# Evaluation of the effect of abutment preparation angles on the repeatability and reproducibility using a blue light model scanner

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**PURPOSE.** The purpose of the study is to evaluate the repeatability and reproducibility of the abutment angle using a blue light scanner. **MATERIALS AND METHODS.** 0°, 6°, and 10° wax cast abutment dies were fabricated. Each of the silicone impression was produced using the replicable silicone. Each study die was constructed from the prepared replicable stone used for scans. 3-dimensional data was obtained after scanning the prepared study dies for the repeatability by using the blue light scanner. The prepared 3-dimensional data could have the best fit alignment using 3-dimensional software. For reproducibility, each abutment was used as the first reference study die, and then it was scanned five times per each. 3-dimensional software was used to perform the best fit alignment. The data obtained were analyzed using a nonparametric Kruskal-Wallis H test (α=.05), post hoc Mann-Whitney U test, and Bonferroni correction (α=.017). **RESULTS.** The repeatability of 0°, 6°, and 10° abutments was 3.9, 4.4 and 4.7 μm, respectively. Among them, the 0° abutment had the best value while the 10° abutment showed the worst value. There was a statistically significant difference (*P*<.05). The reproducibility of 0°, 6°, and 10° abutments was 6.1, 5.5, and 5.3 μm, respectively. While the 10° abutment showed the best value, the 0° abutment showed the worst value. However, there was no statistically significant difference (*P*>.05). **CONCLUSION.** In repeatability, the 0° abutment showed a positive result. In reproducibility, the 10° abutment achieved a positive result. *[J Adv Prosthodont 2020;12:210-7]*

**KEYWORDS:** Blue light scanner; Abutment; Repeatability; Reproducibility

## INTRODUCTION

Recent advances have been made with the introduction of dental CAD/CAM systems in the field of dentistry.[1-5] With these advances, intraoral scanner and extraoral scanner are getting attention.[6-11] The intraoral scanner acquires three-dimension data by directly scanning the injured tooth in the patient's mouth. However, due to the large volume of an intraoral scanner, there are limitations for women and children, who have small mouths, and because of its large vol-

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ume, it is difficult to apply to patients with temporomandibular joint (TMJ) disorders. Also, the accuracy is questioned because of complex environmental factors such as patient movement and moisture in the mouth.[9,12]

Because of these problems, an extraoral scanner is usually used.[6,7,13-16] An extraoral scanner acquires impressions through a conventional method using materials for dental impressions. Then, a work model for a scan is constructed by pouring the scan-dedicated stone into the impression body. This stone is scanned using an extra-oral scanner, and prosthesis is then fabricated using the CAD/CAM system.[17-21]

In general, an extra-oral scanner is introduced with the methods of a laser model scanner and an optical model scanner. The laser scanner irradiates the target with a line pattern laser and measures the reflected triangulation distance.[9,22] However, this method has a slow scan process and negative results in the repeated measurements.[7] In order to solve these problems, an optical scanner is being introduced. The optical scanner includes a white light model scanner and a blue light model scanner.[7] These two measurement methods achieve three-dimension by reading the

surement methods achieve three-dimension by reading the patterns of two-dimensional grid and stripe.[23] In particular, the blue light model scanner has short wavelength, which allows more precise scanning.[7] Recently, studies on the repeatability and reproducibility of the blue light model scanner have been reported to be superior to the white light scanner.[7]

There are various studies of abutment using this blue light model scanner. Among them, Jeon *et al.*[14] showed results for different abutments by directly scanning canine, premolar, and molar inflation. Especially, the worst repeatability was observed for the canine abutment at 4.5 µm, and the molar abutment showed the worst reproducibility at 11.0 µm. Furthermore, according to Jeon *et al.*,[13] when stone abutments of premolars and molars were repeatedly measured, the canine abutment showed relatively negative results. When the prosthesis of a canine and a molar was fabricated after scanning them with a blue light model scanner, the fitness of the prosthesis was evaluated. The canine was 62.04 µm while the molar had great fit with 51.64 µm according to Bae *et al.*[17] Although accuracy of canine, premolar, and molar has been evaluated, there was no accuracy evaluation with regard to prepared angle of abutment.

The objective of this work was to evaluate the repeatability and reproducibility of the abutment angle using a blue light scanner. The null hypothesis is that there is no difference in the accuracy of preparation abutment angles.

