Displacement of scan body during screw tightening: A comparative *in vitro* study

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PURPOSE. The purpose of this study was to evaluate the occurrence of displacement while tightening the screw of scan bodies, which were compared according to the material type. **MATERIALS AND METHODS.** Three types of scan bodies whose base regions were made up of polyether ether ketone (PEEK) material [Straumann Group, Dentium Group, and Myfit (PEEK) Group] and another scan body whose base region was made up of titanium material [Myfit (Metal) Group] were used (15 per group). The reference model was fabricated by aligning the scan body library on the central axis of the implant, and moving this position by the resin model. The screws of the scan bodies were tightened to the implant fixture with torques of 5 Ncm, 10 Ncm, and a hand tightening torque. After the application of the torque, the scan bodies were scanned using a laboratory scanner. To evaluate the vertical, horizontal, and 3-dimensional (3D) displacements, a 3D inspection software program was used. To examine the difference among groups, one-way analysis of variance and Tukey's HSD post hoc test were used (α=.05). **RESULTS.** There were significant differences in 3D, vertical, and horizontal displacements among the different types of scan bodies (P<.001). There was a significantly lower displacement in the Straumann group than in the Myfit (PEEK) and Dentium groups (P<.05). **CONCLUSION.** The horizontal displacement in all groups was less than 10 μm. With the hand tightening torque, a high vertical displacement of over 100 μm occurred in PEEK scan bodies (Myfit and Dentium). Therefore, it is recommended to apply a tightening torque of 5 Ncm instead of a hand tightening torque. *[J Adv Prosthodont 2020;12:307-15]*

KEYWORDS: Dental implant; Scan body; Tightening torque; Displacement; Polyether ether ketone (PEEK)

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INTRODUCTION

With the development of the dental computer-aided design and computer-aided manufacturing (CAD/CAM) system, many studies have verified the stability of the CAD/CAM system. This system has materialized the technique of digital scanning, which substitutes the conventional impression technique.[1-8] Previous studies have reported that the digital impression is clinically more accurate than the conventional impression.[9,10] The digital scan method tightens the screw of the scan body to the implant in the patient's oral cavity and a virtual model is produced when scanning is conducted using an intraoral scanner.[6] On the acquired virtual model, the position of the actual implant is estimated by the position of the scan body.[6] It was reported that the digital scan method reduces error related to the operator's skill and rubber material while increasing the patients' satisfaction as compared to the conventional impression technique.[8] Previous studies have reported that implant restorations produced using a digital workflow had a better passive fit than ones

fabricated with a conventional workflow.[10,13]

In 2004, the coded healing abutment was introduced as a digitally scannable component for the first time.[6] Later, in 2008, the technology of obtaining 3-dimensional (3D) data was proposed for the first time, which successfully substituted the conventional impression technique. This led to the appearance of the first scannable impression coping (scan body).[6]

Recently, a scan body has been produced by various manufacturers according to material, shape, size, implant-abutment connection type, reusability, CAD software, scanner compatibility, and cost.[8] According to previous studies, several factors of the scan body (the design, material, problem of light reflectance, manufacturing tolerance, and the importance of screwing) can affect digital transfer in implants.[6-11] Previous studies reported significant differences in scanning accuracy according to the design of the scan body.[6,11] Although the scan body is produced in various sizes and shapes by different manufacturers, it commonly consists of three regions, namely, the scan region, body region, and base region.[6] The base region mating directly with the implant is produced with various materials such as polyether ether ketone (PEEK), titanium alloy, and aluminum alloy.[6] The use of PEEK materials reduces the problem of light reflectance that can occur in the metal alloy.[6] If there is a transformation of the base region because of repeated use or sterilization, the accurate transfer of the position and angle of the implant becomes difficult, further leading to the production of inaccurate prostheses.[11] Besides, the manufacturing tolerance of the scan body may affect the movement of the position of the implant in the patient's oral cavity.[12] Also, tightening the screw of the scan body to the implant may lead to the transformation of the base region due to the torque.[13] A previous study reported that the tightening torque applied to the screw of the abutment might cause a vertical displacement.[13] However, only a few researchers have studied the effects of various material types of the scan body (PEEK and titanium) on the displacement caused by applying the tightening torque on the screw of the scan body.

