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Effect Of Combinations Of Pick-Up And Transfer Impression Coping In Non-Parallel Implants On Three-Dimensional Accuracy Of The Implant Impression - An In Vitro Study

Keywords
Implant Impression, Pick-Up Coping, Transfer Coping, Non-Parallel Implants, Three-Dimensional Accuracy

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Abstract
A correct implant impression is crucial for transferring the position of the implants to the working cast and for achieving a passive fit of an implant-supported prosthesis. Non-parallel implants can pose impression challenges due to guide-pin interference, incomplete seating of copings, and distortion when taking impressions. The in vitro study in the present work assessed the accuracy of combined pick-up and transfer impression copings for simulated non-parallel implant situations. Two stainless-steel master models were created: one straight and one 15° angulated implant analogue, and the other two converging 15° angulated implant analogues. 48 polyether impressions were taken and 6 groups were set up based on coping combinations and in custom trays. Experimental casts were cast with type IV die stone and evaluated by a coordinate measuring machine. One-way analysis of variance (ANOVA) and post hoc Tukey's test were used to statistically compare mean deviations and inter-abutment distances. The smallest inter-abutment deviation was observed in the case of transfer-on-straight and pick-up-on-angulated combination in the straight angulated model. The model with convergence-angulated pick-up and transfer exhibited the minimum numerical difference. No statistically significant difference was however observed among the groups. Coping strategies can be used together and offer similar accuracy in non-parallel implant impression.

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1. INTRODUCTION

Not only the osseointegration process, but also the precise transfer of implant positions in the oral cavity to the working cast is important for dental implant therapy. Any inherent discrepancy in the impression-making process can impact the passive fit of the prosthesis and can lead to biological, mechanical or other complications including screw looseness, framework strain, marginal bone stress and/or failure of the prosthesis. Hence, the accuracy of implant impression in partially edentulous and multi-implant scenarios is extremely important in prosthodontic rehabilitation as accurate spatial relationships between the implants must be reproduced. The accuracy of both conventional and digital impression techniques for fixed implant-supported prosthesis could be obtained; however the accuracy depends on the clinical conditions, implant position and impression workflow [1].

This is more difficult if they are not set parallel. Sometimes due to anatomical factors like proximity to adjacent roots, mental foramen or the maxillary sinus, implants have to be positioned with an angulation instead of an ideal parallel position. While it may be clinically impossible to avoid angled implant placement, it can be a problem during impression making due to the impression copings interfering with each other, not seating properly, or causing distortion when removing the impression. Digital impression studies also have shown that angulation can have an impact on trueness, which makes angulation a major factor in terms of accuracy even with new acquisition techniques [2].

The typical implant impression technique is to use either a pick-up or transfer impression coping. Copings will typically be left in the impression after being removed, whereas transfer copings will be left on the implant and have to be replaced in the impression after the implant is extracted. There are pros and cons to each method. Pick-up copings can offer the positional stability, but can be challenging in small areas or when converging implants. Although transfer copings generally may be easier to manage clinically, errors in transferring may impact on accuracy. When it comes to making implant impressions, all the above-mentioned factors should influence the choice of the technique, even if there is no systematic evidence comparison between conventional and digital methods [3].

Other factors affecting the accuracy of implant impressions are the material properties and the design of the tray. Elastomeric impression materials must be able to take an impression when removed and be dimensionally stable until casting is completed. Polyether has traditionally been employed in implant impression studies due to its rigidity and stability; however, these properties might be influenced by implant angulation and removal path. Experimental studies have shown that no single of these factors can be analysed independently as they can all affect the accuracy of the dental models [4]. Three-dimensional accuracy has also been tested in multi-implant models with open-tray or snap-on impressions, with the results indicating variations among different models in terms of the retention force that the impression components demonstrate during the impression process [5].

