Vertical Deviation Caused by Tightening Torque on Implant Scan Body: An In Vitro Study

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Purpose: This study evaluated the effects of manipulator level (ML) on implant scan body (ISB) seating. It also investigated ISB vertical deviation with various levels of tightening torque. ***Materials and Methods:*** In total, 10 standard acrylic resin models were prepared with the implant on the first molar site. ISBs were placed on the models by six operators with three MLs, manually and with a torque of 15 Ncm using an electronic torque driver. Digital scans were completed with an intraoral scan device. After superimposition in the software, ISB vertical deviation was compared between the 15 Ncm torque level and manual operation. One experienced operator then placed the ISB with different torque levels (20, 25, 30, and 35 Ncm) using an electronic torque driver. The ISB vertical deviation was also compared among torque levels. Vertical deviations within ML were analyzed using one-way analysis of variance (ANOVA). One-way repeated measures ANOVA was used to analyze the differences between torque levels ($\alpha = .05$). ***Results:*** ISB vertical deviations differed among MLs ($P < .01$). Significant vertical deviations were observed between 20 and 30 Ncm ($P < .01$), 20 and 35 Ncm ($P < .05$), and 25 and 35 Ncm ($P < .05$). The largest estimated marginal mean was 13.5 ± 4.11 μm with a torque of 35 Ncm. ***Conclusion:*** Significant differences in ISB vertical deviation were observed according to MLs and tightening torque levels. The amounts of those deviations did not exceed the previously described occlusal threshold. *Int J Prosthodont 2021 October 5. doi: 10.11607/ijp.7493. Online ahead of print.*

In recent years, new technological developments have substantially changed the prosthetic designs and fabrication workflows of implant reconstructions,[1] improved time-efficiency, and fulfilled patient expectations of modern treatment.[2] Within the new digital workflows, implant scan bodies (ISBs) are essential implant-positioning-transfer devices.

The internal connection of the implant may influence displacements of ISBs and abutments upon tightening[3] and may affect accurate fitting of implant-supported restorations. Extensive studies have investigated factors that affect implant abutments, including tightening torque,[4–7] manipulators,[8,9] repeated detachment and retightening,[10–13] precision of mechanical torque wrenches,[14,15] and differences among restored prosthetics.[16–19] Implant internal connection designs influence the amount of abutment displacement according to the degree of directional torque.[16–18,20] However, few studies have focused on these factors with regard to ISBs.

When ISBs and implant abutments are seated, tightening torque can differ among them. The operator may manually tighten the ISBs with unclear torque for the optical impression procedure in the dental clinical setting. During subsequent suprastructure delivery, the abutment with restoration is tightened to a specific torque in accordance

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Fig 1 Surgical guide on printed mandibular model.

with the manufacturer's instructions. Increased torque can cause positional discrepancies involving some ISBs.[3] To date, the amounts of such discrepancies and their influences on the seating accuracy of the restorations have not been fully investigated.

The primary aim of this study was to evaluate the effects of manipulator level (ML) on ISB seating precision. The secondary aim was to investigate the effects of tightening torque on ISB vertical deviations. Thus, the following null hypotheses were established: ISB seating precision will not differ among MLs; and no ISB vertical deviations will occur in implant digital models due to differences in tightening torque.

MATERIALS AND METHODS

Master Model

In total, 10 standard mandibular acrylic resin models with absent bilateral first molars were printed (Objet30 Pro, Stratasys). Using mandibular right first molars as implant sites, CBCT scans were performed and ideal implant positions were planned in the software (3Shape Dental Manager, version 18.2.0). Surgical guides were then printed to standardize the implant placement for each model (Fig 1).

The preparation of implant sites was performed under full surgical guidance, in accordance with the manufacturer's instructions. The implants (BLT, Straumann, 4.1 × 10 mm) were manually maneuvered into the implant sites, using a thin layer of metal bonding cyanoacrylate adhesive (Permabond 910) to mimic osseointegration. The initial implant torque was > 50 Ncm. The platform was placed 0.5 mm superior to the resin surface, thereby avoiding ISB interference during seating (Fig 2a). All procedures were performed by an experienced implant surgeon (F.L.).