Recently, dental PEEK material has found its applications in various fields due to its biological, mechanical, and esthetic advantages.[14,15] The tightening torque recommended by the manufacturer of PEEK material scan body requires a torque less than 10 Ncm and can be tightened manually.[6] At the moment, when the screw of the scan body is tightened to the implant, the accurate position of the implant cannot be transferred at the instance of displacement.[17-20] The inaccurate position of the implant results in the production of implant-supported prostheses with an inaccurate fit.[17-20] Despite this importance, only a few researchers have studied the displacement due to the tightening torque applied to the screw of the scan body. In addition, no appropriate tightening torque has been presented, which reduces the displacement of the scan body. Therefore, this study investigated the occurrence of displacement when the screw of the scan body is tightened to the implant according to the type of scan body and appropriate tightening torque.

The purpose of this study was to evaluate the occurrence of vertical, horizontal, and 3D displacements during screw tightening of four different scan bodies, selected according to the material type (PEEK and titanium material), tightened to implant fixtures with tightening torques of 5 Ncm, 10 Ncm, and a hand tightening torque. The null hypothesis of this study is that there would be no difference in the displacement according to the types of scan bodies and tightening torques.

MATERIALS AND METHODS

To determine the sample size, a pilot experiment was conducted five times, which determined the sample size to be 15 in each group using power analysis software (G*Power v3.1.9.2; Heinrich-Heine-Universität Düsseldorf) (actual power = 99%; power = 99%; α = .05).

For this experiment, three types of scan bodies whose base regions were made of PEEK material [Straumann (PEEK) Group (RN Straumann CARES Mono Scanbody, Straumann, Basel, Switzerland), Dentium (PEEK) Group (IOS Healing Abutment, Dentium, Seoul, Republic of Korea), and Myfit (PEEK) Group (All PEEK Scanbody, Myfit, Daegu, Republic of Korea)], along with a scan body whose base region was made of titanium material [Myfit (Metal) Group (All PEEK Scanbody, Myfit, Daegu, Republic of Korea)] were used (15 per group, N = 45).

The internal hexagon implant fixture was used as recommended by the manufacturer of each scan body [Straumann (PEEK) Group (033.532S, Roxolid SLActive, Basel, Switzerland), Dentium (PEEK) Group (FX 38 10, superline, Dentium, Seoul, Republic of Korea), and Myfit group (BTS3S4511S, TS III SA, Osstem, Busan, Korea)]. Additionally, dental surveyor (Ney Dental Surveyor, Dentsply Sirona, York, PA, USA) was used to ensure that the long axis of the implant fixture was perpendicular to the horizontal plane. Also, the implant fixture was embedded using auto polymerized resin (Orthodontic Resin, Dentsply Sirona, York, PA, USA).

The CAD reference model (CRM) was obtained to evaluate the displacement due to the tightening torque (Fig. 1). The exterior and interior of the implant were scanned using a laboratory scanner (E1 scanner, 3Shape, Copenhagen, Denmark) (Fig. 1A). The scanned implant and library of scan body were aligned using a 3D inspection software program (Geomagic Control X 2018.0.1, 3D Systems, Rock Hill, SC, USA) (Fig. 1B). At this time, alignment was based on the scanned implant, and the library of the scan body was moved to coincide with the central axis of the implant. In addition, the scan body was vertically moved to match the total original length of the implant and scan body. The moved implant and scan body were merged (Fig. 1C). Also, the resin model with the embedded implant was scanned using a laboratory scanner (Fig. 1D). The resin model and the merged implant were aligned with respect to the interior of the implant (Fig. 1E) and merged (Fig. 1F).