Open-tray techniques have been discussed extensively as it may decrease the number of errors made as a result of coping repositioning. But it may be difficult to clinically perform an open-tray implant when the implants are not parallel or when guide pins are interfering with one another. Recent studies have highlighted the clinical relevance of both accuracy and efficiency of the open-tray techniques, implying that simpler techniques that are technically easier may be clinically useful without compromising the accuracy [6]. Likewise, digital impressions for the fabrication of implant-supported fixed dental prostheses have demonstrated that both the type of prosthetic span and the method of collection impact the accuracy of the impression[7].

The high degree of variability in intraoral conditions further challenges accuracy of impressions. Any of the above factors, as well as soft-tissue movement, restricted visibility, lack of access and patient-related factors could affect the performance of either the digital or the conventional methods. Two-implant-supported prostheses showed that the accuracy of impression methods may be affected by intraoral factors and controlled laboratory tests should be conducted before clinical use [8]. Additionally, a series of in vivo studies revealed that the digital implant impression accuracy differs in different clinical situations [9], further underscoring the importance of evaluating conventional techniques in certain clinical scenarios, such as angulated implants.

In cases of distal extension and edentulous cases, it is even more crucial to record the implant positions accurately since the success of the prosthesis may rely on the precision of the implant. Comparisons between conventional and digital impression techniques in distal extension cases have shown that conventional impression techniques are still highly relevant, especially in cases where the digital workflow may be impacted by the scan path and soft tissues [10]. For edentulous cases in the maxilla, comparisons of digital and conventional impression methods again suggest that accuracy depends on the specific situation and, in line with this, that impression accuracy needs to be assessed based on the number of implants, arch form and clinical accessibility [11]. While some highly advanced procedures like photogrammetry and intraoral scanning have optimized the workflow for full arc implants, traditional impression techniques continue to be the standard approach in clinical environments where factors such as cost, availability of equipment, and clinical comfort play a role in treatment options [12].

In view of this, the present study investigates whether the ability to accurately reproduce the implant position can be achieved in non-parallel implant situations with the combination of pick-up and transfer impression copings. The idea behind this is that a hybrid strategy for coping could help minimize practical concerns (guide pin interference) and still provide acceptable 3-D accuracy. The study is relevant to a clinically important issue about the impression procedure with straight and angulated implants and converging angulated implants, and compares the coping options for different implant models. The major objectives of this study are:

1.To evaluate the three-dimensional accuracy of implant impressions made using combined pick-up and transfer impression copings in non-parallel implant situations.
2.To compare the accuracy of combined coping techniques with impressions made using similar pick-up impression copings.
3.To assess inter-abutment distance deviation in casts obtained from one straight and one 15° angulated implant model.
4.To assess inter-abutment distance deviation in casts obtained from two converging 15° angulated implant models.
5.To determine whether mixed pick-up and transfer coping use can serve as a clinically acceptable alternative in non-parallel implant impression procedures.

2. METHODOLOGY

2.1 Study Design

The three-dimensional accuracy of the various combinations of pick-up and transfer implant copings was assessed via an in vitro experimental study design in non-parallel implant situations. Two simulated clinical conditions were created by using a stainless-steel master model. The first model was one straight, and one angulated implant analog, whereas the second model was two converging angulated implant analogs. This study compared mixed coping combinations with the use of similar pick-up copings. The accuracy was evaluated by comparing experimental casts with the reference ones on basis of measurements obtained by using a coordinate measuring machine.

2.2 Materials and Equipment

The study involved the following impression copings: pick-up impression copings, transfer impression copings, and standard straight abutment supplied by ADIN Dental Implant Systems Ltd., Israel. There were also other materials such as modelling wax, autopolymerizing acrylic resin, alginate, polyether impression material, and polyether tray adhesive and type IV die stone. The armamentarium included two stainless steel master models, silicone mixing cups, digital Vernier caliper, custom acrylic trays and tungsten carbide burs. The main equipment consisted of a 3M ESPE pentamix automixing machine, micro motor, CNC milling machine, and coordinate measuring machine for a 3D assessment.

