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**Title**

Accuracy of Different Implant Impression Techniques: Evaluation of New Tray Design Concept

**Running Title**

Tray Design Effect on Implant Impression Accuracy

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**Abstract**

**Purpose:** To evaluate implant impression accuracy with a new tray design concept in comparison to non-splinted and splinted impression techniques for a 2-implant situation.

**Materials and Methods:** A reference bar titanium framework was fabricated to fit on 2 parallel implants. The framework was used to generate a resin master model with 2 implants that fit precisely against the framework. Three impression techniques were evaluated: (1) non-splinted, (2) splinted, and (3) non-splinted with modified tray impressions. All the trays were fabricated from light-cured

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acrylic resin material with openings that corresponded to the implant impression copings. Ten impressions were taken for each technique using poly(vinyl siloxane) impression material. The impressions were poured with type IV dental stone to generate the test casts. A rosette strain gauge was bonded to the middle of the framework. As the framework retaining screws were tightened on each test cast, the developed strains were recorded until the completion of the tightening to 35 Ncm. The generated strains of the rosette strain gauge were used to calculate the maximum principal strain.

**Results:** A statistically significant difference was observed among the different impression techniques. The modified tray design impression technique was associated with the least framework strains, which indicates greater accuracy compared with the other techniques. There was no significant difference between the splinted and the non-splinted impression techniques.

**Conclusions:** The new tray design concept appeared to produce more accurate implant impressions than the other techniques. Despite the statistical difference among the impression techniques, the clinical significance of this difference is yet to be determined.

**Keywords:** Accuracy; cast; framework; implant impressions tray.

Whenever multiple implants are restored with a prosthesis, the treating clinician should ensure the prosthesis accurately fits on all the implants. An accurate fit between the prosthesis and the implants is defined as the intimate contact between fitting surfaces with no strain on the supporting implant components or the surrounding bone in the absence of an applied external load.<sup>1,2</sup> An inaccurate implant prosthesis fit is thought to be associated with biological complications such as leakage and plaque accumulation within the implant components, peri-implant soft tissue inflammation, marginal bone loss, and potentially the loss of the implant.<sup>3</sup> More commonly, a misfitting implant prosthesis is prone to mechanical complications like frequent retaining screw loosening and fracture, ceramic veneer chipping, accelerated wear of the implant components, and early prosthesis failure.<sup>3,4</sup> The dilemma of implant prosthesis fit is the lack of an accurate clinical approach to measure misfit, which is further complicated by the difficulties of visualizing the interface between the implants and the

prosthesis.<sup>2</sup> Therefore, clinicians and technicians should rely on controlling the precision of each step of implant prosthesis fabrication.

One step that can influence implant prosthesis fit is the implant impression. The implant impression should be accurate in relating the implant position and orientation to the rest of the oral tissues, in order to ensure reliable prosthesis fabrication.<sup>5,6</sup> Earlier studies on the accuracy of implant impressions revealed that impression accuracy is influenced by impression material type; components used; implant depth, number and angulation; and the implementation of adjunctive procedure such as splinting of impression copings.<sup>5-7</sup> For a multiple implant impression, the most popular impression concept is the open tray impression technique with an elastic impression material such, as poly(vinyl siloxane) (PVS) or polyether.<sup>5-7</sup> Since any impression material is prone to dimensional changes,<sup>8</sup> the final implant impression will suffer from inevitable inaccuracy that may influence the spatial position of the impression copings. To enhance the accuracy of multiple implant impressions, several authors proposed splinting the impression copings with self-cured resin material<sup>5-7</sup> to maintain the spatial relationship between the impression copings by rigid fixation. Subsequently, the precision of the implant impression will not rely solely on impression material accuracy.<sup>9</sup> Systematic reviews of the laboratory studies indicated a tendency for greater impression accuracy if the impression copings are splinted.<sup>5-7</sup> However, intraoral splinting of impression copings is a time consuming step in the clinic and is not very comfortable for the patient. Further, it is difficult to apply to the posterior region where the access is limited. In addition, due to the shrinkage of self-cured resin,<sup>10-12</sup> distortion of the implant position may still occur, and was reported by some studies to cause more distortion than non-splinting of the impression copings.<sup>13,14</sup> As an alternative to splinting, this laboratory study investigated a different approach for multiple implant impressions. This approach is based on a modified rigid custom tray design. The custom tray can be altered to provide additional support for impression copings, reducing the amount of impression material and the influence of subsequent dimensional distortion and eliminating the need for splinting. This was achieved by the “chimney” tray design, where the rigid material of the tray surrounds the impression coping. Therefore the aim of this study was to evaluate the accuracy of the chimney tray technique in comparison to non-splinted