The CAD test models (CTMs) were obtained with torques of 5 Ncm, 10 Ncm, and a hand tightening torque.
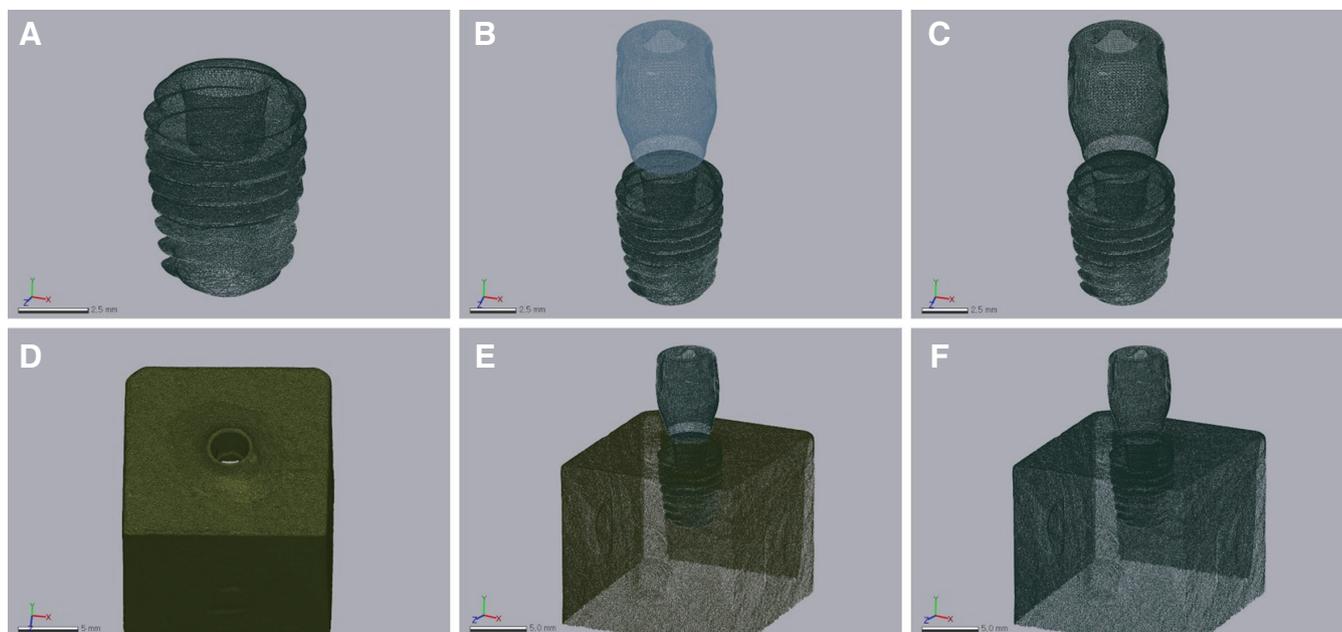
Fig. 1. Fabrication of the CAD reference model. (A) Scanned implant using a scanner. (B) Transferring the scan body to the implant based on the center of the implant and total length. (C) Merging the scan body and implant. (D) Scanned resin model with the implant. (E) Alignment of the implant with respect to the inside of the implant. (F) Merging the resin model, scan body, and implant.

The screws of the scan bodies were tightened to the implant fixture with torques of 5 Ncm, 10 Ncm, and a hand tightening torque. The hand tightening was conducted using the same method applied in clinics, by a dental resident in prosthetics with a clinical experience of four years (J.-H. K.). As a result, the values of the hand tightening torque were measured ten times using a digital torque gauge (MGT12, MARK-10 Co., New York, NY, USA) and was 15.7 ± 1.3 Ncm. This value was similar to the value of hand tightening torque (15 ± 6 Ncm) measured in a previous study.[16] For the accurate application of the torques of 5 Ncm and 10 Ncm, a digital torque driver (MEG-TORQ, MegaGen, Gyeongsan, Korea) was used. After the application of the tightening torque using a laboratory scanner, the scan bodies were scanned. For this study, a scanning accuracy of the laboratory scanner below 10 μm was verified by the manufacturer. In accordance with ISO-12836, at an ambient temperature of 23 ± 2°C, a single operator, who is skillful in using it, conducted the scanning (J.-H. K.). Also, the digital torque driver and laboratory scanner each time were calibrated for accuracy. The virtual modeling obtained in the conditions of 5 Ncm, 10 Ncm, and hand tightening was saved in standard tessellation language (STL) format.

The 3D inspection software program was used to evaluate the vertical, horizontal, and 3D displacements. The STL files of CRM and CTMs (5 Ncm, 10 Ncm, and hand tightening torques) were uploaded on the inspection software (Fig. 2A, 2B). Also, based on the CRM STL file, the initial alignment of the CRM STL file and CTM STL file was conducted. Also, the segmentation of CRM STL file to the scan body region and embedded resin region was conducted (Fig. 2A). Based on the segmented resin region, the optimal alignment (best-fit alignment) except for the scan body region (Fig. 2C) was conducted.

The 3D displacement was calculated for all data points of the segmented scan body region in the 3D inspection software (Fig. 2D). At this time, the data points with the value of root mean square (RMS) were calculated using the following formula:[13]

$$RMS = \frac{1}{\sqrt{n}} \cdot \sqrt{\sum_{i=1}^{n}\left(X_{1,i} - X_{2,i}\right)^2}$$

Where, $X_{1,i}$ is the ith measurement point at the data point of CRM STL, and $X_{2,i}$ is the ith measurement point at the data point of CTM STL. In addition, *n* refers to the number of all the points measured in each analysis.

