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Influence of material and tightening torque on the subsidence of implant scan bodies

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Abstract

Purpose: To compare abutment and scan body subsidence and determine the appropriate tightening torque value for a scan body that can accurately replicate abutment subsidence.

Methods: An internally tapered connection implant was placed in a bone model. The titanium abutment (Ti Abut), polyetheretherketone scan body (PEEK SB), and titanium scan body (Ti SB) were tightened to torque values of 10 or 35 Ncm, with the 10 Ncm models used as reference models. Both the 10 and 35 Ncm models were scanned using a laboratory scanner. The vertical displacements of the Ti Abut, PEEK SB, and Ti SB at each torque value were determined using three-dimensional analysis software.

Results: Upon tightening the scan bodies and abutment to 35 Ncm, the displacement was significantly greater than when tightened to 10 Ncm ($P < 0.01$). At 35 Ncm, Ti SB and Ti Abut showed significantly greater displacements than PEEK SB, whereas no significant difference was observed between Ti SB and Ti Abut.

Conclusions: The titanium scan bodies, when tightened at 35 Ncm, accurately replicated titanium abutment subsidence, unlike the PEEK scan bodies.

Keywords: Dental implant, Digital dentistry, Taper connection, Tightening torque, Scan body

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1. Introduction

The use of internal taper connection implants has become increasingly prevalent in implant dentistry owing to their ability to reduce microgaps and minimize periimplant bone resorption[1–6]. However, the abutment of internal tapered connection implants subsides when the abutment screw is tightened[7]. This subsidence is a critical factor that must be considered when taking impressions at the implant level. Failure to account for abutment subsidence can result in a discrepancy in the position of the implant body between intraoral and extraoral settings, leading to the fabrication of an ill-fitting superstructure. Such discrepancies can lead to complications including periimplantitis[8], superstructure damage[9], abutment screw loosening or breakage[10], and excessive stress concentration around the implant[10].

Intraoral scanners (IOSs) are effective in various areas of dentistry, including impression taking, oral hygiene assessment, and orthodontic treatment planning[11–18]. The IOS provides an ac-

curacy comparable to or exceeding that of traditional impression methods[11–14] and is easier to use[19,20], making it particularly advantageous for implant impressions[21–23]. When using an IOS, a scan body is attached to the implant to record its position. However, the materials and recommended tightening torque values for scan bodies vary by manufacturer (**Table 1**), and many rely on subjective “hand tightening”[24]. While most manufacturers recommend a tightening torque of 35 Ncm for abutments, the tightening torque for scan bodies is frequently ambiguous. Previous studies have reported that scan bodies subside owing to screw tightening[25,26], and discrepancies in the tightening torque between the abutments

WHAT IS ALREADY KNOWN ABOUT THE TOPIC?

» A property of tapered connection implants is abutment subsidence. Scan bodies also exhibited subsidence similar to that of abutments. However, although the tightening torque values for the abutments are specified, those for the scan bodies are ambiguous. Additionally, abutments are made of titanium, whereas scan bodies are made of PEEK or titanium.

WHAT THIS STUDY ADDS?

» To reproduce the subsidence of the titanium abutment when tightened at 35 Ncm, the titanium scan body should be tightened at the same torque value. The PEEK scan body could not replicate the subsidence of the titanium abutment when tightened at 35 Ncm.

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Table 1. Comparison of different scan body materials and recommended tightening torque

Manufacturer	Straumann	Straumann	Nobel Biocare	Dentsply Sirona
Material				
Region	PEEK	Titanium	PEEK	PEEK
Base	PEEK	Titanium	Titanium alloy	Titanium alloy
Recommended tightening torque	Hand torque	Hand torque	Less than 5 Ncm	Hand torque

PEEK: polyetheretherketone

and scan bodies could lead to variations in subsidence. This suggests that the currently recommended tightening torque for the scanning bodies may not accurately replicate the implant position.