and splinted impression techniques for two-implant impressions. The null hypothesis is that all the impression techniques exhibit similar accuracy.

## **MATERIALS AND METHODS**

### ***Master model***

Two tissue-level Straumann implants (Standard Plus; Straumann AG, Basel, Switzerland) were placed into unset dental stone. The implants were regular neck implants of 4.8 mm neck diameter, 4.1 mm implant diameter, and 10 mm implant length. The distance between the centers of the implants was 15 mm, and they were parallel to one another. The stone model was sent to a commercial milling center (Osteon Medical, Melbourne, Australia) where an implant-level and beam-shape bar framework with a cross-sectional dimension of 3 x 3 mm was designed. Subsequently, a single reference titanium framework was produced from milling. Two corresponding implants were then attached to the reference framework and embedded into poly(methyl methacrylate) resin to fabricate the master model (Fig 1). This step ensured the best level of fit between the reference framework and the implants of the master model. As per earlier studies, the reference framework was used to quantify the accuracy of the casts produced by each impression technique.<sup>13,15</sup> The implant necks were located 1 mm above the resin level. The master model was 4 cm long, 2 cm high, with a 1 cm crest width. The model was indexed with vertical grooves to facilitate tray placement and impression making.

### ***Tray fabrication***

Three tray designs were implemented to allow for the different impression techniques (Figs 2-4). For all trays, two sheets of baseplate wax were placed over the master model as a spacer, and a light-cured acrylic resin material (Vertex Dental, Soesterberg, Netherlands) was used for the tray fabrication. For the non-splinted impression, the tray was fabricated with two simple openings in the areas of the

impression copings. For the splinted impression technique, the tray had a wide opening that corresponded to the splinted impression copings. The tray of the chimney technique was fabricated with two openings and vertical height to allow for coverage of the impression copings. To construct the chimney aspect of the tray, a single wax layer spacer was added to cover the impression copings and, subsequently, the tray material surrounded the whole impression coping height. Approximately 2 mm space was allowed between the external surface of the coping and the internal surface of all the trays. This was followed by providing an opening for the impression pin. Ten trays were fabricated for each group.

### ***Impressions***

Ten implant level impressions were taken using each technique. For every impression, two new impression copings were used. Tray adhesive (PVS Tray adhesive; Kerr Corp. Orange, CA) was applied to all the trays. For the splinted impression technique, pattern resin (GC Corp, Tokyo, Japan) was used to splint the implant impression copings with the aid of dental floss. The resin was mixed according to the manufacturer's instructions and was applied onto the impression copings and the dental floss to form a resin bar between the copings. The resin bar had a circular cross-section and a minimal thickness of 3 mm. The splints were left for at least 24 hours, after which they were sectioned and re-joined by freshly mixed resin. The freshly mixed resin was applied using bead-brush approach. Such splinting sequence is anticipated to enhance the accuracy of splinted implant impressions.<sup>5,12,15,16</sup> Prior to the impression making, the undercuts around the necks of the implants were blocked by wax to facilitate the impression making and the subsequent fitting of the implant replicas within the impression. Following routine clinical protocol, all the occlusal openings of the trays were sealed by baseplate wax. All the impressions were taken using heavy body PVS impression material (Kerr Extrude Extra type 1; Kerr Corp.). For all groups, the impression material was applied to the impression copings and in the trays. After removal of the impression, implant replicas were attached to the impression copings, and type IV dental stone (GC Fujirock EP; GC Corp) was used to pour-up the impressions. Eventually, ten test casts were produced for each impression technique.