It is possible to determine the different deviations between two different datasets using the values of RMS. A low RMS represents a high 3D conformity degree of overlapped data.[13] Also, 3D displacement is shown as a color difference map, and the color map range of ± 100 μm (20 color segments) and the color map tolerance range of ± 30 μm (green region) were designated. Thus, in the color difference map, the green region means relatively less displacement, whereas the blue region means a decrease below the standard value (Fig. 2D).
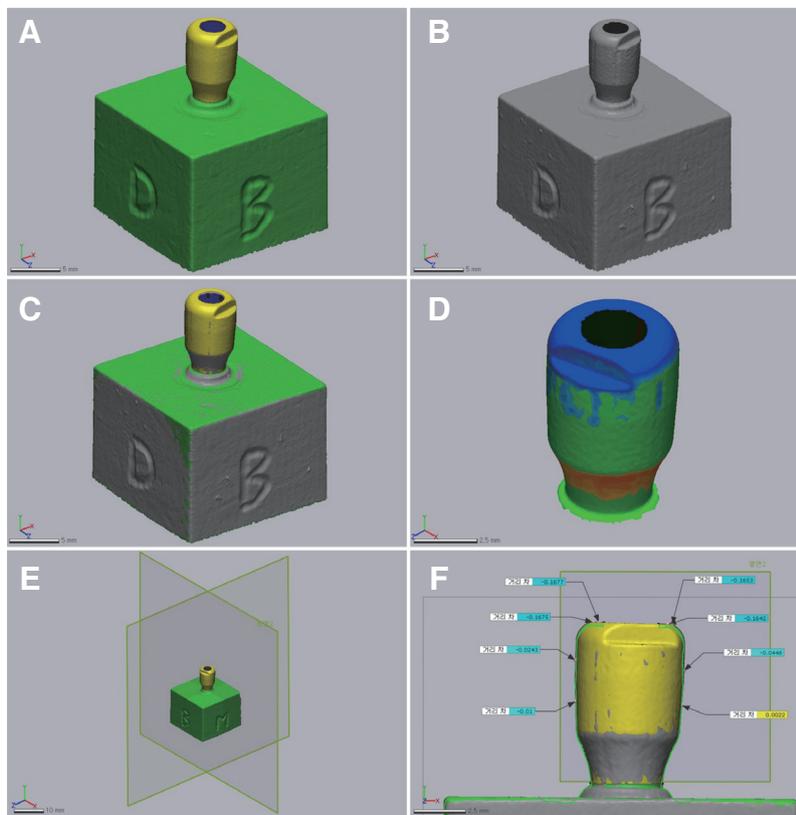
Fig. 2. Analyses of 3D, vertical, and horizontal displacements of the scanned scan body using 3D inspection software. (A) Segmentation of the scan body and resin region (CAD reference model). (B) Scan body (CAD test model). (C) Best-fit alignment based on the resin region. (D) Color difference map of the scan body region. (E) Hypothetical planes setting. (F) Measurement of vertical and horizontal displacements.

To evaluate the vertical and horizontal displacements, two hypothetical planes were produced, passing through the center of the scan body and crossing at right angles in the 3D inspection software (Fig. 2E). On the hypothetical planes, the distance from CRM STL (Fig. 2F) was calculated. On the two hypothetical planes in each sample, eight points on the occlusal surface and eight points on the axial side were measured (Fig. 2F). On the occlusal surface, eight points by vertical displacement were evaluated, whereas on the axial side, eight points by horizontal displacement were evaluated (Fig. 2F). In addition, the hypothetical planes were located on the same coordinate in all the samples.

All the data were analyzed using statistical software (SPSS release 25.0, IBM, Chicago, IL, USA) (α = .05). First, the normal distribution of the data was investigated through the Shapiro-Wilk test. Also, after the confirmation of normal distribution, equality of variance was evaluated by the Levene test. The difference among the groups was evaluated using one-way ANOVA. Also, as a post hoc test, the difference among the groups was analyzed by using Tukey's HSD test. Lastly, to compare 5 Ncm, 10 Ncm, and hand tightening, the difference was verified through a one-way ANOVA.

RESULTS

There were significant differences in 3D, vertical, and horizontal displacements between the different types of scan bodies ($P < .001$; Table 1, Table 2, Table 3, respectively). There was no significant difference between the Myfit (Metal) and Straumann (PEEK) Groups ($P > .05$; Fig. 2, Fig. 3). Also, there was no significant difference between the Myfit (PEEK) and Dentium (PEEK) Groups ($P > .05$; Fig. 2, Fig. 3). Meanwhile, there was a significantly lower displacement in the Straumann (PEEK) Group than in the Myfit (PEEK) and Dentium (PEEK) Groups ($P < .05$; Fig. 3, Fig. 4, respectively).

Except for horizontal displacement, 3D and vertical displacements significantly increased in the hand tightening torque than in the tightening torque of 5 Ncm and 10 Ncm ($P < .05$; Table 1, Table 2, Table 3). The horizontal displacement showed approximately lower 8 μm in the 10 Ncm and hand tightening groups (Table 3, Fig. 5). The horizontal displacement showed approximately lower 3 μm at 5 Ncm (Table 3, Fig. 5).