## MATERIALS AND METHODS

Study dies of 0°, 6°, and 10° abutments were constructed from dental die stones used for scans (Esthetic-base gold, Dentona AG, Dortmund, Germany) (Fig. 1). For the repeatability, 0, 6, and 10 ° study dies were placed on the scan base form (Fig. 2). The study dies were scanned five times separately using a blue light scanner (Identica, Medit, Seoul, Korea) and stored in STL files.

For reproducibility, the positions of scan base form from one to five were defined. The positioning distance was set at twenty-millimeter intervals from one to five (Fig. 3). The 0° study die was scanned at position one on the scan base form as a reference study die and stored as a stereolithography (STL) file. Then, five three-dimensional scan data were obtained by placing each of them on the position of one to five, respectively (Fig. 4). The 6° study die was placed in position one on the scan base form and set as the reference study die. Then, five three-dimensional scan data were obtained by placing each of them on the position of one to five, respectively (Fig. 5). The 10° study die was scanned on the scan base form at position one and set as the reference study die. Then, five three-dimensional scan data were acquired after placing each of them in the position of one to five, respectively (Fig. 6). All the unnecessary structure of the three-dimensional data, which is below the margin of about one millimeter, was removed from both
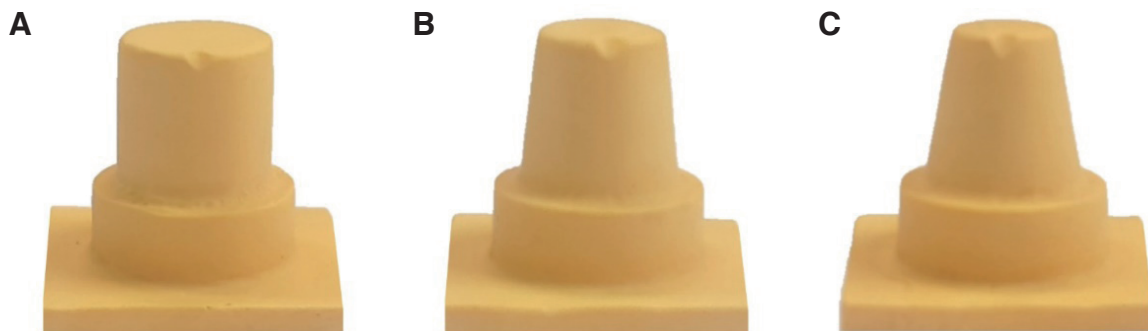


**Fig. 1.** Study dies made of scannable stone. (A) 0° study die, (B) 6° study die, (C) 10° study die.
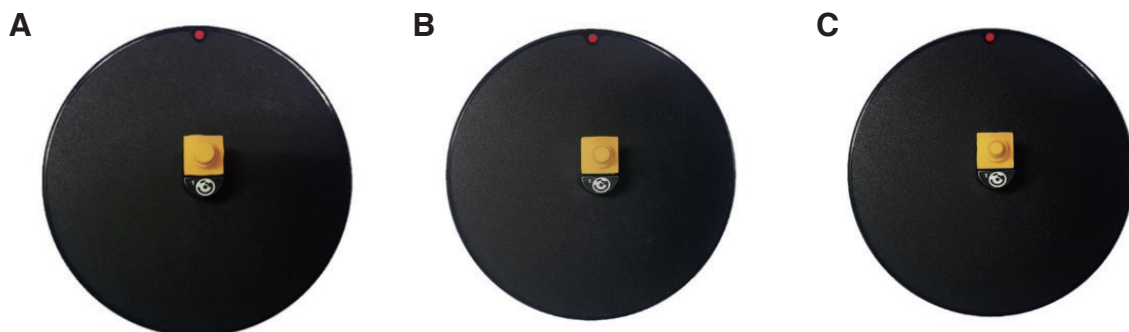


**Fig. 2.** Centered scan base form for repeatability. (A) 0° study die, (B) 6° study die, (C) 10° study die.
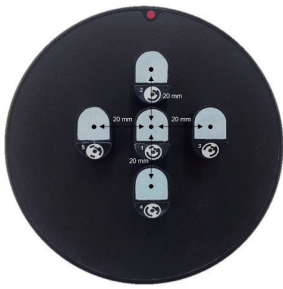
**Fig. 3.** Scan base form 1-5 position setting.

the prepared reference data and the scanned data before superimposition processing. The analysis was performed using three-dimensional software (Verify, Geomagic GmbH, Stuttgart, Germany) for repeatability and reproducibility.

