Original Article

Accuracy of an inverted scanning technique used with an intraoral scanner: a pilot study

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Abstract

Introduction: *The two main difficulties in using intraoral scanners (IOS) are the accuracy of full-mouth impressions and the need for gingival retraction. However, the methods traditionally used for gingival retraction may not meet the needs of IOS. The concept of using an IOS to conduct inverted scanning of a polyvinyl siloxane (PVS) impression was proposed to overcome this limitation. However, the accuracy of this technique and concept still requires verification. Therefore, the purpose of this study was to provide such verification.*

Materials and methods: *A 3DP acrylonitrile butadiene styrene (ABS) maxillary model with tooth 21 crown preparation and 0.5mm width gingival sulcus was used as the standard model. This standard model was scanned with a tabletop scanner (TS) and an IOS to obtain TS and IOS digital standard models. Five PVS impressions of the standard model were made, and each PVS impression was scanned using the IOS three times without powdering and three times with powdering. The results of the inverted PVS impression scanning were then superimposed on the TS and IOS digital standard models.*

Results: *The accuracy levels of the inverted scanning based on the TS model with and without powdering were 35.6± 4.9μm and 42.7± 5.0μm , respectively. The accuracy levels of the inverted scanning based on the IOS model with and without powdering were 21.8± 4.1μm and 31.7± 8.5μm, respectively. The inverted scanning technique presented the best accuracy (22.1± 3.0μm) when intraoral scanning was used without powdering in the marginal area.*

Conclusion: *The inverted scanning technique's accuracy is clinically acceptable, and it provides the most accurate results when intraoral scanning is used without powdering in the marginal area.*

Key words: Intraoral scanner, accuracy, digital impression,margin, inverted scanning

Introduction

Nowadays, the intraoral scanner (IOS) is becoming more and more important in dental clinical work. Using an IOS to make impressions is more comfortable for the patient and more efficient than using the methods traditionally used to make impressions[1,2]. This approach also facilitates communication between dentists, technicians, and patients[2, 3].

The two main difficulties in using an IOS are the accuracy[3,4,5,6,7] of full-mouth impressions and the need for gingival retraction[8,9]. Supragingival margins are not always applicable for natural teeth prostheses, so gingival retraction is necessary to ensure equal gingival and subgingival margins. In other words, in the treatment of natural teeth, if there is a need for subgingival margins, clinicians will inevitably face the problem of gingival retraction.

Traditionally, many methods have been used for gingival retraction, such as the placement of gingival retraction cords, using retraction pastes, and using lasers[10,11,12,13]. However, these traditional gingival retraction methods may not meet the needs of IOS. Moreover, in order to properly expose the margins, the problem of bleeding must be solved, as bleeding will affect the quality of any optical impressions.

Mandelli et al[9]. proposed a mixed analog-digital technique for capturing subgingival margins. Mangano et al[14]. applied a similar concept in 30 patients and achieved good outcomes. However, the accuracy of this technique and the relationship between the prepared abutment, the impression scan, and the stone cast poured from the impression need to be verified in order to achieve reliable clinical outcomes. Also, an even more simplified technique is needed to minimize possible errors stemming from the digital stacking procedure.

On the other hand, a tabletop scanner (TS) can be used to scan traditional impressions in order to avoid human errors, and it has already been proven that the results provided by such scanners are accurate[15,16]. However, without cutting dies, a TS is limited by the fact that it cannot always access all the undercuts, such that such a scanner may not be as practical as an IOS.

This study sought to determine the accuracy of an inverted impression scanning technique, especially with regard to gingival margins. Furthermore, powdering is a technique that can be used to facilitate digital optical scanning, and evaluation of the effects of powdering on the inverted impression scanning technique is also needed. Therefore, this study also sought to determine those effects.

