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ORIGINAL ARTICLE

Impacts of 3D bone-to- implant contact and implant diameter on primary stability of dental implant

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Periotest;
Implant stability quotient

Background/Purpose: This study investigated the effects of three three-dimensional (3D) bone-to-implant contact (BIC) parameters—potential BIC area (pBICA), BIC area (BICA), and 3D BIC percentage (3D BIC%; defined as BICA divided by pBICA)—in relation to the implant diameter on primary implant stability, as well as their correlations were also evaluated.
Methods: Dental implants with diameters of 3.75, 4, 5, and 6 mm and artificial bone specimens were scanned by microcomputed tomography to construct 3D models for calculating pBICA, BICA, and 3D BIC%. Indexes of the primary implant stability including the insertion torque value (ITV), Periotest value (PTV), and implant stability quotient (ISQ) were measured after implants with various diameters were placed into bone specimens. The Kruskal–Wallis test, Wilcoxon rank-sum test with Bonferroni adjustment, and Spearman correlations were all performed as statistical and correlation analyses.
Results: The implant diameter significantly influenced pBICA and BICA, but not 3D BIC%. ITV and PTV were more sensitive to implant diameter than was ISQ. The coefficients of determination were high (>0.92) for the correlations between pBICA (or BICA) and indexes of the primary implant stability.
Conclusion: This study revealed how the implant diameter and the three-dimensional (3D) BIC influence the primary stabilities of dental implant. ITV and PTV were more sensitively

Conflicts of interest: The authors have no conflicts of interest relevant to this article.

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influenced by the implant diameter than ISQ. The pBICA and BICA seem to be more important than 3D BIC % for using wider implant in treatment plan, since those two parameters are highly predictive of variations in the primary stability of dental implant.

Introduction

The primary stability of a dental implant is determined by the mechanical engagement between the implant and bone at the time of implant insertion. A appropriate mechanical engagement between the implant and bone is required for reducing the mobility of the implant, which is facilitates the development of osseointegration between the implant and bone. Poor primary implant stability can jeopardize osseointegration and lead to fibrous tissue growing at the implant–bone interface.[1] Some studies have found that the primary implant stability which occurs at the moment of implant placement positively influences the secondary implant stability[1,2] which is related to implant osseointegration during a given healing period after implant surgery. The primary implant stability significantly affects the final implant outcome.[3] Establishing good primary implant stability is therefore recommended for successful clinical results of dental implant.

The stability of dental implant is affected by various factors related to the bone-to-implant contact (BIC): the size and type of the implant, the surface treatment of the implant, and the quality and quantity of bone.[4–6] Increasing the implant diameter has been proposed for enhancing the BIC area and reducing implant mobility at the time of placement in low-density jaw bone.[7] In addition to implant stability, the implant diameter also affects the pull-out strength of the bone–implant interface.[8] Another noteworthy issue is the use of smaller implant diameters (less than 4 mm), with one study finding that the implant stability and survival rate were both lower when using implants with smaller diameters.[9] In addition, bone stress around the smaller diameter of implant might be relatively high.[10] These negative outcomes might also be related to a smaller BIC, indicating the need for further studies of this issue.

The influence of BIC on primary stability of dental implant indicates the importance of BIC evaluations. Radiography is commonly used in clinics to diagnose bone formation around an implant before and after osseointegration. However, the low resolution of two-dimensional (2D) radiography images limits accurate evaluations of BIC.[11] Similar to radiography, histomorphometry (or histology) is another method for evaluating the peri-implant bone tissue and can also be used for BIC measurements.[12,13] Nevertheless, it is rarely applied in humans,[14] instead being mainly used in animal studies. Moreover, retrieved biopsy samples are only available for one-time measurements that cannot be repeated.

The applications of cone-bean computed tomography (CBCT) in dentistry practice are increasing in the specialties of oral and maxillofacial surgery, endodontics, implant dentistry, and orthodontics.[15] The benefits of cheaper hardware and lower absorbed doses than conventional computed tomography are resulting in CBCT becoming the standard in three-dimensional (3D) dental radiographic imaging.[16] Due to bone remodeling over time involving dynamic 3D volumetric changes and the limitations of 2D techniques (radiography and histomorphometry), volumetric assessments of bony resorption after bone grafting or implant surgery by CBCT have become clinically useful. Since the resolution of CBCT machine is continuously improved, with high quality of CT images using CBCT to evaluate 3D BIC might become popular for predicting primary stability of dental implant within the foreseeable future.

Few studies have investigated the possible correlation between primary implant stability and BIC or other characteristics of implant site surfaces.[17–20] Basically, there are three types of index related to BIC level: (1) potential BIC area[21] (pBICA), which is the exterior surface area of the dental implant inside the artificial bone specimen. It means that the maximum surface area of the dental implant provide the surrounding bone ongrowth. (2) BIC area, BICA, which is the area of the dental implant in actual contact with bone. (3) 3D BIC percentage,[17,22] 3D BIC%, which is calculated as BICA divided by pBICA. Therefore, the purpose of this study was to determine the relationships between these three 3D BIC parameters (pBICA, BICA, and BIC %) and the primary implant stability as quantified by the insertion torque value (ITV), Periotest value (PTV), and implant stability quotient (ISQ) measured by resonance frequency analysis (RFA).[2] In addition, correlations between the primary implant stability and the implant diameter were evaluated.

Materials and methods

Dental implant and artificial bone specimen preparation

Commercial dental implants (all 10 mm long; ICE, Implant Innovation, Palm Beach, FL, USA) with four different diameters were selected in this study: 3.75 mm (model XFOS 310), 4 mm (model XFOS 410), 5 mm (model XFOS 510), and 6 mm (model XFOS 610) (Fig. 1a). Rigid cellular polyurethane blocks (Sawbones, Vashon, WA, USA) representing cancellous bone with a density of 0.32 g/cm^3 (model 1522-12) were attached to 2 mm-thick synthetic cortical shells (model 3401-01) with a density of 1.64 g/cm^3 (Fig. 1b). Artificial bone