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The Effect of Stiffness of Impression Materials and Flexibility of Trays on the Casting Accuracy (An *In-Vitro* Study)

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Abstract

Purpose: Study the effect of using two impression materials of different stiffness with three impression trays of different flexibility on the casting accuracy of cast metal copings.

Materials and Methods: The mandibular right first molar of a typodont model mounted to a semi-adjustable articulator was prepared for a full coverage cast metal coping. Thirty impressions were made with metal dual-arch impression trays, plastic dual-arch impression trays and a custom made acrylic resin impression tray using polyvinyl siloxane and polyether impression materials. Each impression was cast in type IV improved dental stone and the occlusogingival, mesiodistal and buccolingual dimensions of the obtained dies were measured using a traveling microscope and the prepared tooth served as a control. Wax patterns were fabricated on each stone die then cast into metal copings. Each metal coping was fitted on the prepared tooth and examined for vertical marginal gap accuracy using the travelling microscope. One way ANOVA followed by pair-wise tukey's post-hoc tests were performed to detect the significance between groups, then separate student t-tests to detect the significance between subgroups.

Results: The removable stone dies and cast metal copings obtained from the plastic dual-arch impression trays showed the greatest distortion in the occlusogingival, mesiodistal, buccolingual and vertical marginal gap measurements and the metal-dual arch impression trays recorded the least changes in all measurements.

Conclusion: The increased rigidity of the impression trays as well as the increased stiffness of the impression materials produce more accurate dies and cast metal copings.

Keywords: Elastomers; Dual-arch trays; Marginal gap

Introduction

The success of any fixed prosthodontic treatment plan depends on multiple steps. The impression making procedure is considered one of the key steps for reaching a successful final restoration. Its overall goal is to produce an exact three dimensional negative replica of the hard and soft intraoral tissues and its quality significantly affects the accurate fit of the final restoration [1].

Since the introduction of the dual-arch impression technique, its popularity has steadily grown due to its wide range of advantages which includes patient comfort, efficiency, and economy of materials and the convenience of capturing the prepared abutment, the inter-occlusal record and the opposing arch simultaneously. The technique has been referred to as the “dual-arch impression technique”, “double-arch impression technique”, “closed-mouth impression technique” or “triple-tray impression technique”[2].

Ceyhan, et al. [3] conducted a clinical trial to compare the accuracy of gypsum working dies made from impressions with metal dual-arch, plastic dual-arch and complete arch custom trays. Eight patients requiring a posterior single tooth implant restoration were selected. A customized abutment was measured in three dimensions using a measuring microscope. Three polyvinyl siloxane impressions were made of the abutment and each impression was poured with type IV improved dental stone. The buccolingual, mesiodistal and occlusogingival dimensions were measured several times to obtain the mean values. These mean values served as the control and were compared with the same measurements of the gypsum dies generated by the three different impression techniques. There were no significant differences in the die accuracy among the three trays for the mesiodistal and the occlusogingival dimensions but they were significantly larger in the buccolingual dimension.

Cayouette, et al. [4] measured and compared the dimensions of casts made using four types of impression trays; metal dual-arch tray, plastic dual-arch tray, plastic stock tray, custom made acrylic tray and two types of impression materials to the dimensions of an original master model. Polyvinyl siloxane and polyether impressions were made of two crown preparations of ivorine teeth cemented to an acrylic master model. Two grooves were placed on each preparation. In addition, six points were placed on each occlusal surface and six were placed on each finish line. Impressions were poured with type IV dental stone. A (3D) measuring system was used to determine the coordinates of thirty two points on the master model and the resulting casts. Inter and intra-abutment dimensions were calculated from the measured coordinates. Results indicated that only the custom tray did not detect any inaccuracies and was as accurate as the master model.

Tan, et al. [5] determined whether there was a significant difference between the vertical marginal gaps of cast restorations and computer-aided design / computer-aided manufacturing restorations. They created ten working dies from a single master model and then fabricated ten restorations in each of the following groups: (CAD/CAM), (WAX/CAM) and (WAX/CAST). The restorations were seated on the master model and high resolution digital photographs were taken for the marginal area on all of the four sides. The vertical marginal gaps were measured using a calibrated digital software program. The mean vertical marginal gap for the (CAD/CAM) group was 79.43 μm, 73.12 μm for the (WAX/CAM) group and 23.91 μm for the (WAX/CAST) group. There was a statistically significant difference between the (WAX/CAST) group and the remaining groups. The (WAX/CAST) technique produced the smallest vertical marginal gaps among all the tested groups.

