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ORIGINAL ARTICLE

Biomechanical evaluation of one-piece and two-piece small-diameter dental implants: *In-vitro* experimental and three-dimensional finite element analyses

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dental implant abutment design;
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strain gauge

Background/Purpose: Small-diameter dental implants are associated with a higher risk of implant failure. This study used both three-dimensional finite-element (FE) simulations and *in-vitro* experimental tests to analyze the stresses and strains in both the implant and the surrounding bone when using one-piece (NobelDirect) and two-piece (NobelReplace) small-diameter implants, with the aim of understanding the underlying biomechanical mechanisms.
Methods: Six experimental artificial jawbone models and two FE models were prepared for one-piece and two-piece 3.5-mm diameter implants. Rosette strain gauges were used for *in-vitro* tests, with peak values of the principal bone strain recorded with a data acquisition system. Implant stability as quantified by Periotest values (PTV) were also recorded for both types of implants. Experimental data were analyzed statistically using Wilcoxon's rank-sum test. In FE simulations, the peak value and distribution of von-Mises stresses in the implant and bone were selected for evaluation.
Results: In *in-vitro* tests, the peak bone strain was 42% lower for two-piece implants than for one-piece implants. The PTV was slightly lower for one-piece implants (PTV = −6) than for two-piece implants (PTV = −5). In FE simulations, the stresses in the bone and implant were about 23% higher and 12% lower, respectively, for one-piece implants than those for two-piece implants.

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

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Conclusion: Due to the higher peri-implant bone stresses and strains, one-piece implants (NobelDirect) might be not suitable for use as small-diameter implants.

Introduction

The use of small-diameter dental implants has become more popular in specific clinical situations such as a thin alveolar crest, replacing a tooth with small dimensions, or limited inter-radicular space. In addition to small-diameter implants, bone grafting procedure is an accepted treatment for placing wider implants in insufficient width of alveolar bone. However, some patients still refuse this kind of treatment because of the additional surgery (including tissue harvesting and bone grafting), cost, and pain. Especially for autogenous bone grafting, many complications including paraesthesia and morbidity of the donor site have been reported.[1]

Nevertheless, the use of small-diameter implants has to be considered along with their potential limitations. From a biomechanical aspect, small-diameter implants are structurally weaker than standard-size implants (3.75–4 mm in diameter). An implant with a smaller diameter also has reduced surface area to accommodate bone to implant contact, which influences bone stress/strain transference and these high stress/strains may jeopardize the support provided by the bone surrounding the implant.[2–4] Additionally, implants with smaller diameters have a high risk of fatigue failure.[5] Nevertheless, some studies still report good results for small-diameter implants.[6,7] Where alveolar bone width is limited, the use of narrow-diameter implants may produce good survival rates.[8,9]

Many researchers are cautious about using small-diameter implants,[10,11] since different designs of small-diameter implants have recently been introduced into the market.[5] Among these, a one-piece small-diameter implant has been presented as stronger than a two piece design due to the absence of an abutment-fixture connection and retention screw which are features of a two-piece implant. Additionally, the one-piece implants are purported to exhibit minimal resorption of peri-implant bone due to the absence of the microgap, which is a result of the implant-abutment junction. These microgaps have been associated with microleakage and bacterial contamination.[12,13] In addition, two-piece small-diameter implants have demonstrated higher mechanical failure rates associated with small-diameter screws, screw loosening, and fracture.[13] However, high long-term clinical survival rates for two-piece small-diameter implants (up to 95%) have been reported.[8,14,15]

Many studies[16,17] have examined the influences of the small diameter of implants based on biomechanical factors. However, until now, there is no study investigating the effect of implants with both small-diameter designs and one-piece or two-piece concepts on biomechanical performance. Therefore, the present study used both three-dimensional finite element (FE) simulation and *in-vitro* experimental analysis to evaluate the difference of two design concepts (one piece or two pieces) of small-diameter implants on the stresses and strains of the implant and surrounding bone.

Materials and methods

In-vitro experiments

Implant design parameters and bone specimen preparation

Two kinds of implant systems were selected for analysis: (1) a one-piece small-diameter implant (NobelDirect Groovy NP, Nobel Biocare, Gothenburg, Sweden) and (2) a two-piece small-diameter implant (NobelReplace Tapered TiU NP, Nobel Biocare; Figure 1). In order to discriminate these two models easily, "G-NP" and "T-NP" are used henceforth to represent the one-piece and two-piece variants, respectively; their diameter and length were 3.5 mm and 13 mm, respectively.

A Sawbones model of trabecular bone with a density of 0.4 g/cm^3 and an elastic modulus of 759 MPa (number 1522-05, Pacific Research Laboratories, Vashon Island, WA, USA) was prepared for attachment to 3-mm thick commercially available synthetic cortical shell (model 3401-02, Pacific Research Laboratories) with an elastic modulus of 16.7 GPa. The density of trabecular bone used in this study was simulated as Type 2 bone according to the bone-density classification of Misch.[18,19] The thickness of the cortical bone was consistent with that used by Hahn,[20] whereby Type 2 bone was associated with a cortical bone height of 2.5–4 mm. The

Figure 1 Two-piece (left) and one-piece (right) small-diameter implants.