The purpose of this study was to compare the subsidence of abutments and scan bodies made from different materials and to determine the appropriate tightening torque value for scan bodies that can accurately replicate abutment subsidence.

Our hypothesis is:

- 1. Titanium abutments (Ti Abuts) and titanium scan bodies (Ti SBs) will not differ in the amount of subsidence with tightening.
- 2. Polyetheretherketone scan bodies (PEEK SBs) exhibit a more significant amount of subsidence than titanium abutments (Ti Abuts) when subjected to the identical tightening torque.

This study aims to improve the accuracy of implant impressions and reduce the risk of illfitting superstructures by providing a detailed analysis of the subsidence behavior of different scan body materials and their optimal tightening torque values. This, in turn, could lead to better clinical outcomes and provide guidelines for the effective use of scan bodies in implant dentistry.

2. Materials and Methods

2.1. Power analysis

Power analysis was performed using analysis software (JMP pro17; SAS, Cary, North Carolina, United States). The total sample size was calculated based on an actual power of 0.8, alpha error probability of 0.05, and power of 0.8. The results of power analysis revealed that a minimum of nine datasets were required for each workflow. However, to increase the power, the study was performed using 10 datasets.

2.2. Fabrication of experimental model

An experimental model was constructed by placing an internal taper connection implant (Bone Level Implant $\phi 4.1 \times 10$ mm; Straumann, Basel, Switzerland) into a laminated bone model of a cuboid shape (SAW1522-01-07P6; Avicel, Tokyo, Japan). The mechanical fixation of the implant body was confirmed using a digital torque wrench (iSD900; JMM, Osaka, Japan).

2.3. Generation of control data

Five prosthodontists with more than five years of clinical experience working at Kyushu University Hospital were asked to tighten the scan body manually, and the torque values were measured using a digital torque gauge (MGT12, MARK-10 Co., New York, NY, USA). For this measurement, the control tightening torque value was set at 10 Ncm. A PEEK SB (CARES Mono Scanbody RC; Straumann, Basel,

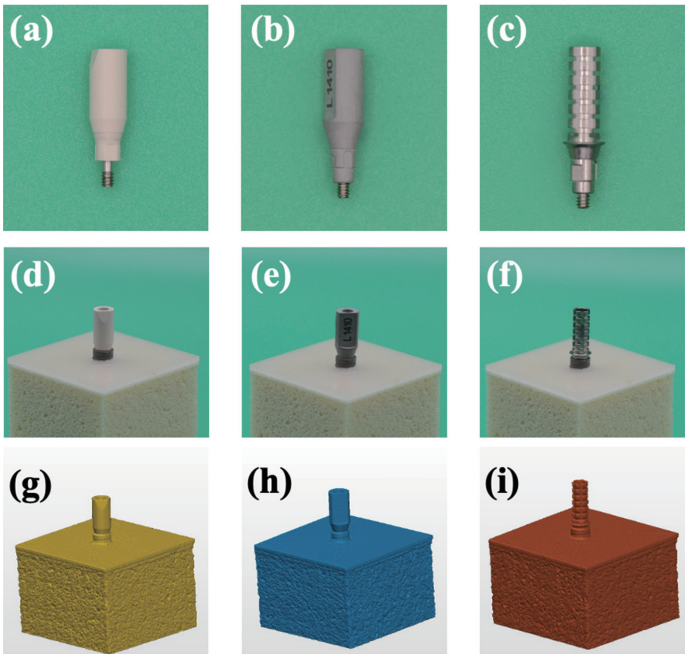


Fig. 1. (a), (b), and (c) are scan bodies and abutment used in the experiment. (a) is the polyetheretherketone scan body (PEEK SB, CARES Mono Scanbody RC; Straumann, Switzerland), (b) titanium scan body (Ti SB, L Series Scanbody RC; Medentika, Switzerland), and (c) titanium abutment (Ti Abut, RC Temporary Abutment, Crown; Straumann). Scan body or abutment tightened to the experimental model using the JMM digital torque wrench at two torque values (10 and 35 Ncm). (d) is the PEEK SB, (e) Ti SB, and (f) Ti Abut. STL data obtained by scanning an experimental model using a laboratory scanner (3shape E4 3D scanner version: 2.22.1.1; 3Shape, Copenhagen, Denmark). One set of data from tightening at 10 Ncm was used as control data. Ten sets of data, each from tightening either at 10 or 35 Ncm, were prepared and used as measurement data. (g) is the PEEK SB, (h) the Ti SB, and (i) the Ti Abut.