In all the types of scan bodies, the vertical displacement occurring with a hand tightening torque was significantly

Table 1. Comparison of 3D displacements according to the type of scan body

Tightening torque	Myfit (Metal)	Myfit (PEEK)	Dentium	Straumann	F	P
	RMS (Mean ± SD, μm)					
5 Ncm	5.4 ± 0.7[Aa]	16.9 ± 2.9[Ba]	17.5 ± 2.1[Ba]	5.6 ± 0.9[Aa]	59.7	< .001*
10 Ncm	9.2 ± 0.8[Ab]	35.6 ± 3.2[Bb]	36.5 ± 2.6[Bb]	8.2 ± 0.8[Ab]	511.1	< .001*
Hand tightening	14.3 ± 1.7[Ac]	50.8 ± 3.3[Bc]	51.9 ± 4.9[Bc]	13.8 ± 1.6[Ac]	312.3	< .001*
F	29.6	456.8	126.1	112.1		
P	< .001*	< .001*	< .001*	< .001*		

*Different letters (upper case: row; lower case: column) indicate that the difference between the groups is significant as determined by Tukey's HSD post hoc test (P < .05).

Table 2. Comparison of vertical displacements according to the type of scan body

Tightening torque	Myfit (Metal)	Myfit (PEEK)	Dentium	Straumann	F	P
	Vertical displacement (Mean ± SD, μm)					
5 Ncm	5.6 ± 1.5[Aa]	18.1 ± 1.6[Ba]	18.3 ± 1.8[Ba]	4.1 ± 0.9[Aa]	11.3	< .001*
10 Ncm	11.1 ± 1.3[Ab]	85.3 ± 5.6[Bb]	90.7 ± 8.6[Bb]	10.2 ± 0.7[Ab]	210.8	< .001*
Hand tightening	22 ± 2.3[Ac]	119.1 ± 9.6[Bc]	116.7 ± 8[Bc]	32.6 ± 3.2[Ac]	162.1	< .001*
F	68.7	268.8	92.8	176.7		
P	< .001*	< .001*	< .001*	< .001*		

*Different letters (upper case: row; lower case: column) indicate that the difference between the groups is significant as determined by Tukey's HSD post hoc test (P < .05).
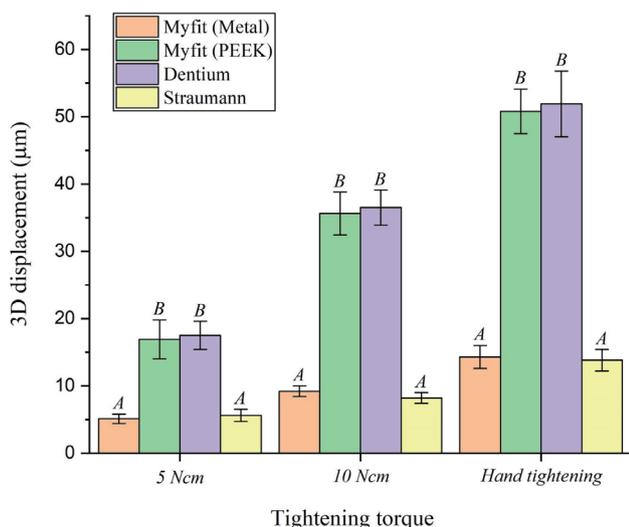
Fig. 3. Comparison of mean 3D displacement according to the tightening torque.
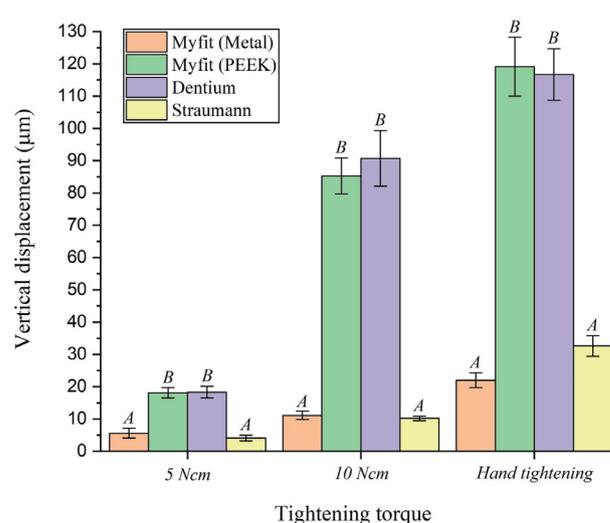
Fig. 4. Comparison of mean vertical displacement according to the tightening torque.

higher (P < .05; Table 4). Horizontal displacement showed a significantly lower value in all the types of scan bodies (P < .05; Table 4).