Gonzalo, et al. [6] compared the changes in the marginal fit of posterior fixed metal ceramic dental prosthesis fabricated with the conventional lost wax technique and zirconium systems manufactured using CAD/CAM technology before and after cementation. Forty standardized master steel dies with two abutments simulating first mandibular premolars were fabricated to receive a posterior three unit FPD. Measurements were made with an image analysis program on the master steel model before and after conventional cementation with glass ionomer cement. No significant differences in the vertical marginal fit before and after cementation were recorded for the analyzed groups. The accuracy of fit achieved for metal ceramic groups and the zirconium groups analyzed was within the range of clinical acceptance and the discrepancies were lower in the metal ceramic group.

The accuracy of the castings generated from the dual-arch impression technique using impression materials of different stiffness along with impression trays of different flexibility however remains in question.

Material and Methods

The mandibular right first molar of a typodont model (Ramsis dental, Egypt) was prepared using a milling surveyor unit (Fraesgerat F1, Degussa, Germany) to receive a cast metal coping (Figure 1). Notches were made on the buccal, lingual, mesial and distal surfaces to act as future reference measuring points as well as an anti-rotational element for the cast coping. The typodont was mounted in maximum intercuspation to a semi-adjustable articulator (Magnetic denture articulator, China) equipped with an aluminum vertical tray positioner to stabilize the dual-arch impression trays in a buccolingual direction, a copper tray clamping jig to stabilize the dual-arch impression trays in a mesiodistal direction and a 1.5 kg lead weight placed on top of the upper compartment of the articulator to simulate constant occlusal force during the setting time of the impression materials [7] (Figure 2). Metal posterior dual-arch impression trays (The Gripper, Discus dental, and USA), plastic posterior dual-arch impression trays (Easy tray 3A, MEDES, Korea) and a lower full arch dentulous auto polymerizing acrylic resin impression tray (Acrostone, Egypt) were obtained. Heavy body polyvinyl siloxane impression material (Panasil tray fast, Kettenbach dental, Germany) and light body polyvinyl siloxane impression material (Panasil initial contact light fast, Kettenbach dental, Germany) were also obtained. A dual viscosity single step impression technique was used. The light body material was injected around and over the prepared molar. Both sides of the dual-arch impression trays were filled with the heavy body impression material which was dispended from an automatic impression mixing unit (Pentamix, ESPE, USA) then the trays were placed over the posterior mandibular teeth on the right side of the typodont and the articulator was closed until the unprepared teeth touched. This was confirmed by the closed position of the guide pin on the articulator table [7]. The trays were positioned so that the back of the tray did not impinge on the simulated gingiva distal to the third molars. A polyether impression material (Impergum Penta, 3M ESPE AG, Germany) was also used with each tray type. The single body material was injected around the tooth and placed in the tray using the same technique previously described. Each impression was allowed to set for six minutes before it was snaply removed from the typodont. Ten impressions were made with each tray type. After that, impressions were cast in improved dental stone (SynaRock XR DIAMON, Germany) and wax patterns were constructed on each removable stone die using a hard inlay and crown blue wax (Renfert Master Wax Singen, Germany) then cast into full metal cast copings using a nickel based dental alloy (MEAlloy DENTSPLY, Italy) using a centrifugal casting machine (Supercast RDO, NJ, USA).

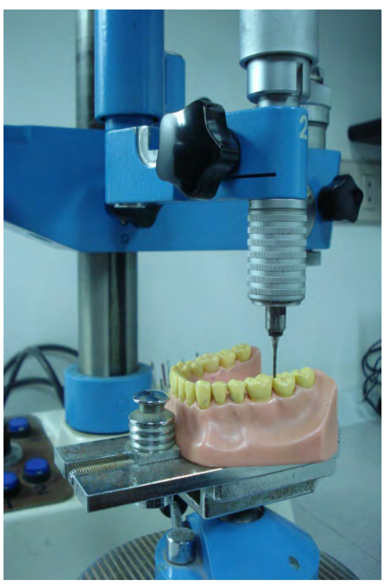

Figure 1: Cutting bur orientation parallel to the long axis of the prepared model.