2.3 Fabrication of Master Models

Two master models were created with a CNC milling machine, each of which was composed of stainless steel. All models were 60 mm long, 27 mm wide and 30 mm high with a base height of 10 mm. The portion of the implant that held the implant was 46 x 20 x 15 mm. For each model, three holes of diameters 3 mm, 4 mm and 4 mm were respectively milled at the distance 10 mm. Master Model 1: One implant lab analog was installed in a straight position and one at 15°. Master Model 2 has both implant lab analogs in at 15° angulation towards each other.
Master Model 1 was fabricated to simulate one straight implant lab analogue and one 15° angulated implant lab analogue, along with a reference rod for coordinate-based measurement, as shown in Figure 1.

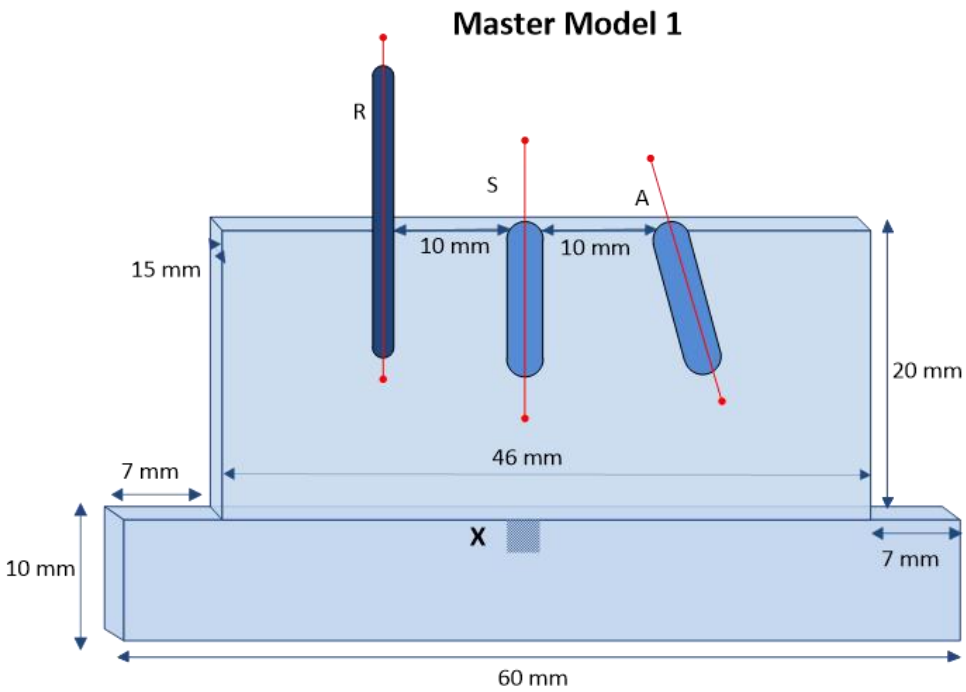

Figure 1. Master Model 1 showing one straight implant lab analogue and one 15° angulated implant lab analogue.

Master Model 2 was fabricated to represent two converging 15° angulated implant lab analogues, as shown in Figure 2