In the color difference map, green regions were observed in all parts of the scan bodies in the Myfit (Metal) and Straumann (PEEK) Groups (Fig. 6). Meanwhile, in the Myfit (PEEK) and Dentium (PEEK) Groups, blue regions were observed on the occlusal surface part (Fig. 6). Also, more blue regions were observed in the hand tightening torque than at 5 and 10 Ncm in the Myfit (PEEK) and Dentium (PEEK) Groups (Fig. 6).

Table 3. Comparison of horizontal displacement according to the type of scan body

Tightening torque	Myfit (Metal)	Myfit (PEEK)	Dentium	Straumann	F	P
	Horizontal displacement (Mean ± SD, μm)					
5 Ncm	2.5 ± 0.4	2.4 ± 0.2^a	2.5 ± 0.3^a	2.3 ± 0.2^a	0.03	.992*
10 Ncm	4.8 ± 0.6^{AB}	7.7 ± 0.8^{Bb}	6.4 ± 0.8^{Bb}	2.5 ± 0.3^{Aa}	6.3	< .001*
Hand tightening	5.4 ± 0.3	6.4 ± 0.6^b	7.6 ± 0.7^b	4.8 ± 0.5^b	2	.112*
F	3	26.8	9.9	5.5		
P	.056*	< .001*	.007*	< .001*		

*Different letters (upper case: row; lower case: column) indicate that the difference between the groups is significant as determined by Tukey's HSD post hoc test ($P < .05$).
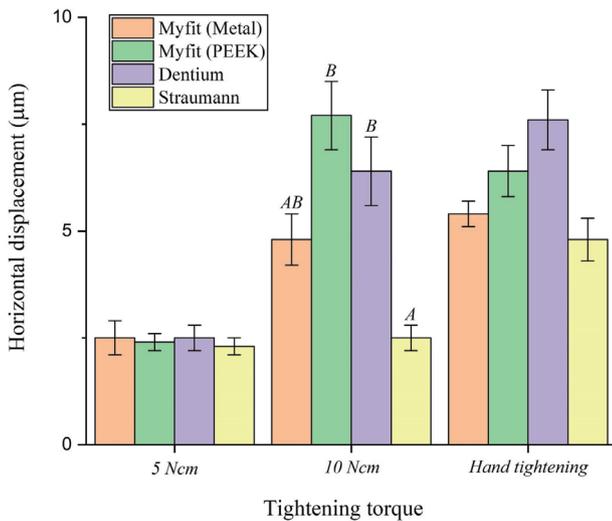
Fig. 5. Comparison of mean horizontal displacement according to the tightening torque.

Table 4. Comparison of horizontal displacements according to the type of scan body

Scan body	Order of displacement amount	P
Myfit (Metal)	Hand tightening (vertical) > 10 Ncm (vertical) = Hand tightening (3D) > 10 Ncm (3D) = Hand tightening (horizontal) = 10 Ncm (horizontal) > 5 Ncm (vertical) = 5 Ncm (3D) > 5 Ncm (horizontal)	< .001*
Myfit (PEEK)	Hand tightening (vertical) > 10 Ncm (vertical) > Hand tightening (3D) > 10 Ncm (3D) > Hand tightening (horizontal) = 10 Ncm (horizontal) > 5 Ncm (vertical) = 5 Ncm (3D) > 5 Ncm (horizontal)	< .001*
Dentium	Hand tightening (vertical) > 10 Ncm (vertical) > Hand tightening (3D) = 10 Ncm (3D) > Hand tightening (horizontal) = 10 Ncm (horizontal) > 5 Ncm (vertical) = 5 Ncm (3D) > 5 Ncm (horizontal)	< .001*
Straumann	Hand tightening (vertical) > 10 Ncm (vertical) = Hand tightening (3D) > 10 Ncm (3D) = Hand tightening (horizontal) = 10 Ncm (horizontal) > 5 Ncm (vertical) = 5 Ncm (3D) > 5 Ncm (horizontal)	< .001*