## **Strain gauge analysis**

To evaluate the accuracy of each impression technique, strain analysis was implemented to quantify the fit of the framework on each test cast. A rosette strain gauge (Vishay Precision Group, Malvern, PA) was bonded to the middle of the occlusal surface of the reference titanium framework. A flowable silicone coating (RTV Coating; Dow Corning Corp, Midland, MI) was applied on the strain gauge to prevent handling damage of the gauge. After fitting each test cast on a fixed metal clamp, the framework was manually fitted on the implant replicas of each test cast. At this point, a baseline micro-strain reading was standardized by setting the strain values to zero. This was followed by hand tightening one framework screw to the first resistance, followed by hand tightening of the other screw to the first resistance. Subsequently, the first retaining screw was torqued to 35 Ncm followed by tightening the other screw. The strain reading after the completion of tightening was recorded. The strains were quantified by a strain data acquisition system in micro-strains (Acquire N Scans; National Instruments, Austin, TX). This process was repeated twice for each test cast by reversing the screw tightening sequence. Therefore, for each test cast, two strain readings were obtained, and were eventually averaged to generate the final strain value. From the strain readings, the maximum principal strain magnitude was calculated using Mohr's circle equation. No strain threshold can be implemented to determine the acceptable impression accuracy.<sup>1,2</sup> Instead, the generated principal strains from all the impression techniques were compared. A low principal strain value indicated less distortion of the framework and a greater accuracy of the impression technique. To evaluate the difference among the groups, the normality of the data was evaluated by the Shapiro-Wilks test. If the data was normally distributed, one-way ANOVA was implemented followed by post-hoc test using SPSS software package (SPSS for Windows, v23; SPSS Inc., Chicago, IL). A p-value of < 0.05 was used for statistical significance.

## **RESULTS**

The Shapiro-Wilks test conducted confirmed the normality of the data. The average maximum principal strain values were 418.3 (89.6)  $\mu\epsilon$ , 413.8 (138.7)  $\mu\epsilon$ , and 276.0 (116.1)  $\mu\epsilon$  for the non-splinted impressions group, splinted impressions group, and chimney tray impressions group, respectively. A box plot diagram representing the data of all the techniques (Fig 5) indicated lower strain values for the chimney tray impressions, while the splinted impression group had the greatest variations. There was a statistical significant difference among the groups ( $p = 0.02$ ). The post hoc test indicated that there were statistically significant differences in the average strain values between the non-splinted and chimney groups ( $p = 0.01$ ) as well as between the splinted and chimney groups ( $p = 0.03$ ); however, there was no statistically significant difference between the non-splinted and splinted groups ( $p = 0.93$ ).

## DISCUSSION

The results of this study revealed that the chimney tray design is advantageous and can produce more accurate casts for two parallel implants in comparison to the other two techniques. Therefore, the null hypothesis that all the impression techniques have similar accuracy is rejected. This could be of clinical benefit, as using the chimney tray for implant impression is relatively simple, less demanding, less time-consuming and will potentially reduce the clinical visit duration and patient discomfort involved with splinting impression copings. Furthermore, it will reduce the additional material costs involved with splinting and subsequent management of misfitting implant frameworks. This is likely due to the chimney tray design that is extended to cover all the impression copings. As a result, the chimney tray will provide a more rigid support and stability of the impression copings and the impression material. Subsequently, the impression copings are less likely to be displaced within the impression during impression removal, placement of analogs, and the setting of stone material. In accordance with the present study, Burns et al and Del'acqua et al found rigid support of impression copings by custom trays yields more accurate and consistent impressions than the less-rigid stock