The occlusogingival, mesiodistal and buccolingual dimensions of the prepared molar and each obtained removable stone die were measured five times using a traveling microscope (M420, Leica Bensheim, Germany) using the sharp corners of the previously prepared notches as reference measuring points. Also, each obtained metal cast coping was seated on the master prepared model and examined for its vertical marginal gap accuracy using the travelling microscope. One way ANOVA followed by pair-wise tukey's post-hoc tests were performed to detect the significance between tray groups, then separate student t-test to detect the significance between subgroups. Multi-factorial (impression material and tray material) analysis of variance ANOVA tests of significance were performed to compare the variables affecting the dimensional accuracy of the stone dies and the vertical marginal gap of the metal copings. P values ≤ 0.05 were considered to be statistically significant in all tests.

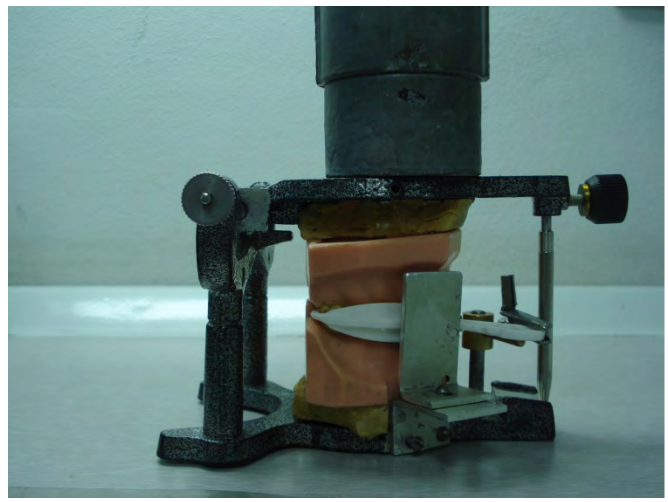

Figure 2: Closed semi-adjustable articulator with mounted models, dual-arch tray, vertical tray positioner, tray clamping jig and 1.5 kg weight on top.

Results

Effect of Different Tray and Impression Materials on The Occlusogingival (OG) Height of the Stone Dies

Stone dies obtained from both impression materials recorded the highest change in (OG) height mean values with the plastic tray followed by the acrylic tray while the metal tray recorded the lowest change in (OG) height mean values (Table 1). The difference in the (OG) height mean values of the obtained stone dies between different tray materials as well as different impression materials was statistically non-significant as revealed by ANOVA (Figure 3). This finding shows that neither the impression nor the tray material exerted any significant effect on the (OG) height accuracy. Although we observed better results with the metal trays followed by the acrylic and finally the plastic trays, the results did not reach significance.

Impression material Tray type	Polyether		Polyvinyl siloxane	
	Mean±SD	Change (%)	Mean±SD	Change (%)
Metal	3.64±0.09	-0.12 (-3.19)	3.68±0.35	-0.08 (-2.13)
Acrylic	3.49±0.16	-0.27 (-7.18)	3.51±0.17	-0.25 (-6.65)
Plastic	3.41±0.21	-0.35 (-9.31)	3.45±0.15	-0.31 (-8.24)
Master	3.76±0.51			

Table 1: Occlusogingival height mean values of the stone dies obtained from both impression materials made in different tray materials measured in mm.

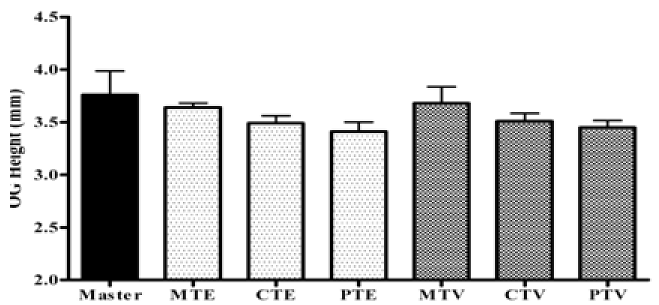

Figure 3: A column chart of the occlusogingival height mean values of the stone dies obtained from both impression materials made in different tray materials (n=5).

Effect of Different Tray and Impression Materials on the Mesiodistal (MD) Width of the Stone Dies

Stone dies obtained from both impression materials recorded the highest change in (MD) width mean values with the plastic tray followed by the acrylic tray while the metal tray recorded the lowest change in (MD) width mean values (Table 2). The difference in (MD) width mean values of the obtained stone dies between different tray materials as well as different impression materials was statistically non-significant as revealed by ANOVA (Figure 4). Although the results did not reach significance, this pattern suggests the possible superiority of the metal trays over both the acrylic and the plastic trays.