Switzerland) (**Fig. 1a**) was tightened to the experimental model at a torque value of 10 Ncm (**Fig. 1d**) by the digital torque wrench. This assembly was scanned using a laboratory scanner (3shape E4 3D scanner version:2.22.1.1; 3Shape, Copenhagen, Denmark), and the obtained stereolithography (STL) data were used as control data for the PEEK SB (**Fig. 1g**). Similar procedures were performed for the Ti SB (L Series Scan body RC; Medentika, Hugelshheim, Germany) (**Figs. 1b and e**) and the Ti Abut (RC Temporary Abutment, Crown; Straumann) (**Figs. 1c and f**), and control data for both components were obtained (**Figs. 1h and i**). For the Ti Abut, powder (Pure Scan Powder; Quest Corporation, Aichi, Japan) was uniformly applied for optical scanning purposes, and the surface condition was identical to that of the Ti SB. The scan powder was reported to have no effect on the scanning accuracy[27]. In this experiment, because of the possibility of unevenness among multiple implants, we used one implant body.

2.4. Verification of scanner accuracy

In a pilot experiment, we verified the accuracy of the scanner used in this experiment, which was a laboratory scanner. The PEEK SB was fixed to an internal tapered connection implant in a laminated bone model by hand tightening. This model was scanned 10 times using a laboratory scanner to produce 10 STL images. We used one of these data sets as control data for the pilot experiment. STL data were imported into the three-dimensional analysis software (PolyWorks Inspector version:18.9.6181; InnovMetric, Quebec City, Canada). We used the best-fit function of the software to superimpose the control and other nine datasets. We measured the distance between the control and other data on the top surface of the scanned body. We defined these distances as the error between the data, and the magnitude of the error as the scanner's accuracy.

2.5. Generation of measurement data

The PEEK SB was tightened at a torque of 10 N cm, and the STL data for 10 Ncm were obtained using a laboratory scanner. This process was repeated 10 times. To prevent material fatigue due to tightening, we replaced the scan body with a new one after each scan and retightened it with the same torque value using a digital torque wrench. Similarly, the PEEK SB was tightened with a torque value of 35 Ncm (the same value as the abutment tightening torque recommended by the manufacturer), and 10 scans were performed to obtain the STL data. The obtained data were used as the measured STL data for the PEEK SB. Similar procedures were conducted for Ti SB and Ti Abut, and the measurement data for both components were obtained. Scanning of the Ti Abut was performed by applying a powder to obtain the control data.

2.6. Generation of superimposed data

The STL data of the control measurements were imported into three-dimensional analysis software. The three planes perpendicular to each other of the bone block used in the experimental model were used as references, and the control and measured data were superimposed (**Figs. 2a and b**).

2.7. Measurement of vertical displacement

The difference in the vertical position in the direction of the implant axis at the topmost surface of the component was considered as the vertical displacement due to the tightening torque (**Figs. 2c, d and e**). For each superimposed data point, 10 measurement points were set symmetrically on both sides (**Figs. 2 f, g, and h**), and the vertical displacement at each point was determined. Vertical displacement was defined as positive if it was above the control value and negative if it was below the control value.

2.8. Statistical analysis

The vertical displacements obtained were compared for different torque values and components. The median and IQR of the vertical displacement were calculated for each group. For analysis, the Mann–Whitney *U* test was employed using JMP pro17 and a value of $P < 0.05$ was considered statistically significant. For multiple comparisons, Bonferroni correction was performed.

