



Trueness and precision of scanning abutment impressions and stone models according to dental CAD/CAM evaluation standards

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PURPOSE. The purpose of the present study was to compare scanning trueness and precision between an abutment impression and a stone model according to dental computer-aided design/computer-aided manufacturing (CAD/CAM) evaluation standards. **MATERIALS AND METHODS.** To evaluate trueness, the abutment impression and stone model were scanned to obtain the first 3-dimensional (3-D) stereolithography (STL) file. Next, the abutment impression or stone model was removed from the scanner and re-fixed on the table; scanning was then repeated so that 11 files were obtained for each scan type. To evaluate precision, the abutment impression or stone model was scanned to obtain the first 3-D STL file. Without moving it, scanning was performed 10 more times, so that 11 files were obtained for each scan type. By superimposing the first scanned STL file onto the other STL files one by one, 10 color-difference maps and reports were obtained; i.e., 10 experimental scans per type. The independent t-test was used to compare root mean square (RMS) data between the groups ($\alpha=.05$). **RESULTS.** The RMS \pm SD values of scanning trueness of the abutment impression and stone model were 22.4 \pm 4.4 and 17.4 \pm 3.5 μ m, respectively ($P<.012$). The RMS \pm SD values of scanning precision of the abutment impression and stone model were 16.4 \pm 2.9 and 14.6 \pm 1.6 μ m, respectively ($P=.108$). **CONCLUSION.** There was a significant difference in scanning trueness between the abutment impression and stone model, as evaluated according to dental CAD/CAM standards. However, all scans showed high trueness and precision. [*J Adv Prosthodont 2018;10:335-9*]

KEYWORDS: Trueness; Precision; Scanning; Dental computer-aided design/computer-aided manufacturing (CAD/CAM); Evaluation standard

INTRODUCTION

With the advent of digital dentistry, it has become important to accurately evaluate dental computer-aided design/

computer-aided manufacturing (CAD/CAM) devices.^{1,2} In this regard, it is vital that clinicians verify the accuracy of their scanners when using abutment stone models, and several investigations have focused on this topic.³⁻⁵ However, in patients with different tooth surface conditions, shapes, sizes, etc., it is almost impossible to find the same abutment. For this reason, it is difficult to evaluate scanning accuracy in such patients.⁶⁻¹¹

Thus, researchers must evaluate scanning accuracy in cases that use the abutment stone model, which is standardized in dental prosthesis manufacturing. According to ISO 12836, a 3-unit bridge model has been used to evaluate the accuracy of dental CAD/CAM devices.¹² However, few investigations have evaluated scanning accuracy using the abutment stone model, which is the most important prosthesis standard used for dental CAD/CAM systems.¹³

Conversely, many studies have evaluated the accuracy of abutment impression scanning, which has been used in

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recent digital dental prosthesis manufacturing.¹⁴ After the CAD file has been transmitted by the CAM milling machine to a 3D printer for manufacture of the dental prosthesis, the data obtained through direct impression scanning are saved in the CAD file.¹⁵⁻¹⁷ However, to evaluate the accuracy of scanning of the abutment impression and stone model, it is necessary to verify both trueness and precision. Specifically, to evaluate trueness, one specimen should be scanned by a single scanner; after the initial scanning, the specimen is removed completely from the scanner table, re-fixed to the table again, and rescanned. The scan data obtained by repeating this process several times can be superimposed and verified. To assess precision, one specimen is scanned several times by a single scanner without being removed. The scan data obtained by repeating the process can be superimposed and verified, as with the above trueness verification method.^{18,19}

In general dentistry, the trueness and precision of abutment stone model scanning are higher than those of impression scanning.^{4,20-23} However, few investigations have evaluated scanning trueness and precision using dental CAD/CAM evaluation standards. This is an important concern in current digital CAD/CAM dentistry.

Therefore, the purpose of the present study was to compare trueness and precision between impression scanning and abutment stone model scanning according to dental CAD/CAM evaluation standards.

MATERIALS AND METHODS

To prepare the abutment impression and stone model according to the dental CAD/CAM evaluation standards, the specimens were produced as shown in Fig. 1. Briefly, the abutment (Geomagic Design X 2016, 3D Systems, Cary, NC, USA) was designed with an upper-end diameter of 5.2 mm. The lower part had a diameter of 8 mm, a crown length of 10 mm, and a crown inclination of 8°. The milling process used the designed CAD data, and a titanium abutment model was produced. Using an extra light body

(Aquasil Ultra, Dentsply, York, PA, USA), which has the best fluidity and refinement among silicone rubber impression materials, a duplicate impression of the titanium abutment model could be obtained.

The abutment stone model was then created using the duplicated impression. The model was made using gypsum (Snow Rock 3D Scan Stone, DK Mungyo, Gimhae, Korea), which is an optimal material for scanning.