ISB Placement

An ISB (ScanPost S BL 4.1L, 6431253, Dentsply Sirona) was placed on each model by six operators (X.R.L., S.M.L., M.Z.W.) with three MLs. ML0 (Manipulators no. 1 and no. 6) included medical professionals without any dental clinical experience, ML1 (Manipulators no. 3 and no. 4) included dentists without implant restorative experience, and ML2 (Manipulators no. 2 and no. 5) included dentists with extensive restorative implant experience. All operators were blinded to the aims of the study. Each operator was asked to place the ISB twice on each master model, once manually and once with a torque of 15 Ncm using an electronic torque driver (16934000, W&H). One experienced operator was then asked to place the ISB on each master model with different torque levels (20 Ncm, 25 Ncm, 30 Ncm, and 35 Ncm) using an electronic torque driver. After ISB placement, a scan cap (Scanbody for Omnicam, 6431311, Dentsply Sirona) was seated on the ISB for scanning. The antirotation structure was placed on the buccal side (Fig 2b).

Scan Procedure

An intraoral scan device (Trios 3, 3Shape) with custom software (3Shape Dental System, version 1.6.4.4) was used for scanning. All scans were performed by an experienced operator who had been trained in the use of the scanning device but was blinded to the aims of the study. The scan procedure involved two components. The first component focused on ML differences: Scans of each master model were performed when ISBs had been seated manually and with a torque of 15 Ncm. The

Fig 2a Implant seated on mandibular model. The platform was placed 0.5 mm superior to the resin surface.

Fig 2b Implant implant scan body (ISB) in place.

second component focused on torque level differences: Each master model was scanned six times with a torque of 15, 20, 25, 30, and 35 Ncm. Each master model was regarded as a scan group. Within each group, baseline scans were performed with a torque of 15 Ncm. The scan sequences were randomized and their order was only known to the research designer. A rest time of ≥ 15 minutes for the operator was implemented between scan groups.

Data Processing

The scan files of each group were imported into the design software (3Shape Dental System) and then aligned using a three-point model. If matching was unsuccessful, rescanning of the corresponding group was performed.

After superimposition, for the analysis of ML, ISB vertical deviation was measured after seating had been performed manually and with a torque of 15 Ncm. For the analysis of torque level, deviations were measured after seating had been performed with a torque of 15 Ncm, and after seating had been performed with other levels (20, 25, 30, and 35 Ncm). Vertical deviation was defined as the distance between the platform of the scan caps under the section model (Fig 3). The sections were acquired, and distances were measured at three distinct positions: buccal, distal, and mesial, as shown in Fig 3.

Statistical Analysis

All analyses were performed using SPSS Statistics version 26.0 (IBM) and R version 3.5.0 (R Foundation for Statistical Computing). Considering the 10 master models and

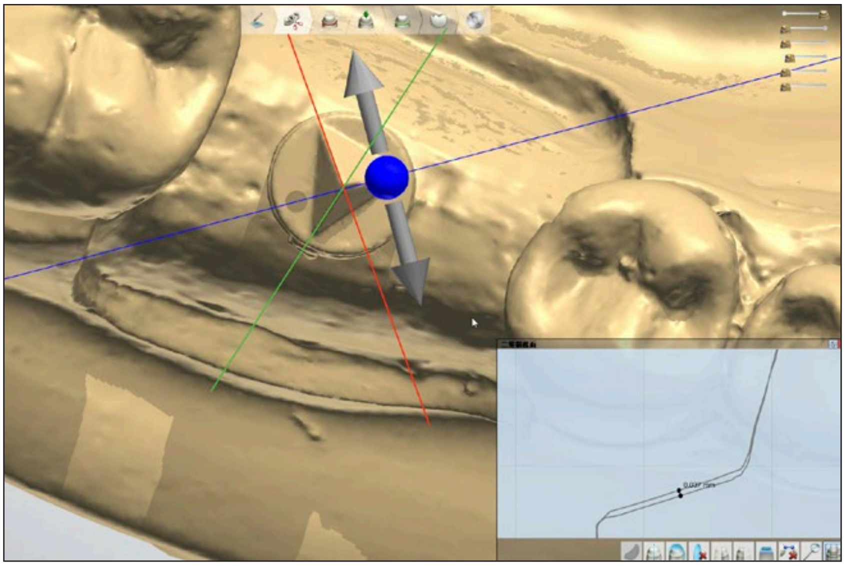

Fig 3 Measurement of vertical deviation in the software. Green line = buccal position; red line = distal position; blue line = mesial position.

