Can we predict the insertion torque using the bone density around the implant?


Abstract. The purpose of this study was to examine the correlation between initial stability and bone density in patients undergoing implant treatment. Twenty-five screw-type dental implants were inserted in 12 patients. All patients underwent multi-detector computed tomography (CT) examination prior to implant insertion. The implant sockets were prepared according to the drilling protocol, and peak insertion torque values were measured. CT values around the implants were measured using preoperatively scanned CT data, which were combined with actual implant positions. Spearman’s rank correlation coefficient was used to investigate the correlation between insertion torque values and CT values (in Hounsfield units,HU). Twenty-three implants (8 or 10 mm in length) were inserted in the mandibular molar region and two (10 mm length) in the maxillary molar region. The mean CT value of the 8-mm implants was 508.6 ± 187.0 HU and mean insertion torque was 27.2 ± 12.1 N·cm; for the 10-mm implants, these values were 579.6 ± 224.3 HU and 28.1 ± 14.6 N·cm, respectively. Statistical analysis revealed a strong positive correlation between the insertion torque and mean CT values \((r = 0.699, 8 \text{ mm}; r = 0.771, 10 \text{ mm})\). The results revealed that bone density around the implant is a useful index. This study indicates that preoperative CT may enable the prediction of initial implant stability.

Key words: CT value; insertion torque; prediction.

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Ensuring good initial stability after implant insertion is reported to be important for the initial success of implant treatment. Orenstein reported that the 3-year survival rate of implants that had mobility when inserted was 79.8%, compared to 93.4% for implants that were stable.1 Initial stability can be evaluated by measuring the implant stability quotient (ISQ) and insertion torque values. The ISQ is a useful index for the evaluation of initial stability and the change in implant stability over time. In fact, there are many reports on the correlation between bone density and the ISQ value.2,3 On the other hand, in an in vitro study, Ito et al. showed that the implant–bone contact in the neck region of the implant affects ISQ values more than the contact in the other implant regions. This means that ISQ values tend to be high when implants are fixed in cortical bone, even when insertion torque values are low.4 Insertion torque is affected by a range of factors, including the implant body shape, size, and surface morphology, the surgical procedure used, and bone density.5 An in vitro study using pig bone showed a significant correlation between the density of the bone around the implant and insertion
torque values.\(^6\) It is thought that there may be a correlation in human subjects, as was found in the in vitro study. Although a few reports have addressed the correlation between bone density and initial stability in human subjects,\(^7\) very few detailed studies have been performed. This study was performed to investigate the correlation between insertion torque values and bone density in patients undergoing implant treatment.

Materials and methods

Twelve patients (nine females and three males, mean age 66.7 ± 6.9 years) who were scheduled for implant treatment consented to participate in this study. Patients who had undergone tooth extraction within the previous 3 months, those who required bone augmentation simultaneously with implant insertion, and patients with any systemic condition were excluded.

Twenty-five screw-type dental implants (Genesio Plus; GC Corporation, Japan) with a diameter of 3.8 mm and length of 8 mm or 10 mm were inserted.

All patients underwent a multi-detector computed tomography (CT) examination prior to the implant insertion procedure (LightSpeed VCT, GE Medical Systems, Japan). The implant sockets were prepared according to the drilling protocol using a 3.1-mm twist drill and a counterbore drill for final preparation, and peak insertion torque values were measured at the time of implant insertion. Insertion torque values were measured with a micromotor capable of measuring to an accuracy of 1 N·cm in real time (Surgic Pro+; NSK Co., Japan).

Measurements of CT values around the implant body were obtained using superimposed CT data. The working model for the provisional restoration, with 16-mm length provisional copings attached, was scanned. Surface rendering was then performed. Implant simulation software (LANDmarker v. 6.13; iLAND Solutions Co., Ltd, Japan) was used to superimpose the scanning data onto the preoperative CT data (Fig. 1). The provisional copings on the CT image were used as indicators for the placement of virtual implants, which were of the same shape and size as the actual implants. The mean CT values at a thickness of 0.5 mm around the outside of each implant were then measured. In addition, the mean CT values at a thickness of 0.35 mm inside the virtual implant, which undergoes compression by the implant body during insertion, were also measured (Fig. 2).

The data were analyzed using IBM SPSS Statistics version 20.0 software (IBM Corp., Armonk, NY, USA). Spearman’s rank correlation coefficient was used to investigate the correlation between insertion torque values and CT values. P-values of <0.05 were considered to be significant. This study was approved by the research ethics committee of the study institution.