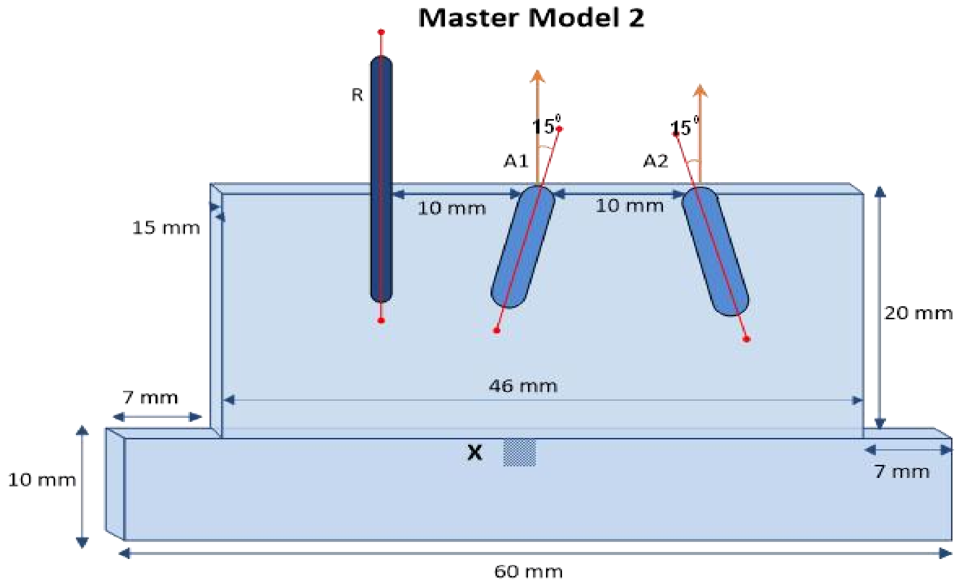

Figure 2. Master Model 2 showing two 15° angulated implant lab analogues converging toward each other.

2.4 Grouping of Samples

The samples were divided into six groups based on the master model and coping combination. Master Model 1: Group 1A pick-up coping on straight analog, transfer coping on angulated analog; Group 1B transfer coping on straight analog, pick-up coping on angulated analog; Group 1C pick-up copings on both analogs. In Master Model 2, Group 2A had pick-up coping on A1 and transfer coping on A2; Group 2B had transfer coping on A1 and pick-up coping on A2; and Group 2C had pick-up copings on both angulated analogs. There were 8 impressions in every group.

2.5 Custom Tray Fabrication

The specific pick-up and transfer impression copings for each group were fastened to the implant lab analogs with a hex driver. A 3 mm wax spacer was modified in the impression copings and master model and was used to ensure even thickness of the impression material. The custom trays were then made with autopolymerizing acrylic resin. Holes were cut in the tray for the pick-up impression coping. The trays that were formed were then pushed into the reorientation grooves found on the master base, which provided uniform seating in impression making.

2.6 Impression Making Procedure

Polyether tray adhesive was applied to each custom tray and allowed to dry for 15 minutes before impression making. Polyether impression material was mixed using the 3M ESPE Pentamix automixing unit to ensure a uniform mix. A small amount of material was loaded into an elastomer syringe and injected around the impression copings, while the remaining material was loaded into the tray. The tray was seated on the master model, and complete seating was confirmed through the reorientation grooves. After setting, the pick-up coping guide pin was loosened before impression removal.

2.7 Cast Preparation

Impression removal was followed by the placement of implant analogs of different copings. In the case of pick-up impression copings, the implant analogs were simply screwed into the copings, which had been left in the impression. In the transfer impression copings, the coping of the master model was removed from the model, placed onto the implant analog and then placed back into the impression. Type IV die stone was used to make all impressions with a water to powder ratio of 25 ml for every 100 g, as specified by the manufacturer. Thirty minutes later casts were separated and forty-eight experimental casts were obtained.

2.8 Three-Dimensional Measurement

The impression copings on the casts were replaced with standard straight abutments before measurement. Baseline measurements were first obtained from both master models using a coordinate measuring machine. A 1 mm probe contacted the vertical and horizontal surfaces to create a reference plane. The centers of the reference rod and abutments were identified, and X, Y, and Z coordinate axes were established. The same measurement procedure was repeated for all experimental casts. The deviations of experimental casts from the master model values were recorded to determine three-dimensional accuracy.

2.9 Statistical Analysis

All groups' deviations from the master models were tabulated. Mean values and standard deviations were determined and compared with the three-dimensional accuracy of the experimental casts and the measurements of the master model. All the groups were compared simultaneously by one-way analysis of variance and pairwise between the groups by Tukey's test. P-value < 0.05 was regarded as statistically significant. The SPSS software version 17 was used to conduct the Statistical analysis as described in the original thesis methodology.

3. RESULTS

3.1 Overview of Three-Dimensional Measurements

All casts of the six study groups were compared to the master model values and were assessed for their three-dimensional accuracy by their measurements. The deviations from the X, Y and Z axes and the inter-abutment distance were evaluated and the overall impression accuracy assessed by comparing inter-abutment distance. Measurable differences between individual axes were found for different coping combinations, but differences in the overall inter-abutment distance did not prove to be statistically significant for either master model. Therefore, the dimensional accuracy achieved by using pick-up and transfer copings was found to be similar to that achieved by using the same pick-up copings.