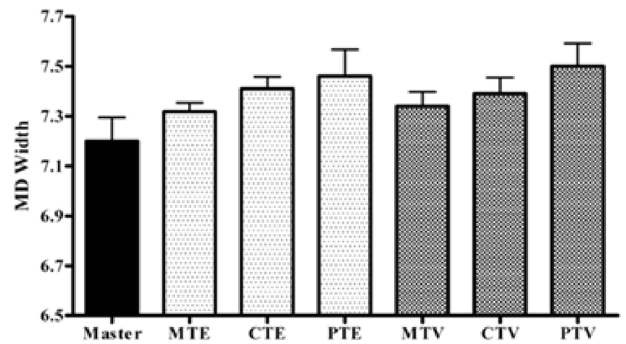

Figure 4: A column chart of mesiodistal width mean values of the obtained stone dies from both impression materials made in different tray materials (n=5).

Impression material Tray type	Polyether		Polyvinyl siloxane	
	Mean±SD	Change (%)	Mean±SD	Change (%)
Metal	7.32±0.08	0.12 (1.67)	7.34±0.13	0.14 (1.94)
Acrylic	7.41±0.11	0.21 (2.92)	7.39±0.14	0.19 (2.64)
Plastic	7.46±0.24	0.26 (3.61)	7.50±0.21	0.30 (4.17)
Master	7.20±0.21			

Table 2: Mesiodistal width mean values of the obtained stone dies from both impression materials made in different tray materials measured in mm.

Tray Material but not Impression Material Affects the Buccolingual (BL) Width of the Stone Dies

Stone dies obtained from both impression materials recorded the highest change in (BL) width mean values with the plastic tray followed by the acrylic tray while the metal tray recorded the lowest change in (BL) width mean values (Table 3). The difference in (BL) width mean values between different tray materials was statistically significant as revealed by ANOVA (Figure 5). Our results suggest the superiority of the metal trays over both the acrylic and the plastic tray materials.

Impression material Tray type	Polyether		Polyvinyl siloxane	
	Mean±SD	Change (%)	Mean±SD	Change (%)
Metal	6.42±0.06	0.33 (5.46)	6.40±0.09	0.31 (5.13)
Acrylic	6.50±0.07	0.41 (6.76)	6.50±0.05	0.42 (6.83)
Plastic	6.98±0.05	0.89 (14.65)	6.96±0.10	0.87 (14.37)
Master	6.09±0.54			

Table 3: Buccolingual width mean values of the stone dies obtained from both impression materials made in different tray materials measured in mm.

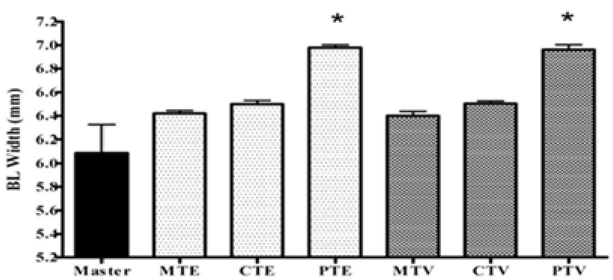

Figure 5: A column chart of buccolingual width mean values of the stone dies obtained from both impression materials made in different tray materials (n=5).

Tray Material but not Impression Material Affects Vertical Marginal Gap (MG) of the Metal Copings

Both impression materials when used with the plastic tray recorded the highest (MG) mean value for the obtained metal copings followed by the acrylic tray while the lowest (MG) mean value was recorded by the metal tray. The (MG) mean value of the obtained metal copings with the plastic tray was significantly higher than the (MG) mean values of the metal copings obtained from the metal and the acrylic trays. The (MG) mean values of the obtained metal copings with the acrylic tray were non-significantly higher than (MG) mean values obtained from the metal tray (Figure 6).

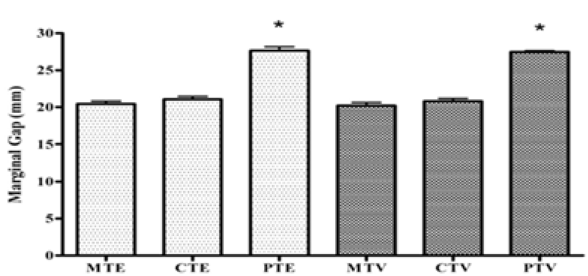

Figure 6: A column chart of vertical marginal gap mean values of the metal copings obtained from both impression material made in different tray materials (n=5).