Material and methods

Fabrication of the standard model:

A 3DP acrylonitrile butadiene styrene (ABS) maxillary model (Stratasys J750 3D printer, Digital ABS plus) with tooth 21 full crown preparation was used as the standard model. The 21 prepared abutment margin design had a 1.0mm chamfer, supragingival margin of 1.3mm, and an abutment height of 7mm. The gingival sulcus was 0.5mm in width and 1mm in depth (Fig. 1, Fig. 2).

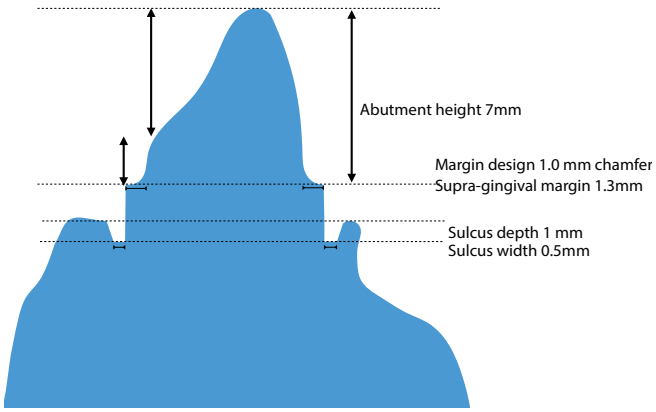

Figure 1. The standard model, 21 prepared abutment margin design is 1.0mm chamfer, supragingival 1.3mm, and the abutment height is 7mm. The gingival sulcus is 0.5mm in width and 1mm in depth.

Acquiring the digital standard model with a tabletop dental scanner (TS model):

The 3DP ABS maxillary model was scanned with a tabletop dental scanner (DOF Freedom UHD) to acquire the digital standard TS model in STL file format (Fig. 2).

Acquiring the digital standard model with an intraoral scanner (IOS model):

The 3DP ABS maxillary model was scanned with an IOS (3Shape Trios 3 wireless) to acquire the digital standard IOS model in STL file format (Fig. 2).