3.2 Results for Master Model 1

Master Model 1 was an analog of one straight implant and one 15° angulated implant. The inter-abutment distance analysis revealed that the best fit with the master model was in Group 1B, with a mean deviation of 43 ± 51 µm. The mean deviation for group 1C was 59 ± 21 µm and for group 1A was 77 ± 31 µm which was the highest. One-way ANOVA revealed no significant difference between the accuracy of all coping combinations (1A, 1B, and 1C) though Group 1B performed marginally better than the other two groups in terms of numbers.

Table 1. Inter-abutment distance deviation in Master Model 1

Group	Coping combination	Mean deviation	Standard deviation	Interpretation
1A	Pick-up on straight analog + transfer on angulated analog	77 µm	31 µm	Highest deviation
1B	Transfer on straight analog + pick-up on angulated analog	43 µm	51 µm	Least deviation
1C	Pick-up on both analogs	59 µm	21 µm	Intermediate deviation
ANOVA	—	—	—	P = 0.21, not significant

3.3 Results for Master Model 2

Master Model 2 consisted of two implant lab analogs at 15° angulation with each other and directed toward each other. The smallest inter-abutment distance deviation was seen in Group 2A (39 ± 22 µm). The deviation obtained for Group 2C was 44 ± 46 µm and for Group 2B it was 46 ± 65 µm. There was no significant difference between the groups despite the numerical least variation from the master model in group 2A. As a result, accuracy was equal for all three coping combinations in the two angulated implant scenario.

Table 2. Inter-abutment distance deviation in Master Model 2

Group	Coping combination	Mean deviation	Standard deviation	Interpretation
2A	Pick-up on A1 + transfer on A2	39 µm	22 µm	Least deviation
2B	Transfer on A1 + pick-up on A2	46 µm	65 µm	Highest deviation
2C	Pick-up on both angulated analogs	44 µm	46 µm	Intermediate deviation
ANOVA	—	—	—	P = 0.95, not significant

3.4 Comparative Interpretation of Inter-Abutment Accuracy

The comparative analysis of both master models showed that the combination coping groups performed similarly to the group using pick-up copings on both implant analogs. In Master Model 1, Group 1B showed the lowest deviation, suggesting that placing the pick-up coping on the angulated implant and transfer coping on the straight implant may reduce positional discrepancy. In Master Model 2, Group 2A showed the lowest deviation, suggesting a possible advantage when the pick-up coping is positioned on the angulated analog closer to the reference rod. However, these differences were numerical only and not statistically significant.

Table 3. Summary of best-performing groups based on inter-abutment deviation

Master model	Implant condition	Lowest deviation group	Mean deviation	Statistical result
Master Model 1	One straight + one 15° angulated implant	Group 1B	43 ± 51 µm	Not significant
Master Model 2	Two converging 15° angulated implants	Group 2A	39 ± 22 µm	Not significant

3.5 Axis-Wise Deviation Pattern

The axis-wise analysis revealed differences in the deviations in the X-axis, Y-axis and Z-axis for each implant angulation and coping combination. There were statistically significant differences between groups in some individual axis measurements, especially selected measurements of Master Model 1 and 2. But these individual co-ordinate differences were not found to be significant in the total inter-abutment distance. This was an indication that, although there were small dimensional changes in certain directions, the overall three-dimensional representation of the location of the implants was similar for the tested copings. Hence, there was no difference in clinically relevant accuracy between groups.

Before analysing the axis-wise deviations, baseline coordinate values were obtained from both stainless-steel master models using the coordinate measuring machine. The CMM probe contacted the vertical and horizontal surfaces of the master model to establish a reference plane. The centres of the reference rod and abutments were then identified to define the X, Y, and Z coordinate axes. These baseline values were used as reference measurements for calculating deviations in the experimental casts. The CMM-based baseline recording procedure for Master Model 1 and Master Model 2 is shown in Figures 3 and 4.