trays, which can be attributed to the increased rigidity of the custom tray material.<sup>17,18</sup> Likewise, other studies reported rigid trays enhance the accuracy of elastomeric material impressions.<sup>19-22</sup> Another potential reason for the superiority of the chimney tray design is the reduction of the impression material bulk around the impression coping, which will eventually reduce the implications of impression material distortion.<sup>19,20</sup> In this study, the impression material was PVS, which exhibits a low polymerization shrinkage and high elastic recovery after deformation that has been reported to be more than 99%.<sup>8</sup> Nevertheless, it is still prone to dimensional distortion due to polymerization and strains during removal from the mouth. A study by de Araujo and Jorgensen revealed that an increased bulk of elastomeric impression material resulted in greater contraction and increased inaccuracy of the impression.<sup>23</sup> Similarly, another study confirmed that excessive space for impression material increased the inaccuracy of the impression.<sup>24</sup> Thus, since the chimney tray design will reduce the bulk of the impression material around the implant impression coping, it is likely that the orientation distortion of the impression coping will be reduced; however, one of the limitations of the present study is the lack of comparison with the closed tray impression technique, which may provide different support to the impression material.

In relation to splinting, the results of this study revealed no statistically significant difference between splinting and non-splinting of impression copings in a two-parallel-implant situation. Since the additional steps implemented to reduce the effect of resin polymerization shrinkage, such as waiting for 24 hours for the splint material and sectioning and reconnection,<sup>5,12,15,16</sup> did not improve the accuracy, it can be speculated that for two relatively parallel implants, rigid fixation of implant impression copings is not superior to non-splinting for PVS impressions. The literature demonstrates a conflicting effect of splinting, with some studies indicating similarity between the two techniques or superiority of one method over the other.<sup>5,6</sup> The variation in the results between studies in the literature could be attributed to differences in methodology and the accuracy of the evaluation techniques. For example, Inturregui et al found that the polyether impression of two parallel implants without splinting was more accurate than impression with splinted copings.<sup>13</sup> Similar to this study, Choi et al<sup>15</sup> and Cabral and Guedes<sup>16</sup> reported that splinted and non-splinted techniques exhibited a

similar accuracy for two parallel implants. While splinting impression copings rigidly connects them together, inaccuracy can still occur from polymerization shrinkage and distortion of the self-cured resin material.<sup>10-12</sup> In addition, separation between the impression coping and the splint can further compromise the quality of the implant impression.<sup>14</sup> On the other hand, Tarib et al found that the splinting impression technique was more superior to the non-splinting impression technique for two parallel implants.<sup>25</sup> Likewise, Assuncao et al observed superior accuracy for the splinted technique compared with the non-splinted impression technique for two implants with an angle of 25° between them.<sup>26</sup> The discrepancy between the observations of the studies<sup>15,16</sup> can be partially explained by the differences in the experiment design. For example, this study and other studies that reported similarity between splinting and non-splinting had used a simple block model of two parallel implants. Such a model represents the least challenging situation for elastomeric material and is less likely to cause strains within the set impression material during removal; however, the studies that reported a superiority of the splinted impression used a dental arch with teeth,<sup>25</sup> or included a tilted implant.<sup>26</sup> Engaging tooth undercuts with elastomeric material or removing the impression copings from tilted implants will exert strains within the set impression material that can eventually cause distortion of the material or displacement of the impression copings.<sup>27,28</sup>

Due to the simple presentation of the master model, it would be beneficial to investigate the use of this tray design in impression procedures of more than two implants or for tilted implants, where greater challenges are encountered in obtaining an accurate impression. While the novel chimney tray design appears to show promising results in a laboratory setting, the clinical significance of this difference at the time of prosthesis delivery cannot be determined by this study. Further, the results of a laboratory strain analysis cannot establish a clinical recommendation. On the other hand, there is lack of strong evidence showing negative implications of implant framework misfit.<sup>3</sup> In addition, the clinical studies that evaluated the clinical impact of different implant impression techniques did not reveal a significant difference in clinical fit<sup>29</sup> or patient comfort.<sup>30</sup>