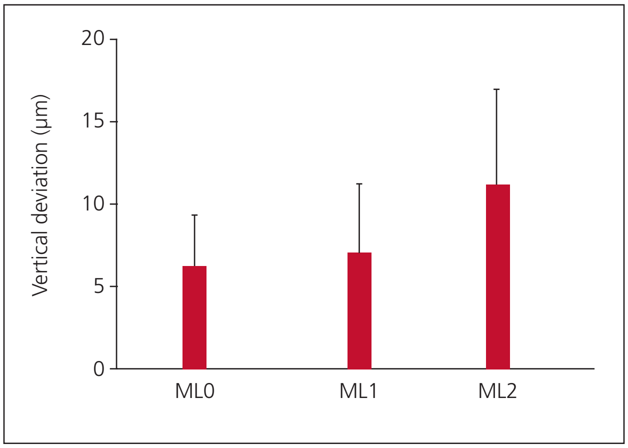

Fig 4 Vertical deviations of ISB in different MLs.

differences among three MLs and six torque levels in each model group, 110 scans were completed and 100 deviations were calculated. Furthermore, each calculation had three positions, so 300 total vertical deviation data points were analyzed. Considering the analysis of variance (ANOVA) approach and assuming a significance level of .05 with 10 master models per group, a test power of 0.97 was determined.

Vertical deviations between manipulators were analyzed using one-way ANOVA. Shapiro-Wilk test was used to determine whether the data had a normal distribution. Differences among positions (buccal, distal, and mesial) were calculated. If these differences were not statistically significant, the mean values of each position were used. Moreover, vertical deviations among MLs were computed.

One-way repeated measures ANOVA was used to analyze differences among torque levels. The Shapiro-Wilk test was used to determine whether the data had a normal distribution. Mauchly's spherical test was used to determine whether dependent variables had equal covariance matrices. If they did not and the epsilon correction was < 0.75, Greenhouse-Geisser calibration was performed. Otherwise, Huynh-Feldt calibration was performed. Comparisons within and between variables were performed.

Differences Between MLs

The Shapiro-Wilk test revealed that the data had a normal distribution ($P > .05$). ISB vertical deviations between seating performed manually and with a torque of 15 Ncm in different positions were first determined by one-way ANOVA. The means ± SDs were as follows: mesial: 7.10 ± 5.25 μm; distal: 7.97 ± 6.19 μm; and buccal: 8.72 ± 7.65 μm. No significant differences were observed among positions ($F = 0.946$, $P = .39$).

Considering the data from measurement positions as three repeated measurements, the ISB vertical deviations among manipulators differed significantly between seating performed manually and with a torque of 15 Ncm ($F = 2.77$, $P = .27$). The difference among MLs was also statistically significant ($F = 7.042$, $P = .002$). The ISB vertical deviations were 5.58 ± 2.56 μm for ML0, 7.08 ± 4.84 μm for ML1, and 11.1 ± 6.31 μm for ML2, as shown in Fig 4. Comparisons between manipulators revealed significant differences between nos. 1 and 2, nos. 1 and 5, nos. 2 and 4, nos. 2 and 6, and nos. 5 and 6, as shown in Fig 5.

Vertical Deviations Among Torque Levels

Shapiro-Wilk test revealed that the data had a normal distribution ($P > .05$). One-way repeated measures ANOVA was used to determine the effects of measurement position and torque level on ISB vertical deviations.

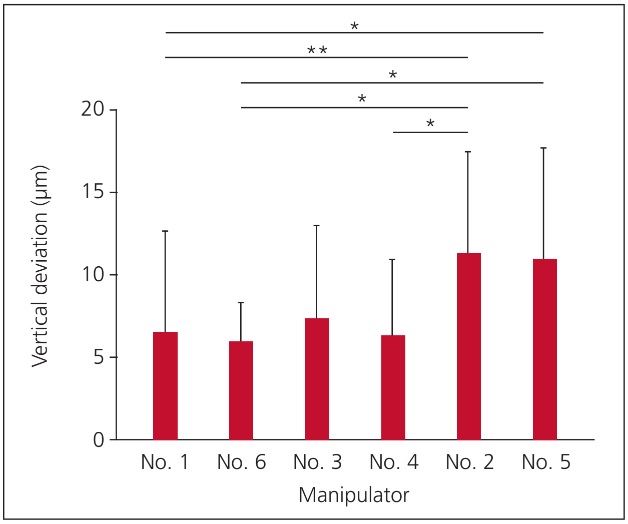

Fig 5 Vertical deviations of ISB between different manipulators (*$P < .05$; **$P < 0.1$).