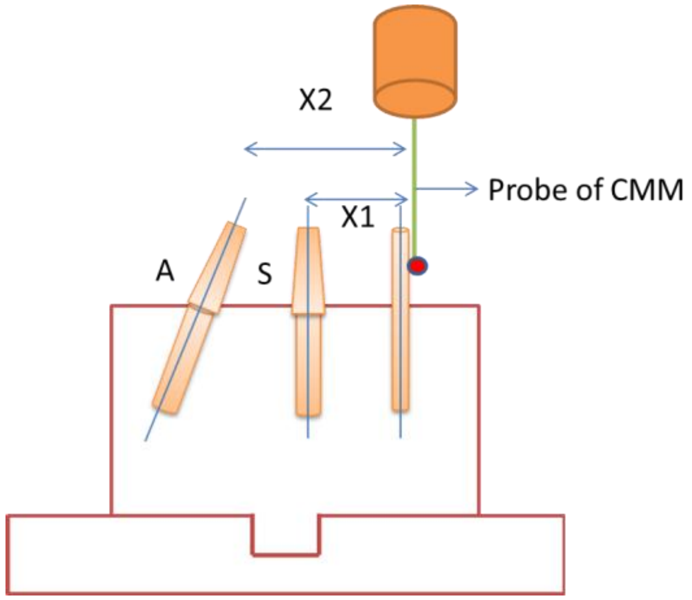

Figure 3. Obtaining baseline data for Master Model 1 using the probe of the coordinate measuring machine.

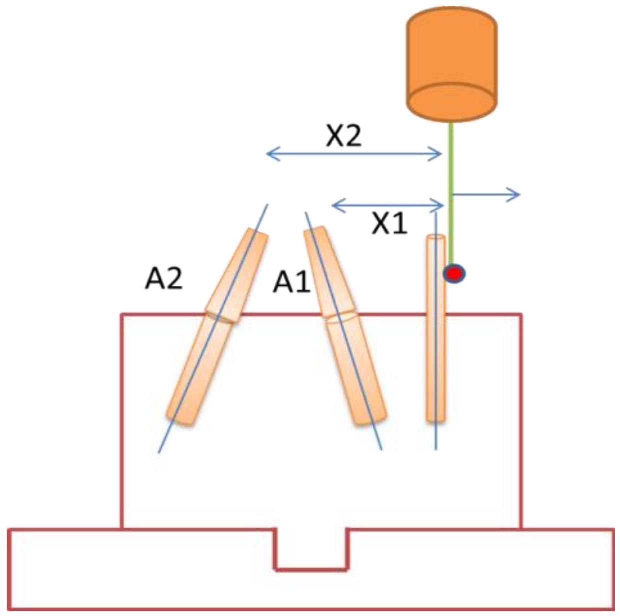

Figure 4. Obtaining baseline data for Master Model 2 using the probe of the coordinate measuring machine.

3.6 Overall Result Summary

The results suggest that the three-dimensional accuracy of implant impression using combined pick-up and transfer impression copings was not significantly different from using similar pick-up copings. The mean deviation was the lowest mean in both non-parallel implant situations in a combination coping Group 1B and Group 2A in both Master Models 1 and 2. The differences between inter-abutment distance, however, were not statistically significant. Thus, the findings support the null hypothesis that combined coping techniques do not differ significantly from similar pick-up coping techniques in terms of inter-abutment distance accuracy in non-parallel implant impressions.

4. DISCUSSION

The present study assessed the 3D accuracy of implant impressions using the various combinations of pick-up and transfer implant copings in simulated non-parallel implant situations. The results indicated that deviations between the axis could be found for each plot (X, Y and Z) but that there was no significant difference in the inter-abutment distance between the groups tested in either master model. The mean inter-abutment deviation of the implants was the lowest in the group with 15° angulation of the implant in the Master Model 1, Group 1B. Group 2A had the minimum mean deviation between abuttments in Master Model 2 which had both implant lab analogs at 15° angulation towards each other. These differences were, however, only numerical; not statistical. Thus, the findings indicate that using pick-up and transfer impression copings can be used to reproduce the positions of the implants with accuracy similar to the accuracy that was achieved by using similar impression copings in non-parallel implant positions.