To evaluate the trueness and precision of abutment impression and stone model scanning, a blue LED scanner was used (Identica blue, Medit, Seoul, Korea). This is a recently developed scanner, and it reportedly has a smaller scan error and higher scanning accuracy than conventional scanners.^{6,7,24,25} Comparative evaluation of the trueness and precision of the abutment impression scanning were then compared with those of the stone model scanning according to dental CAD/CAM evaluation standards. To evaluate the trueness of abutment impression scanning, the impression was fixed on the scanner table. It was then scanned to obtain the first 3-dimensional (3-D) stereolithography (STL) file, named TI_1. Next, the impression was removed and re-fixed to the table and scanned again. This operation was repeated 10 times to obtain 10 more STL files (TI_2-11), and a total of 11 STL files were obtained (TI_1-11). To evaluate the trueness of abutment stone model scanning, the same operations were performed to obtain 11 STL files (TS_1-11).

In contrast, to evaluate the precision of abutment impression scanning, the impression was fixed to the scanner table and scanned to obtain the first 3-D STL file (PI_1). It was then scanned 10 more times without being moved, and 10 more STL files were obtained (PI_2-11), resulting in a total of 11 STL files (PI_1-11). To evaluate the precision of abutment stone model scanning, the same operations were performed to obtain files (PS_1-11).

In all STL files, unnecessary and inaccurate parts were deleted.²⁶⁻²⁹ To verify the trueness and precision of the 3-D STL files, the following method was employed. First, the trueness of the abutment impression scanning was evaluat-

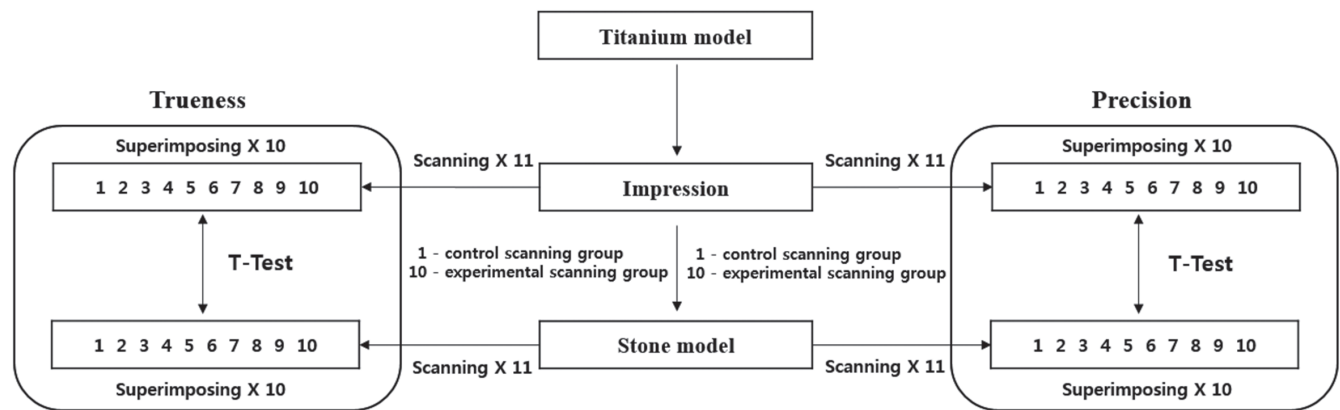


Fig. 1. Experimental schematic diagram of this study.

ed using 3-D superimposing software (Geomagic Verify 2015, 3D Systems, Cary, NC, USA). By superimposing the first scanned STL file (TI_1; control scan) onto the other STL files (TI_2-11; experimental scans) one by one, 10 color-difference maps and reports were obtained. To evaluate the trueness of the abutment stone model scanning, the same operations were performed to obtain 10 color-difference maps and reports.

Similarly, to evaluate the precision of the abutment impression scanning, the first scanned STL file (SI_1; control scan) was superimposed onto the other STL files (SI_2-11; experimental scans) one by one to obtain 10 color-difference maps and reports. To evaluate the precision of the abutment stone model scanning, the same operations were performed to obtain 10 color-difference maps and reports.

In this way, in the report obtained using 3-D superimposing software, 10 quantitative root mean square (RMS) values were obtained for each abutment impression and stone model using the equation below:

$$RMS = \sqrt{\frac{\sum_{m=1}^n (x_{1,m} - x_{2,m})^2}{n}}$$

That is, when two scans were superimposed, the square of the phase difference between a number of points in 3-D space was calculated (x-, y-, and z-axis). The sum of these squares was divided by the number of points, and RMS was calculated as the square root of this value. This may be a more reliable and accurate value than a general arithmetic mean because the difference between each data point is represented by both a positive value (red in the color-difference map; Fig. 2) and a negative value (blue in the color-differ-

ence-map; Fig. 2). The reliability of arithmetic means is limited in cases of simple sums.^{1,30}

With regards to statistical analysis, an independent t-test was used to verify the significance of the differences between the groups. IBM SPSS version 22.0 for Windows (IBM SPSS Inc., Chicago, IL, USA) was used. The level of significance of α error was 0.05.

RESULTS

Table 1 shows the RMS (\pm SD) values of the trueness and precision comparisons between the abutment impression and stone model, which were carried out according to dental CAD/CAM evaluation standards. There was a significant difference in terms of trueness between the abutment impression and stone model scanning ($P < .012$), but not in terms of precision ($P = .108$).