For repeatability, five sets of three-dimensional scan data of 0° study dies were paired and performed the best fit alignment ten times. The 6° and 10° abutments went through the best fit alignment in the same manner. For the reproducibility, the best-fit alignment was performed five times for three-dimensional reference data and five sets of three-dimensional scan data of the 0° study die. The best fit alignment was performed in the same manner at 6° and 10°. These three-dimensional data were calculated and analyzed through root mean square (RMS), and positive error (yellow to red), green area (no error), and negative error (blue to dark blue) were evaluated through color difference map.

Although the normality test was performed, they did not satisfy the normality. Therefore, these measurement data were assessed by non-parametric Kruskal-Wallis H test and Mann-Whitney U test ($\alpha = .05$). The Mann-Whitney U test and Bonferroni correction were used for post-testing ($P < .05/3 = 0.017$).
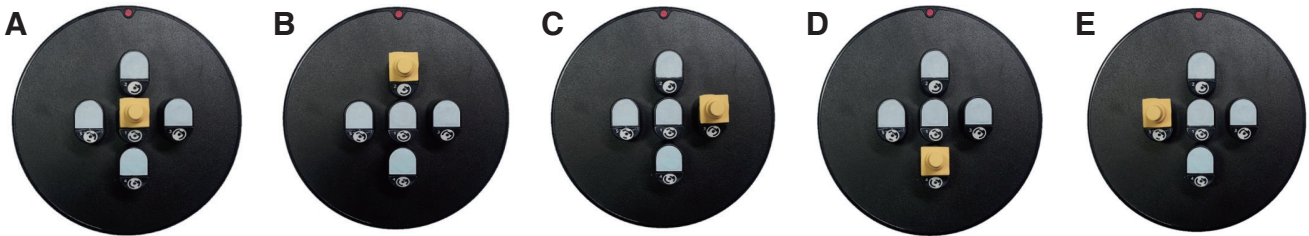


**Fig. 4.** 0° study die scan for reproducibility. (A) scan base form 1 location, (B) scan base form 2 location, (C) scan base form 3 location, (D) scan base form 4 location, (E) scan base form 5 location.
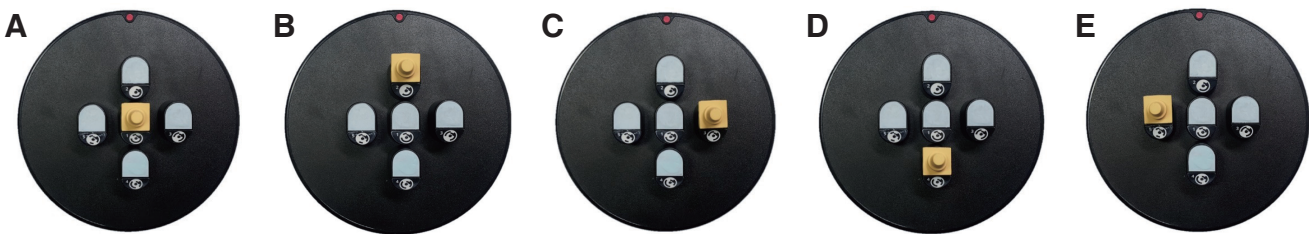


**Fig. 5.** 6° study die scan for reproducibility. (A) scan base form 1 location, (B) scan base form 2 location, (C) scan base form 3 location, (D) scan base form 4 location, (E) scan base form 5 location.
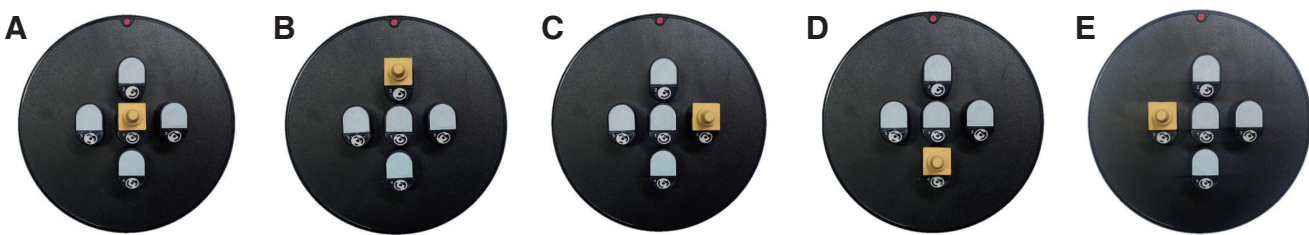