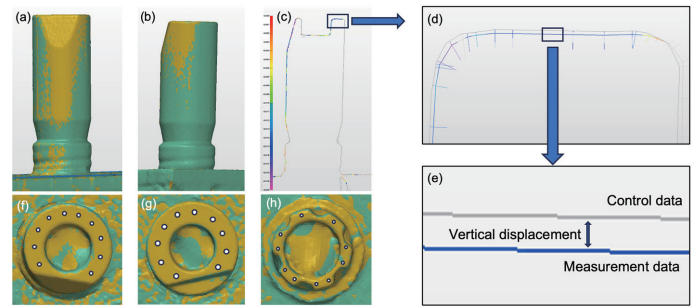


Fig. 2. Control data and measurement data were superimposed by reference planes using three-dimensional analysis software (PolyWorks Inspector; InnovMetric, Quebec city, Canada) (yellow data: control data, green data: measurement data). (a) is the front view and (b) is the side view. (c) is the cross-section of (b). (d) and (e) are enlarged views of (c). Vertical displacement in the direction of the implant axis at the topmost surface of the component was the displacement due to the tightening torque. (f), (g), (h) are 10 measurement points on the superimposed data, arranged symmetrically. (f) is the polyetheretherketone scan body, (g) the titanium scan body, (h) the titanium abutment. The vertical displacement at each point was determined. If the measured data were above the control data, the vertical displacement was defined as positive. If the measured data were below the control data, the vertical displacement was defined as negative.

3. Results

3.1. Control tightening torque value

To generate control data, it was necessary to determine the control-tightening torque value. Because many manufacturers do not specify the torque value for tightening the scan body, we determined the tightening torque of the scan body for the control data. The average value of the hand tightening torque was 10.8 ± 2.5 Ncm.

3.2. Scanner accuracy

The accuracy of this laboratory scanner was approximately ± 3 μ m. Based on the results of the accuracy verification, we determined that a laboratory scanner could be used in this experiment.

3.3. Vertical displacement

Several previous reports have shown that vertical displacement due to screw tightening of abutments and scan bodies is much greater than horizontal displacement[7,25,26]. Therefore, this study focused on the vertical displacement in the experiments. The PEEK SB was displaced vertically by 0.00 μ m (interquartile range (IQR): -1.00 to 1.00) when tightened at 10 Ncm and by -16.00 μ m (IQR: -18.00 to -12.75) when tightened at 35 Ncm, being significantly greater at 35 Ncm ($P < 0.01$) (**Table 2 and Fig. 3**). The Ti SB was displaced vertically by 0.00 μ m (IQR: -2.00 to 2.00) when tightened at 10 Ncm and by -19.00 μ m (IQR: -21.00 to -17.00) when tightened at 35 Ncm, being significantly higher at 35 Ncm ($P < 0.01$). The Ti Abut was displaced vertically by 0.00 μ m (IQR: -2.00 to 2.00) when tightened at 10 Ncm and by -19.00 μ m (IQR: -20.00 to -17.75) when tightened at 35 Ncm, being significantly greater at 35 Ncm ($P < 0.01$). No significant difference was observed between the PEEK SB and Ti SB when tightened at 10 Ncm ($P = 0.5605$), whereas displacements of the Ti SB were significantly greater than the PEEK SB when tightened at 35 Ncm ($P < 0.01$) (**Table 3 and Fig. 3**). No significant differences were observed between Ti SB and Ti A when tightened at 10 ($P = 0.8589$)

Table 2. Comparison of vertical displacement for different torque values by Mann-Whitney *U* test

Material	Median of vertical displacement (IQR)		P value
	10 Ncm	35 Ncm	
PEEK SB	0.00 μm (-1.00 – 1.00)	-16.00 μm (-18.00 – -12.75)	<0.01
Ti SB	0.00 μm (-2.00 – 2.00)	-19.00 μm (-21.00 – -17.00)	<0.01
Ti Abut	0.00 μm (-2.00 – 2.00)	-19.00 μm (-20.00 – -17.75)	<0.01