Results

A total of 25 implants were evaluated in this study. The implant sites were in the mandibular molar region (23 implants) and maxillary molar region (two implants). The mean CT value for the 8-mm length implants was 508.6 ± 187.0 Hounsfield units.
units (HU) and the mean insertion torque value was 27.2 ± 12.1 N·cm. For the 10-mm implants, these values were 579.6 ± 224.3 HU and 28.1 ± 14.6 N·cm, respectively (Table 1). Statistical analysis revealed a strong positive correlation between insertion torque values and mean CT values around the implants (8-mm implants: \( r = 0.699 \); 10-mm implants: \( r = 0.771 \) (Fig. 3).

**Discussion**

Misch classified CT values for the evaluation of bone density into five levels: D1, >1250 HU; D2, 850–1250 HU; D3, 350–850 HU; D4, 150–350 HU; D5, <150 HU.\(^8\) Since this classification is objective, it is currently used for the evaluation of bone density. The mean CT value around the implants in this study was 545.6 ± 210.2 HU, which can be classified as level D2–3. This level is often observed in the mandibular and maxillary molar regions.

It has been hypothesized that CT values can be used to demonstrate the correlation between bone density and the initial stability of implants.\(^2\) In addition, the estimation of insertion torque values using CT values obtained from preoperatively scanned CT data is thought to be valuable for achieving high success rates in the early healing period after implant insertion. Ikumi and Tsutsumi performed a CT study in patients undergoing implant placement and measured CT values at a thickness of 1.0 mm around the outside of the implant using implant simulation software.\(^9\) Their method, which included the circular bone in contact with the implant body in the measurement area, is more precise than that reported by Turkyilmaz et al., who evaluated bone density in one cross-sectional area of a virtual implant.\(^2\) However, the density of bone around the implants in both of those studies was evaluated using only preoperative implant simulation data. If the inserted implant position is not in the planned insertion position, the CT value around the implant will not be evaluated exactly. In contrast, in the present study, CT values around the implants were measured on the superimposed data, which combined the inserted implant positions with the preoperative scanning data. In addition, a circular corridor of bone density was measured at a width of 0.5 mm from the implant surface; this was done in accordance with the results of the study by Tabassum et al., who reported that bone was compressed to the outside up to 0.5 mm regardless of the size of the implant socket.\(^1\) In addition, the bone density at a thickness of 0.35 mm inside the implants was also measured, which is the difference between the implant socket and implant diameter. Therefore, the CT values around the implants could be measured accurately by considering the compression of the implant body during insertion.

A significant positive correlation between insertion torque values and mean CT values around the implants was found in this study. This is consistent with the results of previous in vitro studies, and it is considered that the results of the present study, having been obtained in human subjects, are extremely meaningful. They suggest that measuring the CT values around an implant during the planning period can be used to estimate the initial stability to some extent. Although limited to the implants used in this study, the calculated prediction formula derived from the data collected is as follows:
Fig. 3. Correlation between the mean CT values of the bone around the implant body and the insertion torque values for the 8-mm and 10-mm implants.

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\text{insertion torque value} = \text{CT value} \times 0.038 \pm 5.777.
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The accuracy of this formula was confirmed in implants of other sizes (Fig. 4). Reference to these insertion torque values may help to determine whether or not immediate loading or early loading is possible, and may potentially provide a criterion for the selection of the surgical procedure, such as preparation of an undersized implant socket, and the choice of implant size or design for each patient.

On the other hand, the mean ISQ value in this study was 66 \pm 8 for the 8-mm implants and 62 \pm 9 for the 10-mm implants, and no correlation of the ISQ with the bone density around the implants could be confirmed. It is considered that ISQ values are greatly affected by the cortical bone in regions of moderate bone density (D2–3). However, in a human study using cone beam CT, Sennerby et al. reported that there is a correlation between bone density and primary implant stability assessed with resonance frequency analysis (RFA) measurements. Therefore, further studies on the relationship between initial stability and bone density are required.

Within the limitations of this study, a significant positive correlation was found between CT values of the bone around implants and insertion torque values. This study suggests that preoperative CT may enable the prediction of the initial torque of implants.

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Competing interests

The authors report no conflicts of interest related to this study.

Ethical approval

This study was approved by the Research Ethics Committee of Osaka University Graduate School of Dentistry (H23-E34).

Patient consent

Not required.

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