**Fig. 6.** 10° study die scan for reproducibility. (A) scan base form 1 location, (B) scan base form 2 location, (C) scan base form 3 location, (D) scan base form 4 location, (E) scan base form 5 location.

## RESULTS

In Table 1, the repeatability values of RMS, SD, plus average, and minus average of 0°, 6°, and 10° abutments are indicated. For RMS, SD, plus average and minus average, the best repeatability is the 0° study die when the worst group is the 10° study die. The RMS, SD, and plus average of the three groups have statistically significant differences ($P < .05$), but the minus average shows no statistically significant difference ($P > .05$).

In Table 2, the reproducibility values of RMS, SD, plus average and minus average at 0°, 6°, and 10° are displayed. For RMS, SD, plus average and minus average, the best value belongs to the 10° group, and the worst value is in the 0° group. However, there is no statistically significant difference among the RMS, SD, plus average, and minus average of the 0°, 6°, and 10° abutments ($P > .05$)

Table 3 presents the RMS, SD, plus average, and minus average values of the reproducibility of 0°, 6°, 10° abutments that were placed on the scan base form from one to five. The abutment at position one has the smallest error, and the abutment at position three has the largest error. In addition, abutments at positions two and four were superior to abutments at positions three and five on the basis of the abutment at position one.

In figures 7, the abutment color-difference maps with superimposition processing of repeatability of 0°, 6°, and 10° abutments are represented. There is almost no positive or negative part until the 0° abutment (Fig. 7 A-E). In addition, green (no error) areas are mostly observed. The positive and negative areas of 6° abutment were observed to increase from the 0° abutment in the axial wall area (buccal, distal, lingual, and mesial area) (Fig. 7 F-J). In the 10° abutment, similar mass production with the 6° abutment is observed in the axial wall (Fig. 7 K-O). There are no errors in the occlusal areas of all three abutments (Fig. 7 E, J, and O).

In figure 8, the abutment color-difference map with superimposition processing of reproducibility of 0°, 6°, and 10° abutments are shown. The positive or negative part of the 0° abutment has more errors than the other groups in the axial wall area (Fig. 8 A-D). The positive or negative part of the 6° abutment (Fig. 8 F-J) and 10° abutment (Fig. 8 K-O) has the similar appearance. However, the positive or negative result was greater than those of other abutments of 10° abutment (Fig. 8 O).

In figure 9, there is a color difference map with superimposition processing of reproducibility for each position of scan base form from one to five. The position one on the scan base form of the 0°, 6°, and 10° abutments have the noticeable green color compared with other positions. The positions three and five have the most errored areas (Fig. 9 C, H, M, E, J, and O).

**Table 1.** Repeatability of RMS, standard deviation, plus average, minus average of 0 °, 6 °, 10 ° abutment with blue light model scanner (unit: µm)

| Variable | 0° | | 6° | | 10° | | ᶜP |
| --- | --- | --- | --- | --- | --- | --- | --- |
| | Mean | SD | Mean | SD | Mean | SD | |
| RMS | 3.9ᵃ | 0.2 | 4.4ᵃᵇ | 1.1 | 4.7ᵇ | 1.7 | .023 |
| SD | 3.9ᵃ | 0.2 | 4.3ᵃᵇ | 1.1 | 4.7ᵇ | 1.8 | .043 |
| + | 3.0ᵃ | 0.2 | 3.3ᵃᵇ | 0.4 | 3.3ᵇ | 0.2 | .016 |
| – | 3.0 | 0.1 | 3.2 | 0.6 | 3.2 | 0.6 | .656 |

ᵃ,ᵇ Different letters indicate significant differences ($P < .05$)
ᶜ Kruskal-Wallis H test