*Significant as determined by Tukey's HSD post hoc test ($P < .05$).
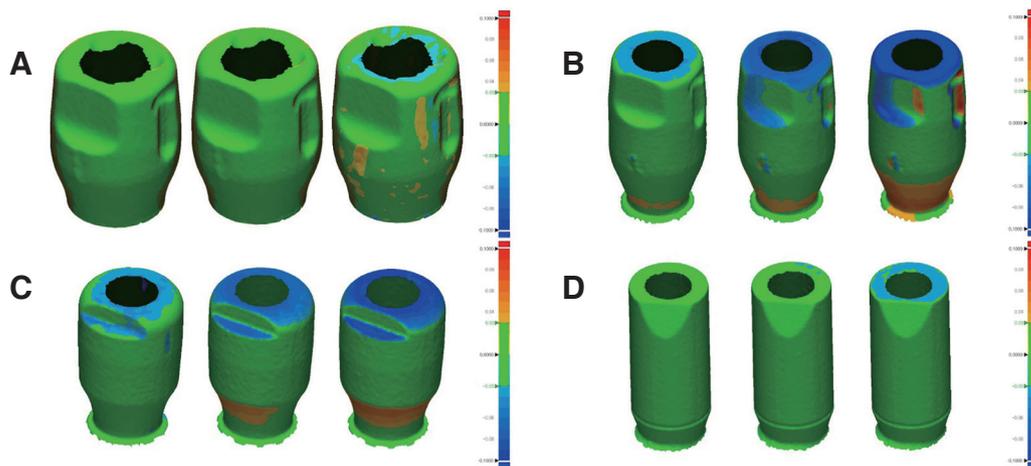
Fig. 6. Comparison of color difference maps according to the four types of scan bodies (from left to right: 5 Ncm, 10 Ncm, and hand tightening torque). (A) Myfit group (Metal). (B) Myfit group (PEEK). (C) Dentium (PEEK) Group. (D) Straumann (PEEK) Group.

DISCUSSION

To achieve the long-term success of implant-supported prostheses, it is essential to obtain a passive fit and estimate the accurate position of implant fixture in the impression process of digital scanning, using a scan body involved in producing implant-supported prostheses. Therefore, this study evaluated the displacement according to the tightening torque and material of the scan body, which might appear when the screw of the scan body was tightened to the implant fixture. The results of this study showed that the tightening torque and type of material affected the displacement of the scan body; therefore, the null hypothesis of this study was rejected ($P < .001$; Table 1, Table 2, Table 3).

Many previous studies have reported that displacement occurs when the screw of the abutment is tightened.[11-13] Kim *et al.* reported that axial displacement occurs with an average torque of approximately 10 Ncm or 11 - 38 Ncm.[13] Gilbert *et al.* measured the axial displacements of nine types of abutment and reported that horizontal displacement was 3 - 12 μm and the vertical displacement was 3 - 5 μm.[20] Rebeeah *et al.* measured the axial displacement in two types of implant system and found that the displacement did not exceed 14 μm.[22] Kim *et al.* evaluated the displacement of four types of abutment by the tightening of the screw and showed that zirconia abutment (internal type) (39.6 ± 10.9 μm) had the largest vertical displacement, whereas titanium abutment (external type) (2.6 ± 0.8 μm) had the smallest displacement.[13] In addition, because there is a small part that can stop vertical movement in the internal type as compared to the external type, there is an occurrence of a relatively larger vertical displacement.[13] In this study, except for the titanium scan body, the scan bodies showed a relatively large vertical displacement as compared to previous studies (Table 2). This is because the implant -abutment connection part of the scan body is made up of the PEEK material. In this study, the same scan body in the internal type produced by the same manufacturer (Myfit) showed a much less displacement in the titanium scan body than in that with PEEK material (Table 1, Table 2). However, it is difficult to compare this study with other studies as there are only a few studies on the occurrence of displacement when the abutment with PEEK material is tightened.

In this study, the displacement of the Straumann (PEEK) Group of PEEK material is similar to that of the Myfit group (Metal), unlike the other PEEK groups (Myfit and Dentium) (Table 1, Table 2). This is because, although the base region of the scan body is PEEK, a much lower displacement occurred due to the difference in the design of the base region. The implant-abutment connection part of the scan body of the Straumann (PEEK) Group is the internal type; however, it has a shape such that the neck section of the implant fixture is covered by the base region of the scan body. This structure acted as a part that could stop the vertical movement like in the external type. Thus, displacement is greatly affected by the type of material of the scan body (PEEK material versus titanium material); however, it is also essential to consider the design of the base region.

In all groups of this study, the displacement was larger when hand tightening was done at 10 Ncm (Table 1, Table 2). Many manufacturers recommend hand tightening torque for PEEK scan body, including the manufacturer of the scan body used in this experiment.[6] As a result of the measurement of the hand tightening torque in a previous study, the average torque was 15 ± 6 Ncm.[16] Hand tightening torque (15.7 ± 1.3 Ncm) applied by a single clinical expert in this study was similar to the result of the previous study. Yet, the strength of hand tightening would differ depending on the operator and how strong the torque should be applied is not clear. Since vertical displacement increased more in hand tightening than at 10 Ncm, it is difficult to recommend the hand tightening torque. Also, according to the results of the present study, the torque of 5 Ncm can be recommended because it showed the smallest displacement.

