression was left undisturbed for 6 minutes and then removed in one quick pulling action. The 2-mm plastic spacer was removed carefully from the putty impression. The light body material was then injected around the abutments and inside the already set putty impression. The top plate was placed and guided close to the stops, and then a 3-lb weight was placed on top to fully seat the tray to the pre-established ideal cast-tray relation. The impression was left undisturbed for 10 minutes and then removed in one quick pulling action.

Ten impressions of each tray–impression technique combination were made. All 60 impressions were made at room temperature (23°C to 25°C) and kept at that temperature for 24 hours before being measured under a microscope. The humidity where the impressions were stored was 55% ± 1%.

Measurements

The x-, y-, and z-coordinates of the 11 marks on the master cast were first measured with a measuring microscope (Unitron Universal Measuring Microscope, Unitron). These coordinates were recorded 10 times on the master cast for the abutments on the right side and the reference rod located between them. Similar readings were made on the impressions 24 hours after they had been taken. The spatial distances between the marks on the abutments and the reference point between them were calculated. Since each abutment had 5 marks, a total of 10 distances were measured on each impression.

Statistical Analysis

The mean values of the different distances on the master cast were compared with the matching mean values measured on the impressions, and comparisons between the different tray (stiffness) and impression thickness groups were conducted by use of the Student t test at a significance level of $P < .05$ (SAS).

Results

Table 1 shows the five distances measured between the five points on the second molar abutment tooth (1–5) and the reference point (6) and the five distances between the five points on the first premolar abutment tooth (7–11) and the reference point on the master cast. As seen from the distance values, the standard deviation (SD) for the different distance values varied from 18.9 to 70.1 μm. The largest SDs were associated with points 5 and 11, the points located on the top of the abutment teeth. Of all measured points, these were the points that were most out-of-plane with the other points. Minor errors in x, y, and z determinations have a more dramatic effect on points located out-of-plane, and the 5-6 and 11–6 distances were determined from space coordinates.

Of the measured distances, the difference between the two extreme measurements (maximum and minimum values) for a certain distance was below 100 μm for most measurements. However, for distances 5–6 and 11–6, the differences between the extreme values were around 200 μm, which can be related to the out-of-plane location of points 5 and 11.

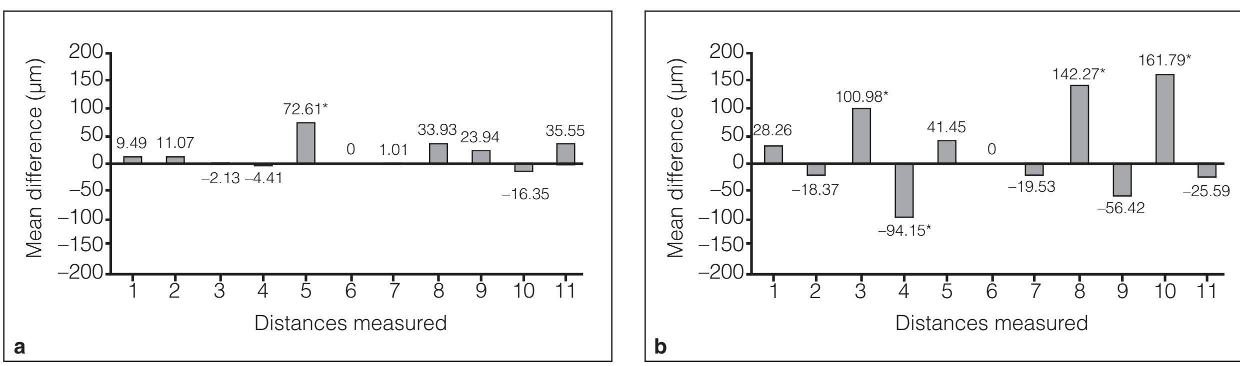
Considering the results presented in Table 1, it is obvious that the measuring technique being used is not as reliable as one would like it to be (SD as large as up to 0.4% of the distance). Despite that limitation, it was possible to use the Student t test and perform pairwise comparisons, and by doing so, significant differences between four of the investigated groups and the master cast were identified ($P < .05$, Figs 4 and 5).