**Table 2.** Reproducibility of RMS, standard deviation, plus average, minus average of 0 °, 6 °, 10 ° abutment with blue light model scanner (unit: µm)

| Variable | 0° | | 6° | | 10° | | ᵃP |
| --- | --- | --- | --- | --- | --- | --- | --- |
| | Mean | SD | Mean | SD | Mean | SD | |
| RMS | 6.1 | 1.9 | 5.5 | 0.9 | 5.3 | 0.8 | .646 |
| SD | 6.0 | 1.9 | 5.3 | 0.8 | 5.2 | 0.7 | .456 |
| + | 4.2 | 0.8 | 4.5 | 0.9 | 4.2 | 0.7 | .689 |
| – | 4.2 | 0.8 | 3.9 | 0.6 | 4.0 | 0.5 | .543 |

ᵃ Kruskal-Wallis H test

**Table 3.** Reproducibility of RMS, standard deviation, plus average, minus average of 0 °, 6 °, 10 ° of 1-5 position abutment with blue light model scanner (unit: µm)

| Variable | 1 | | 2 | | 3 | | 4 | | 5 | |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| | Mean | SD | Mean | SD | Mean | SD | Mean | SD | Mean | SD |
| RMS | 3.9 | 0.1 | 5.5 | 0.1 | 7.1 | 1.7 | 5.6 | 0.2 | 5.9 | 0.2 |
| SD | 3.9 | 0.1 | 5.4 | 0.1 | 6.8 | 1.9 | 5.6 | 0.1 | 5.7 | 0.2 |
| + | 3.1 | 0.2 | 4.1 | 0.1 | 5.0 | 0.5 | 4.6 | 0.2 | 4.7 | 0.7 |
| – | 3.0 | 0.1 | 4.4 | 0.1 | 4.5 | 0.6 | 4.0 | 0.2 | 4.2 | 0.4 |
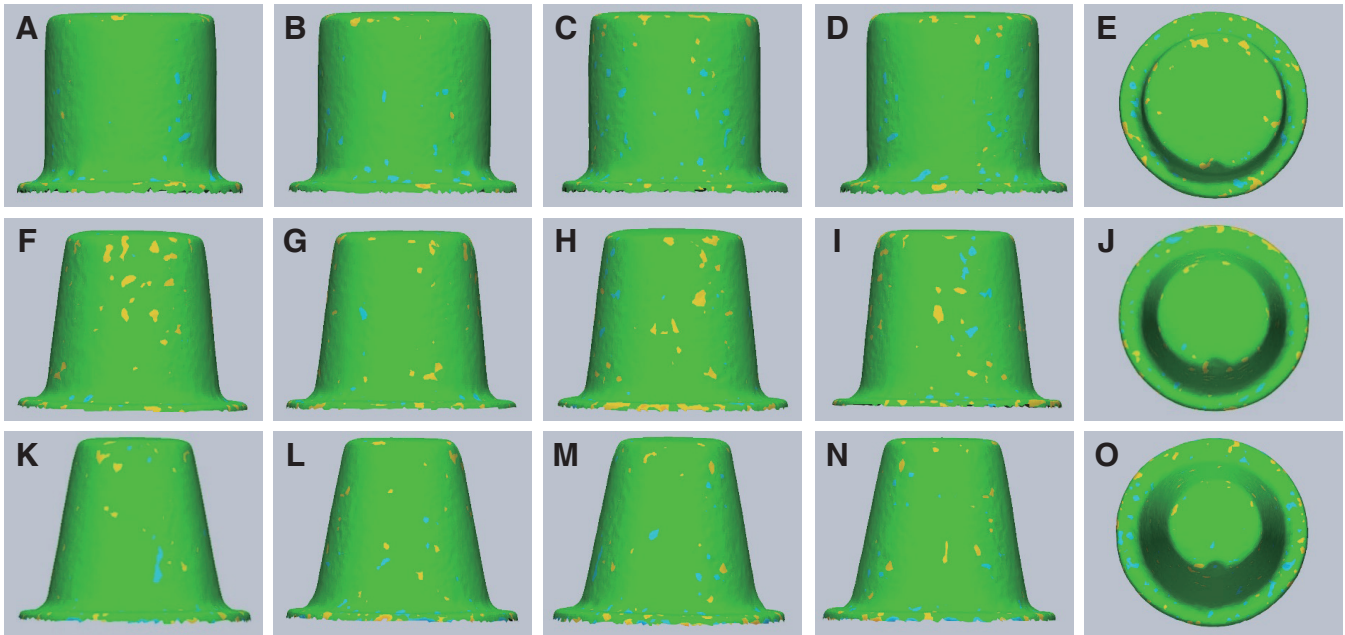
**Fig. 7.** Evaluation of repeatability color difference map. Result value (A-E) of color difference map of 0° study die, 6° study die color difference map result (F-J), the result value (K-O) of the color difference map of the 10° study die. Buccal (A, F, K), distal area (B, G, L), lingual area (C, H, M), mesial area (D, I, N), occlusal area (E, J, O).
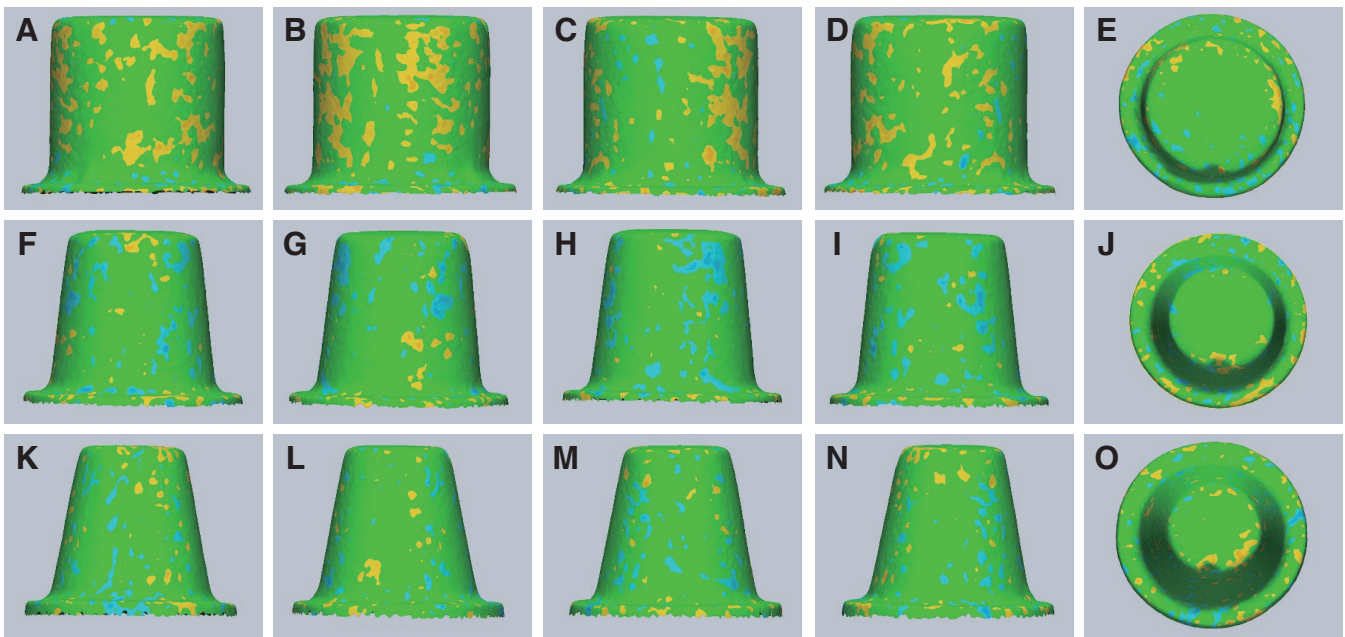