In the comparison of the vertical and horizontal displacements in this study, the vertical displacement was found to be very large (Table 2, Table 3). Even Dentium (PEEK) and Myfit Groups (PEEK) with large vertical displacement had small horizontal displacements (Table 2, Table 3). Also, there was no significant difference in the horizontal displacement according to the tightening torque (Table 3). Therefore, to examine the result of this study, a large vertical displacement does not greatly affect the horizontal displacement. In other words, when the screw is tightened in the scan body, the position of the implant fixture has vertical rather than horizontal movements. This result is similar to the results of the previous studies that evaluated the displacement of abutment instead of the scan body.

The displacement of the scan body may adversely affect the final implant-supported prostheses. The production of the final implant-supported prostheses using the position of the implant fixture obtained through an inaccurate scan body leads to the production of implant-supported prostheses having an error of vertical displacement. Brånemark *et al.*[17] argued that the passive fit of the prosthesis should have a gap of less than 10 μm between a prosthesis and an abutment, whereas Jemt *et al.*[18] argued that there should be a gap of less than 150 μm between a prosthesis and an abutment. In addition, Karl *et al.*[19] noted that there should be no stain after screw tightening of the prostheses to the implant. Also, they said that the stress produced by the misfit of implant-supported prostheses has a force similar to the occlusal force.[17] In addition, Kunavisarut *et al.*[20] noted that after the formation of the passive fit of prostheses, the force is dispersed to all elements of the implant, and each element can have a minimal stress. To obtain the passive fit of implant-supported prostheses, it is essential to reduce errors in the impression process using the scan body.

Optical impressions using an intraoral scanner reduce patient discomfort. The intraoral scanners are time-efficient and simplify clinical procedures for the dentist, eliminating

plaster models and allowing better communication with the dental technician and with patient.[23] According to the previous studies of scanning accuracy to produce prostheses through the digital scan, prostheses might fit inaccurately if there was a deviation of more than 100 μm in the scanning accuracy.[24,25] Also, the scanning accuracy of less than 100 μm was presented as a clinically permissible range for the acceptable cement space of prostheses.[24,26] The torque recommended by the manufacturer of the scan bodies used in this study was presented as Max. 15 Ncm for the Straumann (PEEK) Group, Max. 30 Ncm for the Dentium (PEEK) Group, and 5 - 8 Ncm for the Myfit group. Myfit (PEEK) and Dentium (PEEK) Groups showed a vertical displacement of over 100 μm when hand-tightened (Table 2). As shown in this study, the use of an ambiguous recommended torque causes a considerable displacement and the accumulation of the errors occurring in the impression process, resulting in the implant-abutment misfit. Therefore, it is necessary to present a recommended torque smaller than that presented by the manufacturer.

This study has a few limitations. The displacements according to the tightening torque were measured; however, this study did not investigate the clinical results when the implant-supported prostheses were produced. Therefore, it is necessary to conduct an additional study examining the impact of displacement on the relationship and occlusion with the adjacent teeth of implant-supported prostheses. The accuracy of the impressions of implant may vary depending on the type of intraoral scanner.[27] Therefore, further studies using various intraoral scanners are needed.

CONCLUSION

In the limited results of this *in vitro* study, the displacement by tightening torque differed depending on the type of scan body. In all the groups, there was a vertical displacement lower than 100 μm at the tightening torque of 5 Ncm and 10 Ncm. Meanwhile, the hand tightening torque resulted in vertical displacements larger than 100 μm in PEEK scan bodies (Myfit and Dentium) except for the Straumman Group (32.6 ± 3.2 μm). In contrast to the results of the vertical displacement, the horizontal displacement in all groups was less than 10 μm.

Displacement was affected by the material of the base region of the scan body (PEEK and titanium material). There was a higher displacement in PEEK scan bodies (Myfit and Dentium) than in the titanium scan body, except for the Straumman Group. Also, there was a big impact according to the shape of the base region, even in the same PEEK material. The Straumman Group with a shape that could stop vertical movement showed a much lower vertical displacement than the other PEEK scan bodies (Myfit and Dentium).

High vertical displacement of over 100 μm may displace the position of implant fixture to an inaccurate position, thereby having a negative impact on the passive fit of the final implant-supported prostheses. Thus, to reduce the ver-

tical displacement of the PEEK scan body, as a recommended torque, it is necessary to apply a tightening torque of 5 Ncm instead of the hand tightening torque.

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