## CONCLUSIONS

Within the limitations of this study, the following conclusions can be drawn:

1. The new tray design concept investigated in this study appeared to produce more accurate implant impressions than non-splinted or splinted impression techniques.
2. No significant difference was observed between the non-splinted and splinted impression techniques.
3. Despite the statistical difference among the different impression techniques, the clinical impact of this difference is yet to be determined.

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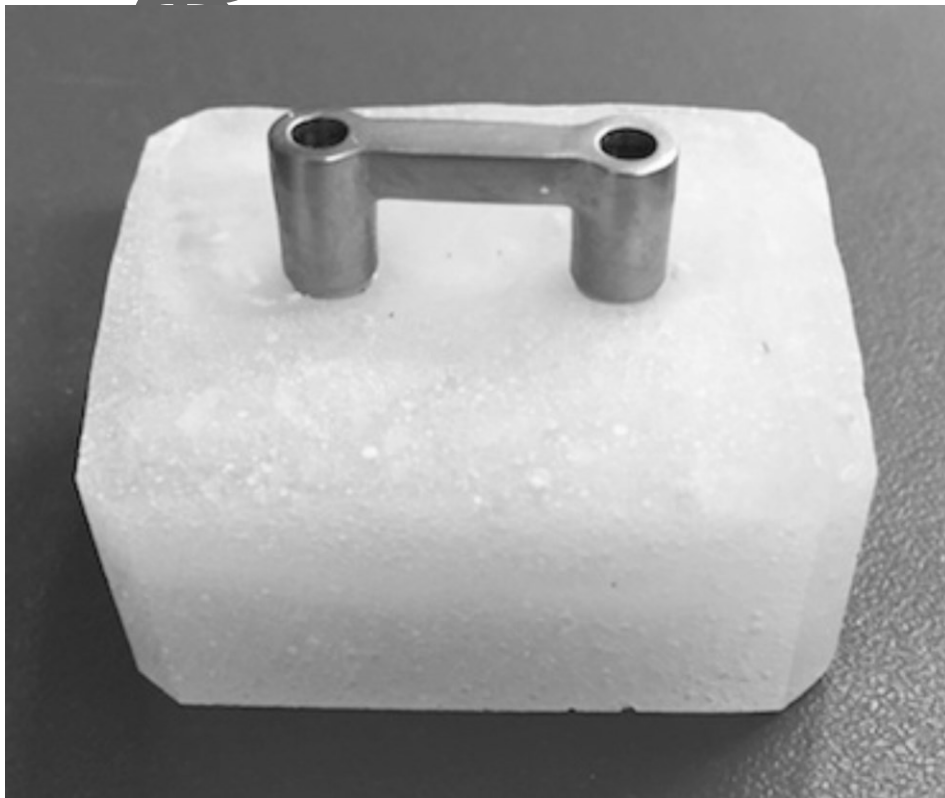
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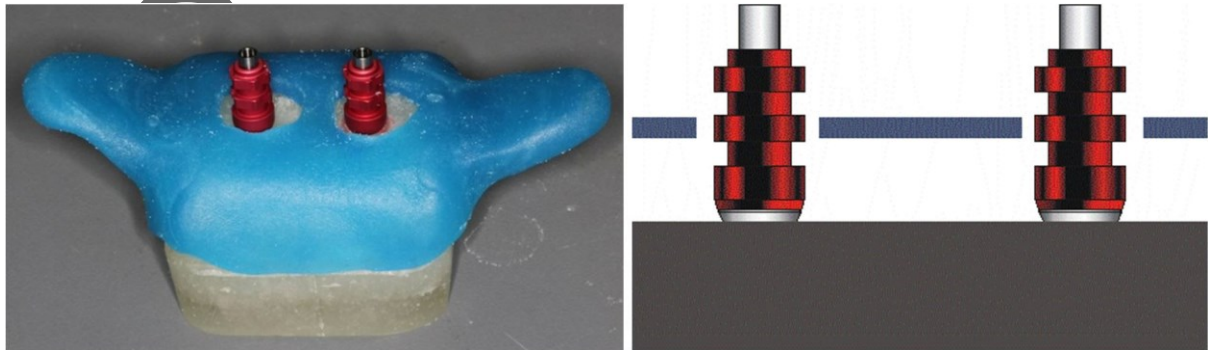
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### Figures legends