Fig. 2 shows the color-difference map comparing trueness and precision between the abutment impression and stone model according to dental CAD/CAM evaluation standards.

The color-difference map of trueness showed many positive (red) errors and negative (blue) errors throughout both the abutment impression (Fig. 2A) and the axis part of the stone model (Fig. 2B).

The color-difference map of precision showed some positive (red) errors and negative (blue) errors in the axis parts of both the abutment impression (Fig. 2C) and stone model (Fig. 2D).

DISCUSSION

In the present study, we began with the null hypothesis that trueness and precision do not differ between the abutment impression and stone model, as measured using dental CAD/CAM evaluation standards.

There was a significant difference in trueness between the abutment impression and stone model ($P < .012$) perhaps due to a high probability of error at the time of scanning, as some shadows were generated when the impression was scanned. Despite this significant difference, few errors occurred, and each was only of about 5 μ m in size.

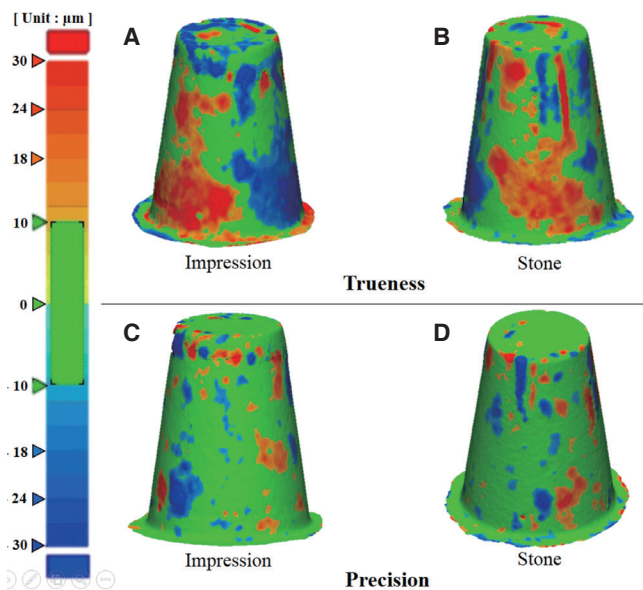


Fig. 2. Qualitative comparison data, represented using a 3-dimensional color map of both trueness and precision (impression vs. stone model).

Table 1. Quantitative comparison of trueness and precision of scanning impression and stone model (10 images per scan type)

	Impression	Stone	P value
Trueness (RMS \pm SD)	22.4 \pm 4.4	17.4 \pm 3.5	< .012
Precision (RMS \pm SD)	16.4 \pm 2.9	14.6 \pm 1.6	.108

Unit: μ m, RMS: root mean square, SD: standard deviation

On the other hand, there was no significant difference in scanning precision between the abutment impression and stone model ($P = .108$). In general, it has been taken for granted in dental CAD/CAM that the abutment stone model is superior to the abutment impression in terms of scanning accuracy.^{2,18} However, we found no significant difference, and only a few errors occurred, each of which was only about 2 μm in size.

The color-difference map of trueness showed many positive (red) errors and negative (blue) errors in the axis parts of both the abutment impression and stone model (Fig. 2A, Fig. 2B). This is because the area into which the LEDs are projected at the time of scanning expands in the direction of the major axis, resulting in a high probability of scan error.^{7,31}

The color-difference map of precision showed some positive (red) errors and negative (blue) errors in the axis parts of both the abutment impression and stone model (Fig. 2C, Fig. 2D). This is because the blue light scanner used in this study uses short-wavelength light, so it is hardly affected by the factors that cause scanning errors, such as the shape, color, and size of the scanning object.^{7,22,24}

To obtain more reliable results, we made some additional effort in experimental design in the present study. First, the stone model was produced using 3-D scan stone, which is an optimal material for dental scanners, as was shown recently. In addition, we evaluated the trueness and precision of abutment impression and stone model scanning using 3-D superimposition software, which has been used not only in dentistry, but also in engineering, medicine, pharmacy, and other fields. In fact, the software is recognized worldwide for its reliability.³²⁻³⁵

Nonetheless, there were some limitations to this research. First, we failed to adequately explain errors due to reflection, refraction, and scattering of light while using the blue light scanner, which is only one type of optical scanner.^{25,31,36} Next, trueness and precision were evaluated using the 3-D superimposing method rather than the conventional 2-D measurement method. However, we could not explain the best fit alignment process used to minimize and verify the errors between the data^{24,37} because it is difficult to judge abutment impression and stone model scanning, or the best fit alignment process, in terms of errors in qualitative and quantitative data obtained using 3-D superimposition software.^{22,38-39}

Therefore, future research must seek to reduce errors in trueness and precision evaluation using 3-D superimposing software, and continuing efforts must be made to improve scanning quality using abutment impressions and stone models, in accordance with dental CAD/CAM evaluation standards.

CONCLUSION

There was a significant difference in scanning trueness between the abutment impression and stone model, as evaluated according to dental CAD/CAM standards. However,

all scans showed high trueness and precision. The results of this research will be useful in digital CAD/CAM dentistry.

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