All techniques used with the plastic trays had one or more distance that was significantly different from the master cast, while for the metal trays, only the IT1

Table 1 Means and Standard Deviations of 10 Rounds of Measurements Performed on the 11 Marks of the Master Cast

Distance*	No. of measurements	Mean (µm)	SD (µm)	Minimum (µm)	Maximum (µm)
1–6	10	18,071.5	27.9	18,032.4	18,121.8
2–6	10	14,899.0	32.5	14,846.2	14,948.7
3–6	10	15,577.4	26.3	15,538.3	15,613.6
4–6	10	9,186.0	46.7	9,087.3	9,251.2
5–6	10	17,665.2	70.1	17,567.9	17,789.3
6–6	10	0	0	0	0
7–6	10	9,994.1	26.1	9,959.0	10,036.5
8–6	10	14,336.6	25.3	14,313.2	14,390.0
9–6	10	12,629.7	35.5	12,594.5	12,708.0
10–6	10	15,721.6	18.9	15,694.6	15,765.6
11–6	10	14,758.2	58.3	14,655.2	14,861.1

SD = standard deviation.
*See Fig 2 for location of measuring marks.



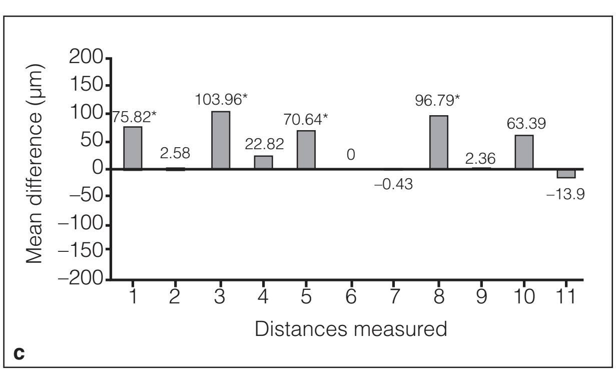
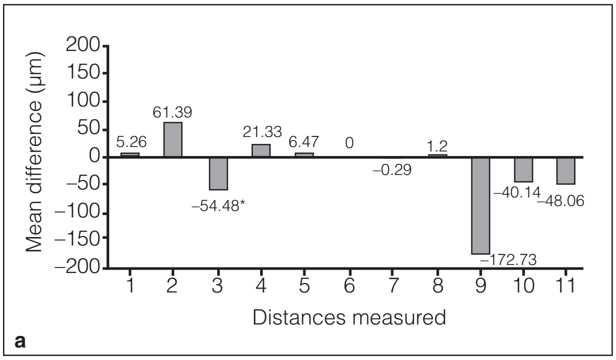


Fig 4 Mean difference values for **(a)** IT1, **(b)** IT2, and **(c)** IT3 with the disposable plastic impression tray for all disances in comparison to master cast. *Significant difference between impression and master cast. A negative number implies a shorter distance on the impression than on the original.

group had a distance that was significantly shorter than the matching distance on the master cast.

When plastic trays were used, groups IT2 and IT3 (Figs 4b and 4c) had the greatest number of distances that were significantly different from the master cast. For IT2, distances 3, 4, 8, and 10 had values of 101.0, −94.2, 142.3, and 161.8 µm, respectively, all of which were significantly different. For IT3, distances 1, 3, 5, and 8 differed from the master cast with differences of 75.8, 104.0, 70.6, and 96.8 µm, respectively.

IT1 with the plastic (Fig 4a) and metal tray (Fig 5a) each had one distance that was significantly different from the master cast. IT1 with the plastic tray was significantly different in distance 5 with 72.6 µm; IT1 with the metal tray was significantly different in distance 3 with −54.5 µm. Regarding the metal tray, it should be noted that distance 9 had a higher numerical value, but despite being larger, that value was not significantly different from the master cast.



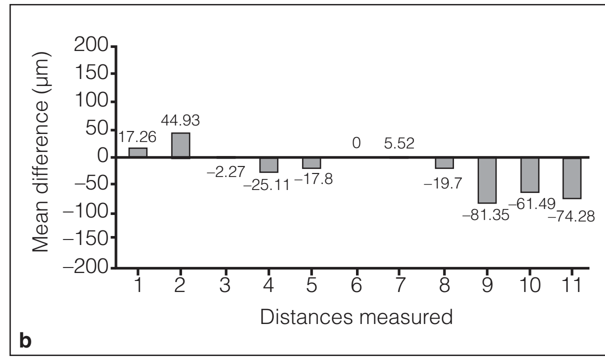
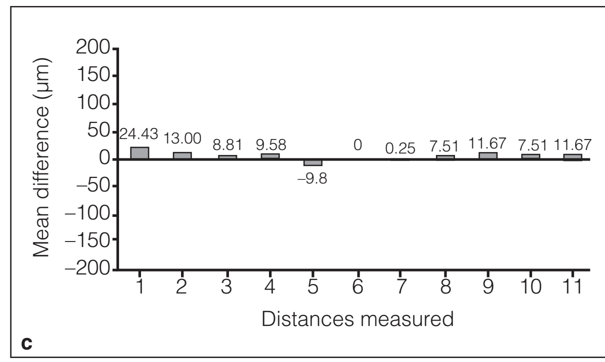


Fig 5 Mean difference values for **(a)** IT1, **(b)** IT2, and **(c)** IT3 with the metal tray for all distances in comparison to master cast. *Significant difference between impression and master cast. A negative number implies a shorter distance on the impression than on the original.



