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Short communication

A comparison of stress distributions for different surgical procedures, screw dimensions and orientations for a Temporomandibular joint implant

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ABSTRACT

Finite element analysis is a useful analytical tool for the design of biomedical implants. The aim of this study was to investigate the behavior of temporomandibular joint implants with multiple design variables of the screws used for fixation of the implant. A commercially available implant with full mandible was analyzed using a finite element software package. The effects of different design variables such as orientation, diameter and stem length of the screws on the stress distribution in bone for two different surgical procedures were investigated. Considering the microstrain in bone as a principal factor, the acceptable ranges for screw diameter and length were determined. Parallel orientation of the screws performed better from a stress point of view when compared to the zig-zag orientation. Sufficient contact between the implant collar and mandibular condyle was shown to reduce the peak stresses which may lead to long term success. The distance between screw holes in the parallel orientation was much closer when compared to the zig-zag orientation. However, the stresses in bone near the screw hole area for the parallel orientation were within acceptable limits.

1. Introduction

The temporomandibular joint (TMJ) is a load-bearing joint where forces are transmitted mainly during mastication. TMJ implants are used to rehabilitate patients with advanced forms of arthritis, ankylosis of the joint following trauma or infections and total joint reconstruction following excision of a tumor (Christensen, 1964 ; Saeed et al., 2002; Kashi et al., 2006). Stress distribution in TMJ implants and bone have been studied previously by other researchers (Chou et al., 2008; Lin et al., 2009; Ramos et al., 2010; Hsu et al., 2010). The goals of this study were to observe the stresses and strains in a TMJ implant and the adjacent bone when several variables were varied, including the orientation (i.e., parallel and zig-zag screws), diameter and depth of penetration of the screws used for implant fixation. Finite element analyses (FEA) of the TMJ implants, screws and mandible were carried out for implant collar in contact with bone (surgical procedure A) and for implant collar with no bone contact (surgical procedure B; Fig. 1).

2. Methods

A commercially available TMJ implant (TMJ Implants, Inc., CO) was used to obtain its actual measurements. The effect of the implant and screws made of titanium alloy on the stress distribution in the adjacent bone was evaluated by the finite element method. The dimensions of the basic implant remained the same (thickness, length/height and holes for screw head), while the diameter and the length of the screw stem were varied. The geometry of the mandible was obtained from CT images of a 47 year old female. This data was used in MIMICS, an image processing software to form the geometry. ANSYS, a finite element software, was used for finite element data generation (i.e., to create the nodes and elements). The material properties of cancellous and cortical bone were calculated from bone density of each element measured by CT (Park et al., 2008). We have previously described the boundary conditions, implant dimensions, instrumentation and software used and thus they will not be repeated here (Kashi et al., 2010). Implant with a maximum of 10 screws was utilized for the analysis (Fig. 2). The total number of elements and nodes generated for each mandible and implant complex models was approximately 78,000–79,000 and 122000–144000, respectively.

At the top of the implant we applied a force of 300 N vertically downward to simulate the direction of force that the condyle experiences during chewing, taking into consideration safety as a design factor and previous reports

