One-piece and two-piece implants demonstrate comparable stress levels in bone: preliminary results of an FEA study

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Introduction

Peri-implant bone loss is a highly complex phenomenon with numerous etiologies currently debated in the dental literature. Endosseous, root-form dental implants distribute occlusal stresses into the supporting bone as a function of their overall design and the amount of bone-to-implant interface achieved. Various reports in the dental literature suggest that both high and low stresses can lead to marginal bone resorption.[1] Preservation of peri-implant marginal bone height thus depends, in part, on proper distribution of marginal stress; however, major variations in the abilities of different implant designs to resist and distribute vertical and lateral occlusal loads have been documented using three-dimensional (3D) finite element stress analysis (FEA).[2-4] The ability of one-piece dental implant designs to maintain peri-implant crestal bone levels to the same degree as two-piece implant designs has recently been questioned.[5] The aim of this biomechanical analysis was to compare the level of stresses generated by one-piece and two-piece implant designs in simulated homogenous bone to determine if load distributions were significantly different.

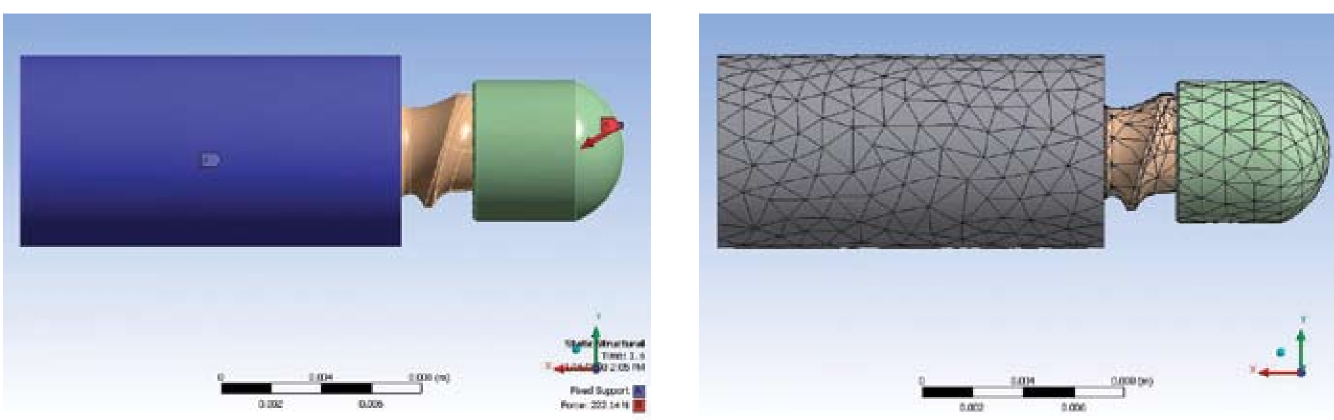

Fig 1. *Typical FEA boundary conditions and meshes.*

Materials and methods

Three-dimensional FEA code (ANSYS Workbench 11.0, ANSYS, Inc., Canonsburg, PA) was used to simulate one-piece implants (1P) and two-piece implants with internal hexagon connections and assembled with friction-fit abutments (2P). The implant and abutment of the 2P model were designed with bonded interfacial surfaces to replicate the documented “virtual cold weld”[6] between the assembled components, and this bonded relationship was also assumed in the analysis. All implant models were surrounded by a block of simulated homogenous bone that had linear elasticity with an average Young’s modulus value of 3 GPa, which is the mid-range stiffness value of cancellous bone. For the study models, a uniform, 2-mm thick bone material surrounded each implant, and it was assumed that bone-to-implant contact (BIC) was 100% with bonded interfacial surfaces. All the simulated implant-and-bone-block models adhered to the manufacturer’s protocol for implant placement. Identical load and boundary conditions were used for all of the study implants. The material properties for titanium alloy (Ti-6Al-4V) were used for implants, restorative parts, and retaining screws. Figure 1 shows typical boundary conditions and mesh configurations used in various simulations. A compressive load of 222.4 N (50 lbs) at an offset with respect to the implant axis and at a 30-degree angle was applied to all the various assemblies.