**Fig. 8.** Evaluation of reproducibility's color difference map. Result value (A-E) of color difference map of 0° study die, results of 6° study die color difference map (F-J), the result value (K-O) of the color difference map of the 10° study die. Buccal (A, F, K), distal area (B, G, L), lingual area (C, H, M), mesial area (D, I, N), occlusal area (E, J, O).
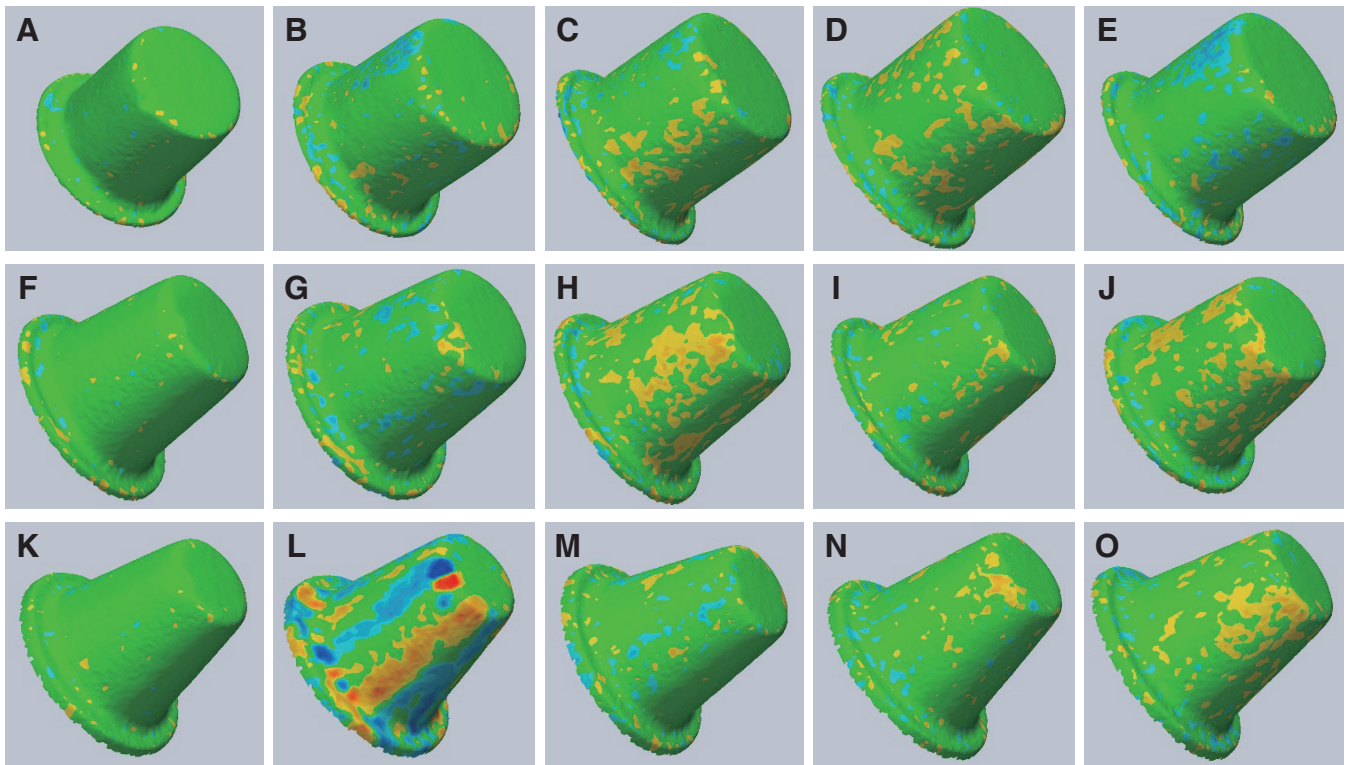
**Fig. 9.** Evaluation of color difference map of each reproducibility of scan base form 1-5. Result value (A-E) of color difference map of 0° study die, 6° study die color difference map result (F-J), the result value (K-O) of the color difference map of the 10° study die. Scan base form 1 location (A, F, K), scan base form 2 location (B, G, L), scan base form 3 location (C, H, M), scan base form 4 location (D, I, N), scan base form 5 location (E, J, O).

## DISCUSSION

In this study, the repeatability and reproducibility of the abutment axial wall angle were analyzed using a blue light model scanner. According to ISO 12836, repeatability is to measure repeatedly at one position, and reproducibility is to evaluate three-dimensional data while changing position. In this study, three-dimensional analysis of the repeatability was performed for each group of 5 scan data items: scan_1-scan_2, scan_1_scan_3, scan_1_scan_4, scan_1_scan_5, scan_2_scan_3, scan_2_scan_4, scan_2_scan_5,scan_3_scan_4, scan_3_scan_5, scan_4, and scan_5. Reproducibility was designated as the reference three-dimensional data by acquiring the scan three-dimensional data at position 1 of the scan base form. Then, the scan base form was scanned at positions 1 - 5, respectively, and the reference three-dimensional data and the scan 1 - 5 data were aligned with the best fit alignment.