IQR: interquartile range, PEEK SB: polyetheretherketone scan body, Ti SB: titanium scan body, Ti Abut: titanium abutment

Table 3. Comparison of vertical displacement between different materials by Mann-Whitney *U* test with Bonferroni correction (for the PEEK SB and Ti SB)

Tightening torque	Median of vertical displacement (IQR)		P value
	PEEK SB	Ti SB	
10 Ncm	0.00 μm (-1.00 – 1.00)	0.00 μm (-2.00 – 2.00)	0.5605
35 Ncm	-16.00 μm (-18.00 – -12.75)	-19.00 μm (-21.00 – -17.00)	<0.01

IQR: interquartile range, PEEK SB: polyetheretherketone scan body, Ti SB: titanium scan body

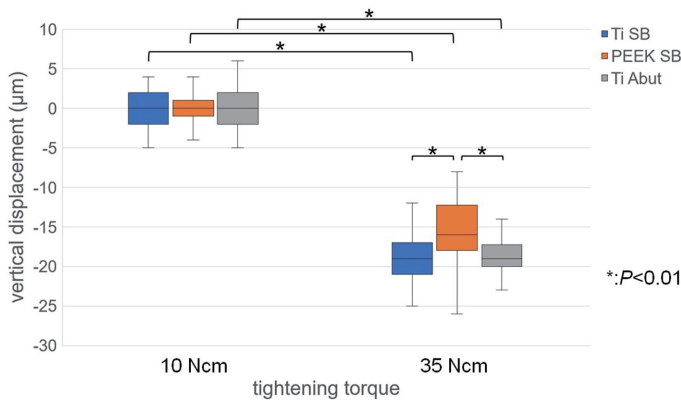


Fig. 3. Comparison of vertical displacement by Mann-Whitney *U* test. For all components, vertical displacement increased significantly with the increased tightening torque value. No significant difference in vertical displacement was observed at 35 Ncm between the titanium scan body (Ti SB) and titanium abutment (Ti Abut), whereas a significant difference was found at 35 Ncm between the polyetheretherketone scan body (PEEK SB) and Ti Abut and between the PEEK SB and Ti SB.

or 35 Ncm ($P = 0.8941$) (**Table 4 and Fig. 3**). No significant difference was observed between PEEK SB and Ti A when tightened at 10 Ncm ($P = 0.7084$), whereas the displacements of Ti Abut were significantly greater than those of PEEK SB when tightened at 35 Ncm ($P < 0.01$) (**Table 5 and Fig. 3**).

4. Discussion

4.1. Scan body subsidence

Tightening both the PEEK and Ti SB with a strong torque significantly increased the vertical displacement in the negative direction. This increase in the vertical displacement indicated that the scan body subsidence was due to screw tightening. As the scan bodies were also connected to the internal taper connection, it was proposed that the tightening caused scan body subsidence, as reported in a previous study[25].

4.2. Error in scan bodies (when tightened at 10 Ncm)

No significant difference was observed between the PEEK SB and Ti SB when tightened at 10 Ncm. This result suggests that there is no difference in the scanning accuracy between the PEEK SB and Ti SB because the tightening torque value of 10 Ncm was the same as that of the control data. In contrast to the current study, past reports indicated that Ti SBs had poorer scanning accuracy than PEEK SBs. Because both the Ti and PEEK SBs used in that report were custom-made, this may include an implant-abutment misfit[28]. In this study, an implant system with approved high implant-abutment fittingness was employed[29]. This may explain why there were no differences in scanning accuracy between the Ti and PEEK SBs in the current study.