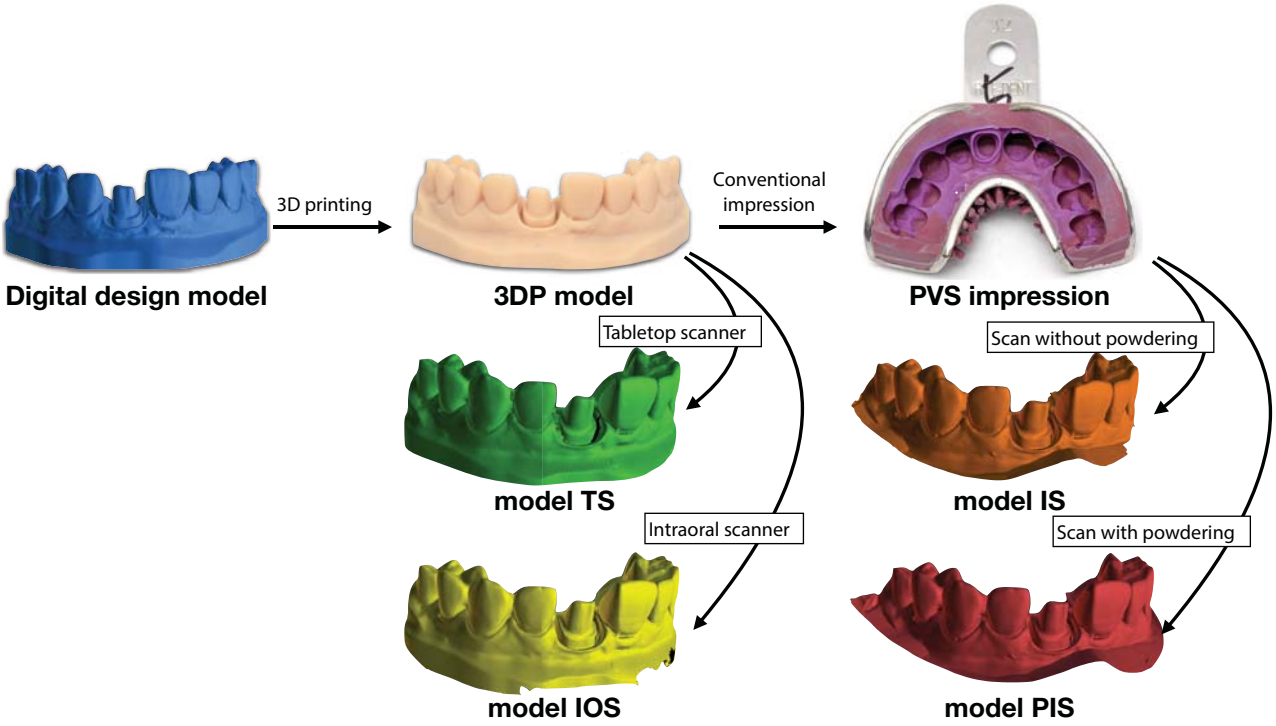

Figure 2. The figure shows the workflow to generate all the study models. 3DP model was fabricated according to the digital design model. Digital impressions were made on this 3DP model to generate model TS and model IOS as standard models.
Conventional PVS impressions were made on the same 3DP model, and the PVS impression was scanned to create model IS and model PIS. Digital superimposition and comparison were made between models, TS-IS, TS-PIS, IOS-IS, IOS-PIS.

Conventional PVS impression:

Five conventional impressions of the standard model were made with polyvinyl siloxane (PVS; Panasil contact plus X-light and 3M Inprint II heavy body) with a stainless steel perforated lower impression tray and a one-step two phases impression technique (Fig. 2).

Inverted scanning of the PVS impressions:

Using an IOS (3Shape Trios 3 wireless) to scan, the AI scan was turned off, and the scanning was performed in normal mode. In order to enable the IOS to scan the PVS model as clearly as possible, a No.15 blade was used to remove any PVS material that may have interfered with the scanning of key areas. The key areas included the teeth, abutment, and gums extending about 3mm around the teeth. The results of each scan were exported as STL files, and all the scans were performed by the same experienced operator. The operator held the handle of the impression tray in his left hand and the IOS in his right hand to perform the scanning. Each PVS impression was scanned 3 times without powdering, and 3 times with powdering. The inverted digital models were then inverted again (software: Autodesk Meshmixer 3.5) to generate the PIS (with powdering) model and IS (without powdering) model (Fig. 2).

3-dimensional digital model superimposition and comparison:

A 3d inspection and metrology software (Geomagic control X) program was used to proceed with digital model superimposition. In each digital model, the targeted abutment tooth was selected, and the 4 neighboring teeth surfaces were selected for superimposition with the "best fit" mode. After conducting the superimposition, the same selected area (abutment and marginal area of the abutment) was used to crop all the models to be compared. Then a 3D comparison was performed in the software and the root-mean-square deviation (RMS) was used to represent the deviation between the two digital models (Fig. 3).

Comparison of areas of interest:

The digital model was divided into 2 parts, the margin portion and the abutment portion (Fig. 3). The margin portion (M) was the portion extending from 1mm below the margin to 2mm above the margin. The abutment portion (A) was the portion extending from 2mm above the margin to the top of the abutment. The all portion (All) was the

combination of both the margin and abutment portions.

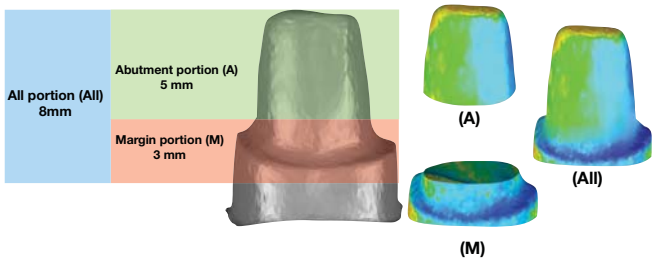

Figure 3. After the superimposition of STL files, the digital die was compared in three portions. Margin portion (M), from 1mm below the margin to 2mm above the margin. Abutment portion (A), from 2mm above the margin to the top of the abutment. All portion (All), combining both the margin and abutment portions.