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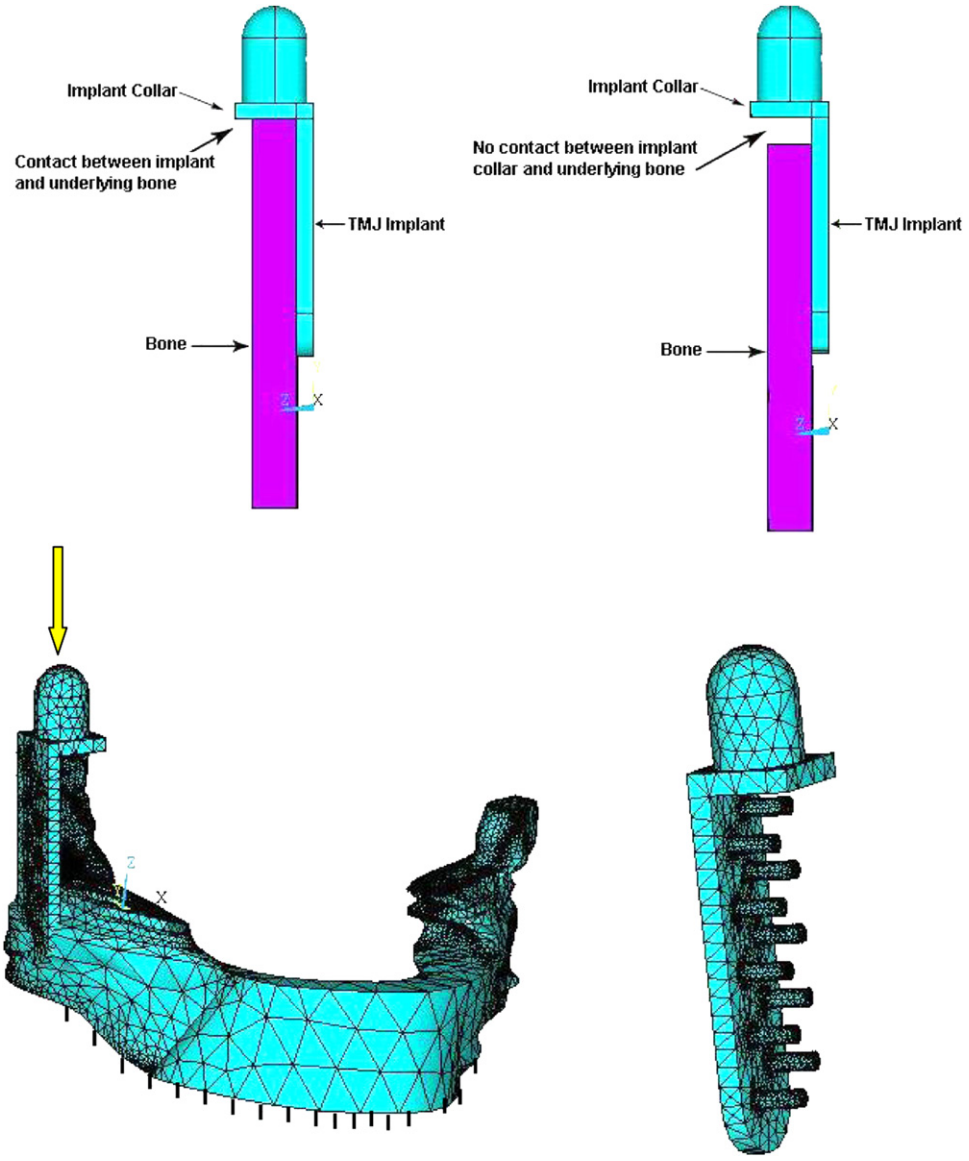

Fig. 1. Implant on the top left–surgical procedure A (has no contact with underlying bone); the implant shown on the top right–surgical procedure B (has contact with underlying bone); bottom–finite element model of mandible with implant simulating post-surgical condition is shown on the left and implant with 10 screws is shown on the right.

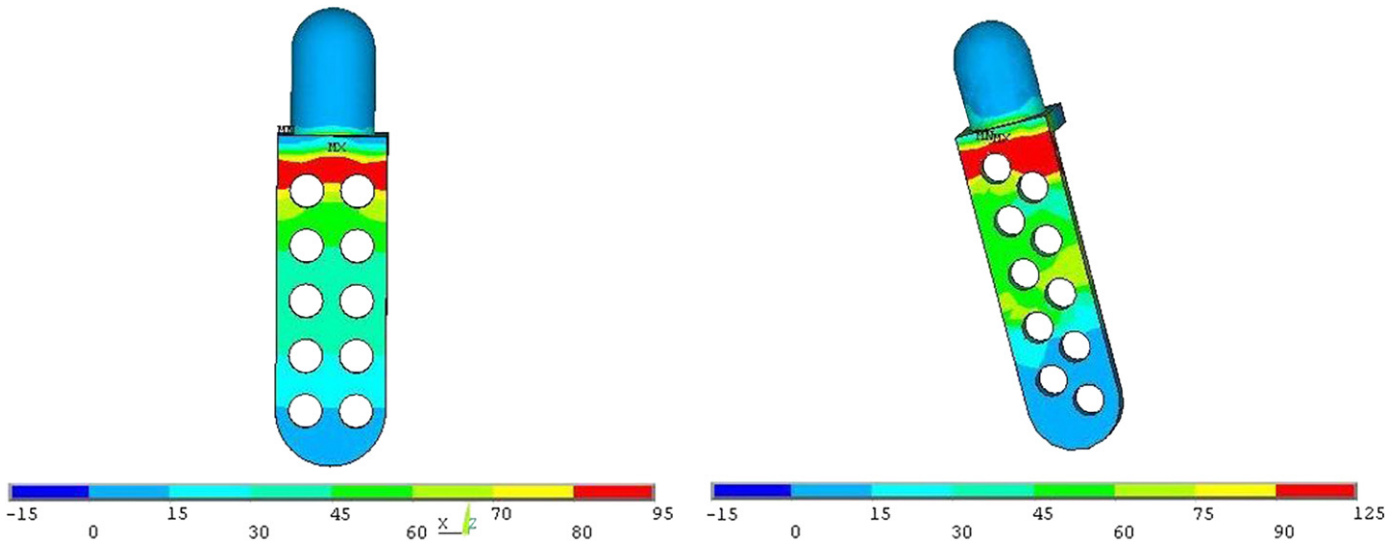

Fig. 2. Von-Mises stresses (MPa) in TMJ implant with parallel and zig-zag orientations of the screw holes.