Results

Results for maximum bone stress levels using various implants subjected to 222.4 N (50 lbs) of applied load at a 30-degree angle are summarized in Figure 2 and Table 1. Average dental bone yield stress in compression is approximately 180 MPa.[7] Brunski[8] also states that the vertical component of biting force in the incisor regions of adults is approximately 222 N (50 lb), which was used for this analysis with the assumption that 3.7 mm-diameter implants are often used in incisor region. Utilizing those parameters with a 2-mm thick bone, there was only a 3 MPa difference between 1P and 2P models that were 3.7 mm in diameter. In a separate FEA study, Sugiura et al.[9] reported that 50 MPa (3,600 micro strain) is the critical threshold

Table 1. Comparison of maximum stress values by implant diameter and design

Implant diameter	Maximum stress value (MPa)		Difference in maximum stress (1P vs 2P) (Design with higher maximum stress value)
	One-piece design (1P)	Two-piece design (2P)	
3.7 mm	30 MPa	27 MPa	3 MPa (1P)
4.7 mm	18 MPa	18 MPa	No difference; same maximum stress values

value for bone resorption. This 3 MPa Von-Misses stress value difference only represented 6% of Sugiura et al.'s[7] total threshold value. The increase of 3 MPa was only around 1.6% of total yield stress. According to Natali et al.[7] ultimate bone stress is 195 MPa, which would result in an even smaller ratio of 1.5%. It was therefore concluded that no significant difference was found in bone stress

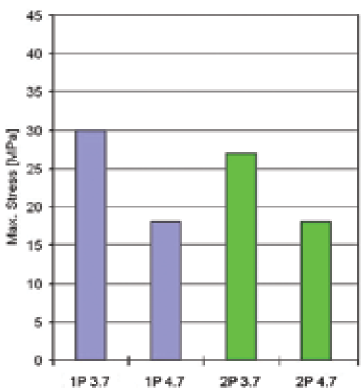

Fig 2. *Maximum stresses in the bone based on FEA results for various implants (@50-lb load and 2-mm thick bone around the implant).*

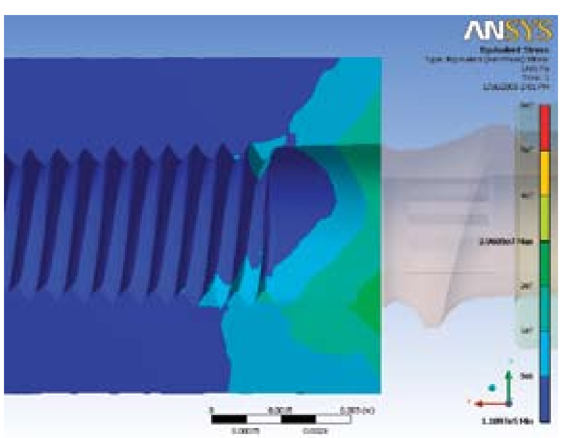

Fig 3. *Typical stress distribution in the bone.*

concentrations between simulated 1P and 2P implants with the same length and diameter [Table 1]. It should also be noted that 2 mm of peri-implant bone is the borderline for the 3.7 mm-diameter study models; as the peri-implant bone increases in thickness, the maximum stress values of 1P and 2P merge exponentially according to the present calculations. For example, at 222.4 N (50 lb) of load, 1.6% is the maximum difference between these implants utilizing the present calculations. Typical stress distribution from the marginal bone level to deep within the bone is illustrated in Figure 3.

Discussion

During the course of this study, it was observed that a residual plate that is less than 2 mm in thickness could have an adverse affect on bone stress levels and crestal bone maintenance. It is important to note that this same phenomenon has also been clinically documented in a prospective, multi-center clinical study[10] that was conducted by the U.S. government and involved the placement of approximately 3,000 implants. The present study also noted that both vertical and lateral load stresses decreased in inverse proportion to an increase in implant diameter. All of these findings will be thoroughly addressed in a future publication.

Conclusion

Within the limitations of this study, it was found that one-piece implants create similar stresses to two-piece implants in the same length and diameter. Reported differences in marginal bone levels between one-piece and two-piece implants[5] may be attributable to variables independent of implant design since other reports[11] in the dental literature have not observed this same phenomenon.

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