Discussion

The results support the hypotheses that a metal tray is less likely to result in impressions that deviate significantly from the master cast. Of all six groups, IT2 and IT3 with the metal tray were the only ones that did not have any distance that deviated significantly from the master cast, while IT1 with the metal tray had only one distance that deviated significantly. Regarding the plastic trays, IT1 had one significant difference, while IT2 and IT3 had four and three significant differences, respectively.

When it comes to the different impression techniques, IT2 and IT3 were predicted to be more reliable than IT1. However, the results do not support that hypothesis when it comes to the plastic trays. It was only for the metal trays that the results were in line with the proposed hypothesis. The reason this hypothesis did not find any support when it came to the plastic trays can be related to the lower tray rigidity. During the impression-taking process, both the IT2 and IT3 techniques required much higher impression load than the IT1 technique. The IT1 technique needed a force of 3 lbs to seat the tray, while IT2 needed 20 lbs when the first putty impression was taken and then 28 lbs when the final impression with the light-bodied PVS was created. IT3 needed 20 lbs when the putty impression was taken and then 3 lbs for the light body impression. Considering these differences in loads, it seems reasonable to explain the poor performance of IT2 and IT3 with the plastic tray as primarily being attributed to tray distortion during loading. Considering that IT2 used a higher load than IT3, it is interesting to note that IT2 had four significant distance deviations with the plastic tray, while IT3 had three such significant differences. The comparison becomes even more interesting when IT2 and IT3 with the plastic tray are compared to that with the metal tray. There were no significant deviations for IT2 and IT3 with the metal tray, but by comparing Figs 5b and 5c, the results favor IT3, an outcome that can be related to the lower pressure used for the final light body impression.

The changes seen for IT1 with both the plastic and metal trays may primarily be related to material bulk thickness and associated polymerization shrinkage. Based on clinical experience from use of technique IT1 with the plastic tray, it seems as though the discrepancies found for these two groups are still clinically acceptable for certain, if not most, clinical procedures. Differences in distances up to 90 μm between abutments for a fixed partial denture have been estimated as acceptable[14] because the periodontal ligament measures between 100 and 250 μm.[18] Even higher values than 90 μm are probably acceptable for some patients. However, a 90-μm distortion for a multiple implant structure would have a different outcome; it would probably be clinically unacceptable because of its inability to adapt to the stiff implants. Vigolo et al[19] found that discrepancies up to 34 μm were judged as acceptable and "passive" to manual and visual inspection for multiple implant structures. Fortunately, such variations in length are found only when dealing with edentulous spans where the impression material bulk is large and highly susceptible to polymerization shrinkage and thermal changes. Intra-abutment dimensions are not affected enough by the impression variables to make them clinically important. It has been recognized that dimensional changes in intra-abutment dimensions are very minimal when PVS or polyether is used in conjunction with stock or custom trays.[2,8,16] These claims, though, may not be valid for the IT2 and IT3 techniques with plastic trays.

The findings of this study confirm other findings that the rigidity of the tray is one factor related to impression accuracy.[12,23] Cho and Chee[13] showed that tray distortion must be considered when plastic stock or metal trays are used in combination with putty material. Rigid trays have also been recommended to reduce distortion during seating and removal of the trays from the patient's mouth.[12,22] For example, Gordon et al[9] found up to 100-μm differences in interabutment distances and a 260-μm cross-arch discrepancy when plastic stock trays were used. They attributed this distortion to tray flexibility.

Undercut size and their effect on distortion was not included in this study. Its importance regarding impression accuracy is well recognized[15] and could have impacted the results. The greater the undercuts are, the more likely a thin layer of impression material will deform permanently. Thus, in such cases, the IT1 technique might perform better than IT2 and IT3.

Conclusion

Plastic trays produce less accurate impressions than metal trays. However, if plastic trays are used, one should avoid using techniques IT2 and IT3 to minimize the risk of tray deformation. If metal trays are used, the best results can be achieved with putty-and-wash impressions, particularly with the IT3 technique.

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