4.3. Error in scan bodies (when tightened at 35 Ncm)

When tightened at 35 Ncm, a significant difference was observed between the PEEK SB and Ti SB. This difference is attributed to the distinct physical properties of PEEK and Ti. Factors contributing to scan body subsidence due to tightening include changes in position due to the internal taper connection[7] and deformation of the scan body due to torque[25,26]. The Young's modulus of PEEK is approximately 3–4 GPa[30], whereas that of titanium is approximately 102–104 GPa[31], indicating that PEEK is significantly more deformable. Therefore, the impact of scan body deformation due to the tightening torque[25,26] likely disproportionately affected the PEEK SB, resulting in differences in subsidence. The difference in the base design between the PEEK SB and Ti SB (**Figs. 1a and b**) might also influence the difference in subsidence.

4.4. Comparison of subsidence between the Ti Abut, Ti SB, and PEEK SB

When comparing the subsidence of Ti Abut to that of Ti SB at 35 Ncm, no significant difference was observed, whereas a significant difference was observed when compared to PEEK SB. This result suggests that the subsidence of Ti Abut could be reproduced with the Ti SB but not with the PEEK SB.

Because an implant superstructure requires a passive fit, a possible misfit, at any value, is unavoidable. The misfit should reportedly be less than 10 μm to achieve an acceptable fit[32], but the amount of acceptable misfit has been changing in recent years. Other reports in-

Table 4. Comparison of vertical displacement between different materials by Mann–Whitney *U* test with Bonferroni correction (for the Ti SB and Ti Abut)

Tightening torque	Median of vertical displacement (IQR)		P value
	Ti SB	Ti Abut	
10 Ncm	0.00 μ m (-2.00 – 2.00)	0.00 μ m (-2.00 – 2.00)	0.8589
35 Ncm	-19.00 μ m (-21.00 – -17.00)	-19.00 μ m (-20.00 – -17.75)	0.8941

IQR: interquartile range, Ti SB: titanium scan body, Ti Abut: titanium abutment

Table 5. Comparison of vertical displacement between different materials by Mann–Whitney *U* test with Bonferroni correction (for the PEEK SB and Ti Abut)

Tightening torque	Median of vertical displacement (IQR)		P value
	PEEK SB	Ti Abut	
10 Ncm	0.00 μ m (-1.00 – 1.00)	0.00 μ m (-2.00 – 2.00)	0.7084
35 Ncm	-16.00 μ m (-18.00 – -12.75)	-19.00 μ m (-20.00 – -17.75)	<0.01

IQR: interquartile range, PEEK SB: polyetheretherketone scan body, Ti Abut: titanium abutment

icated that a misfit greater than 100 μ m was unacceptable because it caused strain above the adaptation threshold of the bone[33], or misfit larger than 30 μ m was unacceptable because it caused superstructure failure[9]. The differences in the vertical displacement measured in this experiment may be considered acceptable because they were smaller than the acceptable values. However, each step in the fabrication of a prosthetic device is a misfit factor. To reduce misfits, all dentists eliminated errors in all the processes. We considered that reproducing the subsidence of the abutment by the scan body was very important in terms of preventing misfits because it reduced the error of the prosthetic device.

As mentioned above, many implant manufacturers recommend tightening the scan bodies with low torque. However, to reproduce abutment subsidence caused by screw tightening in the scan body, when using scan bodies for implants with internal taper connections, it was suggested that scan bodies of the same material as the abutment were tightened at the same torque value.

4.5. Limitations of this study

In the current study, we used only one implant body because of the possibility of unevenness among multiple implants. However, damage to the implant body owing to tightening may have affected these results.

In this study, a laboratory scanner was employed to accurately measure the displacement values of the scan body/abutment. However, in clinical situations, scanning is performed using an IOS, which is less accurate than a laboratory scanner. Thus, our results obtained using a laboratory scanner did not necessarily reflect actual clinical settings.

5. Conclusions

In internal taper connection implants, both the scan bodies and abutments subsided with screw tightening. The titanium scan bodies, when tightened at 35 Ncm, accurately replicated titanium abutment subsidence, unlike the PEEK scan bodies.

To reproduce the subsidence of the abutment with the scan body, it is recommended to tighten the scan body made of the same material as the abutment with an equivalent torque value.

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Conflict of interest statement

The authors have no conflicts of interest to declare.

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