When making the abutment, a triangular notch was made 1.5 mm in width and 1 mm in length on the occlusal buccal region. The reason for this was to enable accurate identification of positions when superimposing reference 3D data and scan 3D data. In addition, the horizontal and vertical lengths were made different so that overlapping could be effectively performed.

In this study, we used stone for scanning only to reduce errors and reliability during the scanning process. According to American Dental Association specifications, this material corresponds to the type IV dental stone. It has a compressive strength of 85/120 MPa, setting expansion of 0.08%, and hardness of 210/280 N/mm². The blue light model scanner used in this study was a non-connectivity laboratory scanner equipped with a blue light emitting diode (LED) as the light source, scan time within 24 seconds for full arch scans, scan principle for phase-shifting optical triangulation, and accuracy within 7 µm.[24]

In the present study, the 0° abutment showed the smallest error and the 10° abutment showed the largest error in the repeatability. According to Jeon *et al.*,[7,14] scan error is caused by canine abutment when the canine is scanned because the shaft wall is narrow. Like the canine abutment, the conic model has poor repeatability. Because the 10° abutment is a tapered abutment, the error of the abutment is larger than those of the other groups. Therefore, the null hypothesis regarding repeatability was rejected. Overall, in Fig. 8, the color difference map of 0° abutment was observed to have more green color than the 6° and 10° abutments. In 0°, 6°, and 10° abutments, positive and negative errors occurred in the axial wall area and there was no apparent error in the occlusal area. Reproducibility, on the

contrary, showed that 0° abutment had the largest error compared to other abutments. This phenomenon is larger than the other groups because of the large area of 3D data and the number of points, when changing position, the scanner has to read a large amount of data using light. It is judged as an error in the process of reading data during the scanning process. Therefore, when the abutment size increases, the amount of data increases, and when the position change is accompanied, the error occurs.[14]

In detail, the scan base form 1 - 5 of three abutments showed different results for each position. Scan base form showed the most stable result at position 1 at 3.9 µm and the largest error at position 3 at 7.1 µm. In general, when position one was excluded, the other position showed poor results. The authors hypothesize that this phenomenon is influenced by the type of camera, light conditions, and the equipment sensor because the amount of light irradiated onto the object, and reflected toward the sensor, varies depending on the location.[25] Few research studies exist in the literature to support this hypothesis and further research is needed to prove it.

In this study, the minimum error of repeatability of 0°, 6°, and 10° abutment was 4.7 µm at 3.9 µm and the minimum error of reproducibility was 5.3 µm and maximum error was 6.1 µm. The minimum error of the reproducibility of the scan base form 1 - 5 was 3.9 µm and the maximum error was 7.1 µm. In the existing literature, it has been reported that the scanners are reliable when the error is within about 10 µm.[7,13,14,26] The results of this study showed interesting results with the inconsistent results of repeatability and reproducibility.

In this study, the color difference map bar has a maximum error of 50 µm and a minimum error of 5 µm. The reason for setting the minimum error to 5 µm was that the error was not able to be distinguished from each other because all the groups were within the range of 10 µm. For this reason, we could observe the error of the abutments by setting it to 5 µm. The results of repeatability and reproducibility in this study were generally reliable and can be used as reference materials for the final restoration of good quality.

There is no detailed description of the reproducibility and repeatability measurement locations. In case of repeatability, replicate measurements were made at one location, and reproducibility measured the position, angle, height, and rotation at random. In particular, reproducibility measured randomly; therefore, there was a limit in comparing the difference between the control group and the experimental group. To compensate for these shortcomings, we selected the measurement position with a spacing of 20 mm for scanning positions 2 to 5 from number 1 on the scan base form. In this way, we tried to improve the reliability of the measurement data by supplementing the reproducibility measurement method.

The limitations of this study are limited in generalizing the use of abutment teeth that do not use the morphological clinical tooth shape. In future studies, similar abutments that are similar to the morphological teeth should be used

to evaluate the site by angle of the abutment. In addition, the accuracy of the final restoration should be evaluated.

## CONCLUSION

In the repeatability of the results of this study, the 0° abutment showed good results and the reproducibility showed good results at 10° abutment, but all results were reliable. According to our results, we recommend that the scanning be performed at the center of the scan base form.

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