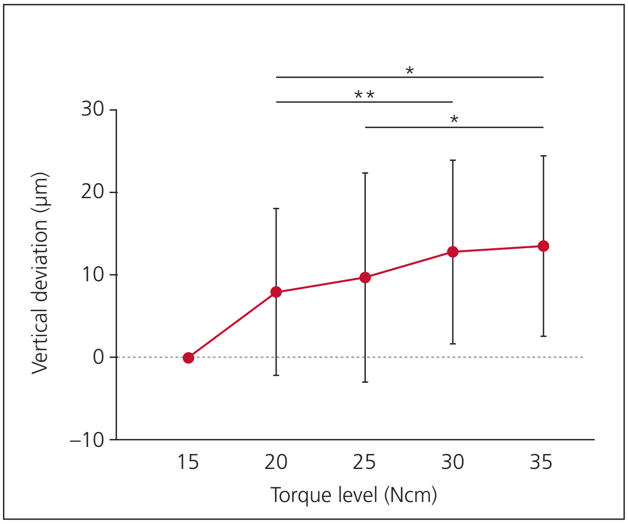

Fig 6 Vertical deviations of ISB under different torque levels (*$P < .05$; **$P < 0.1$).

Mauchly's spherical test revealed that the covariance matrixes of dependent variables were unequal (χ^2 = 25.782, *P* = .000), so the Greenhouse-Geisser calibration was performed (ε = 0.599).

With regard to the effect of measurement position, Table 1 lists the means of vertical deviations with a torque of 15 Ncm. After calibration, the data did not differ significantly (F [3.593, 48.502] = 1.604, *P* = .193). Thus, the data from the different measurement positions were regarded as three repeated measurements.

Comparison of ISB vertical deviations between 15 Ncm and other torque levels revealed a significant difference after calibration (F [1.556, 14.004] = 5.152, *P* = .027). Estimated marginal means of the vertical deviations of 20-, 25-, 30-, and 35-Ncm torque levels were as follows: 6.4 ± 4.11 µm, 9.8 ± 4.12 µm, 12.8 ± 4.11 µm, and 13.5 ± 4.11 µm, respectively. Significant differences were observed between 20 and 30 Ncm (*P* = .004), 20 and 35 Ncm (*P* = .027), and 25 and 35 Ncm (*P* = .013), as shown in Fig 6.

Table 1 Mean (± SD) Vertical Deviations of ISB (in µm) in Different Measurement Positions

Torque level (Ncm)	Measurement position		
	Mesial	Distal	Buccal
20	11.1 ± 17.1	3.6 ± 12.9	4.5 ± 12.3
25	8.6 ± 12.1	8.7 ± 14.3	12.1 ± 13.2
30	11.6 ± 11.3	13.5 ± 14.3	13.4 ± 9.7
35	12.3 ± 12.1	12.0 ± 13.5	16.3 ± 10.9

DISCUSSION

Significant differences in vertical deviations were found among MLs and among tightening torque levels. Therefore, both null hypotheses were rejected.

The primary literature concerning the implant abutment tightening torque reported no significant differences in mean maximum torques according to operator level.[8] Moreover, manual tightening was insufficient to achieve the manufacturer-recommended preload values.[9] However, operator differences reportedly did not affect the accuracy of ISB image matching.[21]

In the present study, significant differences were observed among MLs when ISBs were manually tightened. Because few comparable investigations have been conducted, these results might be influenced by the absence of a clear manufacturer recommendation concerning ISB torque. A previous study reported no difference in mean maximum torque generated by professors and postgraduate dental students.[8] However, the present study found that inexperienced manipulators (groups ML0 and ML1) implemented maximum torque, but experienced manipulators did not.

The ISB constitutes a digital impression of the implant position. It commonly consists of three regions: scan, body, and base. ISB construction materials influence changes in position, especially with regard to torque-induced base region transformation.[3] In the present study, a two-piece ISB was used, containing a titanium base region and a polyetheretherketone (PEEK) scan region. The use of PEEK materials is presumed to reduce the light reflectance problem that can occur in metal alloys, and the titanium base region can tolerate tightening torque similar to that of abutments.