Statistics:

A one-way ANOVA with the non-parametric Wilcoxon method was used to test the following:

1. The accuracy of the inverted scanning performed with the tabletop dental scanner with and without powdering.
2. The accuracy of the inverted scanning performed with the regular IOS with and without powdering.
3. The impact of the powdering procedure on that accuracy.
4. The accuracy of the margin portion in comparison with the abutment portion.

Results

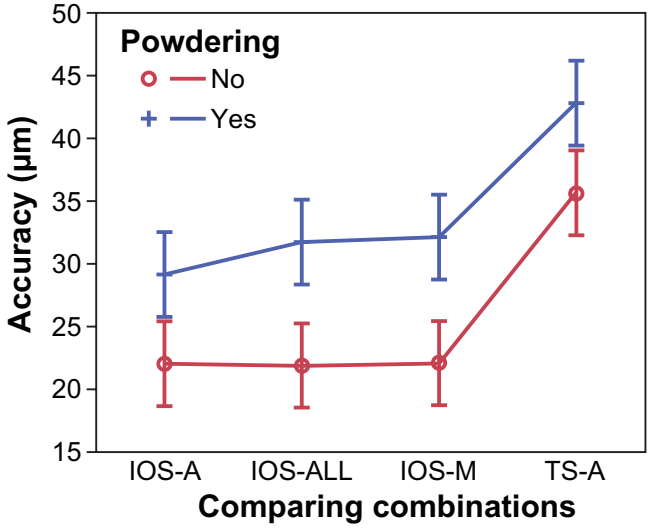

Figure 4. This figure shows that powdering procedure causes larger deviations, and TS-A group has larger deviation then IOS groups.

Table 1. The table shows the measuring outcome of all groups

Accuracy (µm)	IOS-All (all portion)	IOS-A (abutment portion)	IOS-M (margin portion)	TS-A (abutment portion)
No powder (IS)	21.8± 4.1	22.0± 6.2	22.1± 3.0	35.6± 4.9
Powder (PIS)	31.7± 8.5	29.1± 6.8	32.1± 10.9	42.7± 5.0

IOS-All: Model IOS as standard, test all portion of the die.
IOS-A: Model IOS as standard, test abutment portion of the die.
IOS-M: Model IOS as standard, test margin portion of the die.
TS-A: Model TS as standard, test abutment portion of the die.
IS: The inverted scanning performed without powdering.
PIS: The inverted scanning performed with powdering.

1. The accuracy of the inverted scanning using the TS-A model with no powdering (42.7± 5.0µm) was better than that with powdering (35.6± 4.9µm), p=0.016.
2. The accuracy of the inverted scanning using the IOS-All model with no powdering (21.8± 4.1µm) was better than that using powdering (31.7± 8.5µm), p=0.0005.
3. All the groups without powdering showed better accuracy than the groups with powdering, including for the IOS-All (p=0.0005), IOS-A (p=0.0037), IOS-M (p>0.0013), and TS-A (p=0.0016) models.
4. There was no statistically significant difference between the margin and abutment portions. However, the results showed a slightly larger deviation with powdering for the margin portion (32.1± 10.9µm) than for the abutment portion (29.1± 6.8µm).
5. It was interesting to note that the IOS-A model showed better accuracy than the TS-A model in both the powdering (p<0.0001) and no powdering groups (p<0.0001).
6. The inverted scanning technique presented the best accuracy (22.1± 3.0µm) when used with an IOS and without powdering in the marginal area.

Discussion

What had we learned from previous studies?