The results are in agreement with recent studies that have indicated that the technique of taking the impression and the angulation of the implant can affect the dimensional accuracy, but the amount of difference may differ depending on the model design, measurement method and coping configuration. A study reported that angulations of the implant would affect the cast accuracy and direct impression procedures would be more successful in angulated implant conditions than indirect procedures [13]. Osman et al. noted that impression coping geometry and retention design have an impact on implant impressions accuracy, which is why coping selection plays an important role in non-parallel situations [14]. In multiple and angulated implant circumstances, the accuracy of the impressions was influenced by implant angulation, coping type and splinting [15]. Another study also showed that the type of transfer and the angulation of the implants can influence the accuracy of the impressions in three dimensions, especially as the implant divergence angle increases [16]. Abduo and Palamara found that the angulation of the implant affects deviations in 2-implant scenarios, contributing to the clinical significance of measuring inter-implant or inter-abutment distance [17]. Dohiem and colleagues pointed out that the exact transfer of the implant location from the X-rays to the patient's mouth is important for clinical purposes as inaccuracies can lead to prosthetic misfit and biomechanical troubles [18]. Patil et al. tested the positional accuracy of multiple-implant impressions and demonstrated that stabilization of impression copings may affect the positional accuracy of multiple implant impressions [19]. Recently, Seif and colleagues found that various transfer methods can achieve consistent accuracy in both straight and angulated implant implantations, adding to the tolerance of alternative coping techniques in specific scenarios [20].

Clinical implication of the present findings is that a combination of pick-up and transfer impression copings might be considered when using similar impression copings is technically challenging due to guide-pin interference, limited access or convergence of non-parallel implants. The fact that the combination groups did not statistically significantly increase the overall accuracy may provide a reasonable alternative in specific clinical situations. The results must therefore be taken with a grain of salt, however. The study is not intended to demonstrate the superiority of combination coping techniques, but it does suggest that these techniques might be equally accurate in controlled environments. The difference between these is significant as it will be important to balance accuracy, impression removal, accessibility and risk of coping displacement when making clinical decisions.

There are some limitations of the study. It was performed in vitro with stainless-steel master models and did not simulate intraoral factors like saliva, blood, movement of soft tissues, limited opening, patient movement, and/or clinical handling. Only 15° of implant angulation was examined and the results are limited to implants that diverge more than this. The study employed polyether impression material and type IV die stone and results are subject to change with other impression materials and/or die stones. Only an eight-impression sample size was used per group. Besides, this study had also assessed dimensional accuracy but had not directly measured on the hardness of the operator, interference of the guide pin, impression retrieval force, and clinical feasibility in the patient. Additional clinical and laboratory research with varying angulations, materials, implant systems and larger numbers should be conducted.

5. CONCLUSION

The correct positioning of the implant is still critical for the passive fit and to minimize any possible complications associated with the prosthetic. The results revealed that using impressions with combinations of pick-up/transfer copings provided three-dimensional accuracy similar to the other non-parallel implant impressions with similar pick-up copings. The lowest inter-abutment deviation for the model with the combination of one straight and one 15° angulated implant analog was obtained for the transfer-on-straight and pick-up-on-angulated implant combinations. The pick-up-and-transfer combination was also the one with the lowest numerical difference in the model of models with two converging 15° angulated analogs. These differences were not statistically significant, however, indicating impression accuracy was not impaired by using a combination of coping strategies.

The findings indicate the clinical potential of using a combination of coping strategies when a similar pick-up coping might create technical challenges, such as angulated and/or converging implants where guide pin interference may arise. However, the technique ought to be regarded as an alternative and not the better technique. Clinical factors, including the recovery of impressions, soft-tissue elasticity, patient motion and access, as well as saliva, were not assessed in this investigation. These results should be further validated in larger numbers of patients, different implant angulations, various impression materials and different implant systems.

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