These results show that the tray but not the impression material affects the vertical marginal gap of the metal copings. The results also suggest the superiority of the metal trays over both the acrylic and the plastic trays.

Discussion

Dual-arch impression trays are routinely employed for final impressions of fixed prosthodontics preparations. Of concern, is the accuracy of the castings obtained from these trays as the accuracy studies for the dual-arch impressions vary in their conclusions [8].

This study was conducted to evaluate and compare the dimensional accuracy of the stone dies and the vertical marginal gap accuracy of the metal copings obtained from two different types of impression materials of different stiffness; namely, the polyvinyl siloxane impression material and the polyether impression material used in conjunction with three different types of impression trays of different flexibility; the metal and plastic dual-arch impression trays and a custom made self-curing acrylic resin impression tray.

The dual viscosity single step impression technique is a technique which employs a light body impression material in an elastomer syringe and a heavy body impression material in the impression tray [9]. This technique was suggested by some authors as being one of the best techniques to be used with elastomeric impression materials of such viscosities [10].

A 1.5 kg weight was placed on top of the semi-adjustable articulator during the setting time of the impression materials because the maximum voluntary biting force (MVBF) in adults with normal occlusion ranged from 15 to 16 Newton which is equivalent to 1.5 kilogram-force [11].

In this study, the obtained mean values of the dimensional accuracy of the stone dies showed that the metal dual-arch trays produced the most accurate dies followed by the custom made acrylic resin tray and greater variability existed in the die dimensions produced with the plastic trays regardless of the impression type. These findings coincided with those reported by Davis and Schwartz [10] and Breeding and Dixon [7].

The variation between plastic and metal dual-arch impression trays could be attributed to the relative flexibility of the plastic dual-arch impression trays in comparison to the rigid metal dual-arch impression trays. Similar results were quoted in the studies done by Davis and Schwartz [10] and Cox, Brandt and Hughes [12].

The stone dies obtained from the impressions in this study were generally larger in size than the standard model except for the occlusogingival height dimensions. This may be due to the effect of using a tray adhesive which redirected the impression materials polymerization shrinkage towards the impression tray walls and away from the unsupported areas instead of the center of the impression material [13].

In this study, the occlusogingival height of the stone dies obtained from the two impression materials and the three impression trays combinations were measured and compared to the original prepared model and it was found that there were no significant differences between the two impression materials used in this study, but there was a difference between the impression tray materials yielding the largest change for the plastic dual-arch impression trays and the smallest for the metal dual-arch impression trays. This may be attributed to the fact of using a tray adhesive, which in case of the plastic dual-arch impression trays was sprayed on all of its surfaces which included additional retention plugs that increased the surface area available for the adhesive resulting in an increased shrinkage towards the tray walls and in turn to a die with an altered dimension. This finding goes in accordance with the results reported by Breeding and Dixon [7].

In this study, the mesiodistal and the buccolingual widths of the obtained stone dies from the two impression materials and the three impression trays combinations were measured and compared to the original prepared model and it was found that there were significant differences between different tray materials for the buccolingual width with the highest change for the plastic tray and the smallest change for the metal tray with no significant difference between impression materials. Ceyhan, et al. [3] reported similar results.

In this study, the vertical marginal gaps for the cast metal copings obtained from the two impression materials and the three impression tray materials combinations were measured. It was found that the mean vertical marginal gap openings ranged from 20.2 ± 0.9 µm for the metal dual-arch impression trays to 20.8 ± 0.9 µm for the custom made auto polymerizing acrylic resin impression tray and 27.7 ± 1.1 µm for the plastic dual-arch impression trays. All measurements were within the clinically acceptable range for the cast restorations made from base metal dental alloys which was up to 55±3 µm [0] with no significant differences between the used impression materials. Although the use of custom made impression trays has long been proven to produce more accurate working casts for restorative procedures, dual-arch stock trays were able to provide accurate clinical results when used for single unit restorations [14,15].

Conclusion

Within the limitations of this study:

- The increased rigidity of the impression tray materials and the increased stiffness of the impression materials produce more accurate stone dies.
- The interaction between the tray material and the impression material significantly affects the dimensional accuracy of the obtained stone dies especially in the buccolingual dimension.
- The impression tray materials significantly affected the vertical marginal gap mean values.
- All of the obtained vertical marginal gap values are within the clinically acceptable range.

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