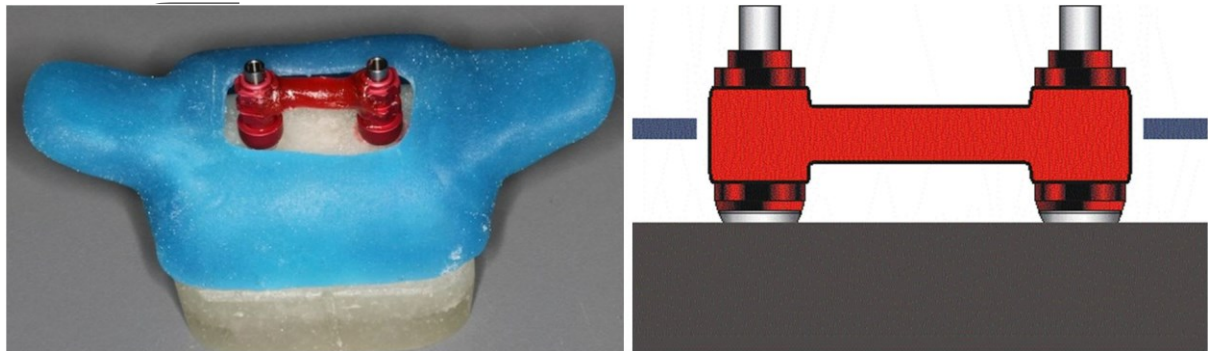
**Figure 1** The milled reference titanium framework fitted on the master model.



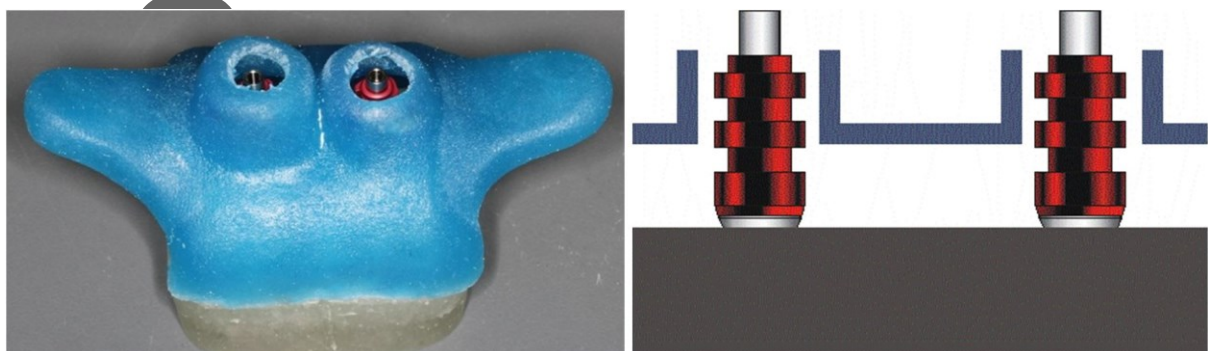
**Figure 2** Open tray for non-splinted impression.



**Figure 3** Open tray for splinted impression with resin pattern bar.



**Figure 4** Modified tray design with chimney covering most of the impression copings.



**Figure 5** Box and whisker diagram outlining the impact of each impression technique on framework strains.