Although more displacement has been reported in one-piece PEEK scan bodies than in titanium scan bodies, PEEK scan bodies also require less tightening torque (as recommended by the manufacturer), usually < 10 Ncm or a manually achieved torque. Excess ISB torque could damage the internal connection of the implant or the scan body. Notably, the Straumann products have shown no material-related differences in positional displacement.[22]

Most manufacturers do not have clear recommendations concerning the tightening torque of titanium-based ISBs. Large deviations in tightening torque between ISBs and abutments might create difficulty in the selection of appropriate torque level in dental practice, especially during immediate implant restorations with digital methods.

The results of this study revealed no significant vertical positional difference between torque levels of 20 and 25 Ncm, nor between torque levels of 30 and 35 Ncm. However, significant differences were observed between torque levels of 20 and 30 Ncm, and between torque levels of 20 and 35 Ncm. The torque level of 20 Ncm may constitute an inflection point. With regard to the estimated marginal means, this study found that without considering other systematic error, a maximum vertical deviation of 17.61 μm would be caused by a torque of 35 Ncm.

Previous studies have reported that implant restorations have a lower passive threshold level compared with natural teeth,[23] such that the occlusal force of implant restorations cannot exceed 60% of the occlusal force in normal natural teeth.[24] Some researchers have reported that the occlusal threshold of implant vs natural teeth is approximately 48 μm, and they suggested that the occlusal contact of implant restorations would be 30 μm less than that of adjacent natural teeth.[25–27]

Systematic error might also have been caused by the intraoral scan device. The Trios 3 was used in the present study; this is a third-generation intraoral scan device fabricated by 3Shape. Many investigations have focused on its scan accuracy and precision, and accordingly the device has significantly improved mean trueness and precision compared with the closed-tray method.[28] Trueness values were 16.8 ± 3.8 μm in the complete-arch scanning condition,[29] 50.2 ± 2.5 μm in the partial edentulous scanning condition (three implants),[28] and 22.3 ± 0.5 μm in single-crown implant restorations.[30] Considering these findings with the above-mentioned vertical deviation, a vertical deviation of 39.51 μm would be caused by a torque of 35 Ncm. However, this value remains below the occlusal threshold mentioned in the literature.

The data of the present study and the findings in the literature suggest that patients would experience minimal potential occlusal deviation of implant-supported single crowns caused by ISB tightening torque alone. However, potential errors might occur in other steps during the fabrication of the restorations, so the present study involved some limitations. Notably, the vertical deviation of the final restoration could be influenced by the combination of errors from all steps. Therefore, further investigations are needed to identify the effects of other dental clinical and laboratory steps. Ultimately, those potential effects, including the ISB vertical position change investigated in the current study, should be integrated to analyze their influence on overall accuracy of final restorations.

Moreover, scanning precision is not substantially influenced by ISB detachment and repositioning.[3] With regard to the scan strategy, a one-step strategy may be more beneficial than a two-step strategy (ie, a digital overlay performed with a scan of the master model, without integrated scan bodies, followed by a second scan with the integrated scan bodies).[31] Therefore, the present investigation method is not expected to add further systematic error.

A previous study reported that a conical-joint design implant system had more position changes in the vertical direction.[17] The Straumann and Astra Tech systems did not significantly differ, so the classical Straumann implant BL system was used in the present study. In accordance with the surgical guide, the implant shoulder of the BL system should be positioned approximately 3 to 4 mm below the prospective gingival margin. During ISB seating, greater soft tissue resistance might be encountered. Overall, in this study there were more opportunities to observe the effects of torque differences when ISBs had been placed.

In accordance with the manufacturer's recommendation, the two-piece ISB used in this study is intended for single use. However, for nonedentulous implant restorations, repeated ISB use (≤ 10 times) does not affect digital impression accuracy.[32] In this experimental design, 11 scans were completed for each master model (six for comparison of MLs and five for comparison of torque levels). To minimize the wear caused by multiple detachment, the PEEK scan portion was replaced after each scan, and the titanium base portion was replaced after each master model analysis.

CONCLUSIONS

Within the limitations of this in vitro study, the following conclusions can be drawn:

- Different MLs caused significant differences in ISB vertical positions in the digital impressions of single-implant restorations.
- The extent of changes in ISB vertical positions in the digital impressions was influenced by the levels of tightening torque applied to the ISBs.

- Further studies are needed to determine positional changes in other directions and to confirm whether the aforementioned factors could have clinically significant effects on the final restorations.

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