Güth et al., in 2016, scanned a traditional impression with multiple different ISO systems. They concluded that the accuracy of a single

quadrant was clinically acceptable[17]. However, the study sample consisted of a titanium bridge die without the gingival portion, so more investigation was needed to evaluate how the gingiva would affect the outcome. Mandelli, in 2017, was the first researcher to present evidence that inverted impression scanning was able to capture deeper margins than regular intraoral scanning in his clinical cases, thus revealing the advantages and potential of this method[9]. Mangano et al., in 2020, presented successful outcomes of 30 single zirconia crown cases treated with a similar technique[14]. The current study might be the first, however, to verify the accuracy of inverted impression scanning and thus prove that its use is clinically feasible.

Limitations of the present study

Although this study's setting included a supragingival margin in the standard cast to test whether a tabletop dental scanner could capture the margin, unfortunately, the results indicate that the tabletop dental scanner still could not recognize the complete margin (Fig. 5). We therefore decided to discard the margin data for comparison and only considered the abutment portion in this group. The IOS model groups showed better accuracy than the TS model groups, although the accuracy levels for both types of groups were still clinically acceptable. This outcome did not match the author's original expectation. One possible reason why the TS was not as accurate might have been related to the scanning resolutions for different machine settings and their effects on the digital superimposition procedure. On the other hand, the IOS group was scanned under the same settings, and the information matching was straightforward. More experiments and research are thus still needed to clarify this issue.

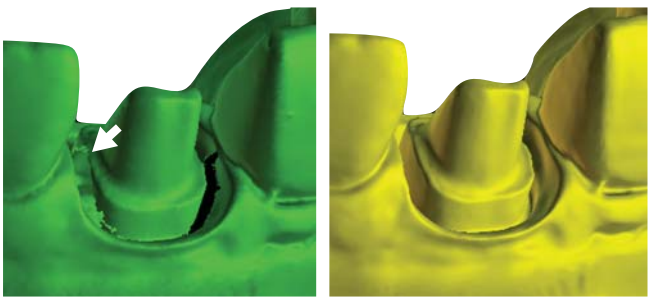

Figure 5. The margin information of model TS is incomplete (arrow) due to limited access for the tabletop scanner. We decided to avoid using the margin portion of model TS for digital comparison.

A possibility to improve both analog and digital workflows

Although accurate stone casts are still the clinical standard, using such casts might not be the best way to obtain information from a conventional impression. The process of pouring casts might cause errors such as, for example, a bubble in the marginal area or fractures in slim abutments. Also, repeated pouring causes dimensional changes[18] and damage to a conventional impression. With the investigated inverted impression technique, we could avoid such errors from pouring casts.

On the other hand, it is known that the model-less digital workflow is more efficient than the conventional workflow[19]. However, intraoral optical scanners have not yet overcome the limitations posed by subgingival margins or bleeding. Therefore, finding a solution that combines their use with conventional impressions is a wise strategy, and the investigated inverted scanning technique perfectly fits this need.

Practical suggestions and future exploration:

The group without powdering showed better accuracy than the group with powdering, which indicated that one should perform this technique without powdering in order to obtain better results. Relatedly, the powder used in powdering might accumulate on the margin area and affect the outcome. At the same time, the experiences in the present study showed that the scanning procedure is more comfortable and faster when performed with powdering. Therefore, when using this technique, the operator needs to fully understand these issues in order to decide whether or not to use powdering.

The accuracy of an impression includes the details and the shape of the die and the die's position. An accurate die means proper fit of the restoration. At the same time, the die's position affects occlusion and contact quality, which are also essential concerns. An improper digital superimposition might result in a precisely fitting crown but a massive mistake in occlusion and contact, and clinicians who would like to apply this method should be aware of this possibility. Professional superimposition software is essential, and the operator should evaluate superimposition quality; this is the weak link of dental CAD/CAM software at present. Further studies are needed of this and related topics, such as the margin location, the scanner's scanning depth, and the

reflective properties of the impression materials used.

Conclusion

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

1. The accuracy of the inverted scanning technique is clinically acceptable.
2. To achieve the best outcome when using this technique, one should use the technique in combination with a regular IOS and perform the scanning without powdering.

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