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Load transfer in the fossa component in TMJ arthroplasty.

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SUMMARY

The TMJ articulation is a very complex system with muscles, ligaments and cartilage. The latest option is TMJ arthoplasty. The present work studies the behavior of a commercial fossa in a total TMJ implant. The most critical region is the first two screws in the condyle and the cranium. The fossa component presents some critical aspect in the stress observed. The contact point with the fossa component generates bone damage and could increase the risk of fracture of the fossa component.

INTRODUCTION

So many people are currently suffering from TMJ disorders that, according to epidemiological studies, they can be seen in 20–25% of the population [1]. There are three TMJ systems on the market, all fixed by screws to the condyle and the fossa. The best known TMJ implant on the market is the Christensen system. At first this had an acrylic cap but is now a metal–metal system with screw fixation [2].

The existing systems do not present good results in the short term, with high failure rates in the fossa component of around 40% in 8 years [3]. There are other problems associated with wear in the fossa component [4] and changes in the biomechanics of the mandible, thus reducing mobility. This complex TMJ articulation requires finite element (FE) analysis to simulate and analyze the behavior of an intact and implanted mandible and bone remodeling [5, 6].

The objective of the present study was to analyze strain distributions and load transfer in total TMJ, including the fossa component in the cranium.

METHODS

The model was constructed from CT scan images of a 40-year-old man, with a resolution of 0.3x0.3 mm per pixel. The cortical thickness and cancellous bone were modeled according to the CT information with ScanIP® software. The CAD model of the commercial implant with external fixation was copied from a commercial implant (Cristensen). The implant is composed of two components and fixed by 3 screws to the cranium and by 9 screws to the mandible condyle (figure 1). The position of the implant was defined according to the center of condyle geometry, in the same position as a natural mandible. The fossa component was positioned as a best fit position in the bone, as in a real situation. The screws were 2.0 mm in diameter and 7mm in length.

The materials applied in each model component were considered isotropic and linear elastic as, demonstrated in previous studies [7-9].

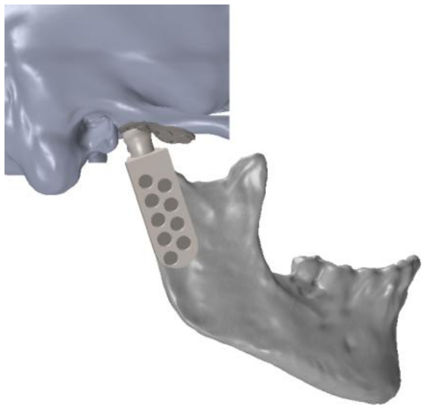

Figure 1: CAD model of total TMJ implant.

We considered that the teeth have marginal influence on the biomechanics of the mandible [9]. The mechanical properties of the models are given in table 1. The cranium bone properties were defined for this region according to other studies [10].

Table 1: Material properties.

	Young's Modulus (GPa)	Poisson coefficient
Cranium	6	0.28
Fossa component	210	0.30
Condyle component	210	0.30
Screws	210	0.30
Mandible cortical	14.7	0.28
Mandible trabecular	0.4	0.28

The model was simulated with 5mm mouth aperture in the incisor teeth. The boundary condition used considered symmetry in the mandible, and fixed the cranium bone in the upper region. Boundary conditions took into account three muscles on each side, as in a previous study [11], the two masseters (deep and superficial) and the pterygoid, temporalis and medial temporal. The load magnitudes in each direction are shown in table 2. Actions were calculated considering a load of 10N on the incisor teeth.

The models looked at contact between components. This consisted of touching between the fossa and condyle component with friction 0.1, and between bones. The screws were considered as glue between different types of bone.

Table 2: Muscle actions.

	Load (N)		
Muscle actions	X	Y	Z
Deep Masseter	3.89	64.15	7.78
Superficial Masseter	6.44	91.03	0.92
Medial pterygoid	70.19	118.90	-38.68
Temporalis	-0.03	0.18	-0.08
Medial Temporal	-0.19	2.62	-4.03

RESULTS AND DISCUSSION

The model is used to measure stress and strain in the bone and TMJ components. The equivalent stress and displacement in the fossa component of a TMJ prosthesis is presented in figure 2. It can be seen that the maximum stress is in the fossa component, with maximum value around 900 MPa, close to the elastic limit of a CoCr alloy.

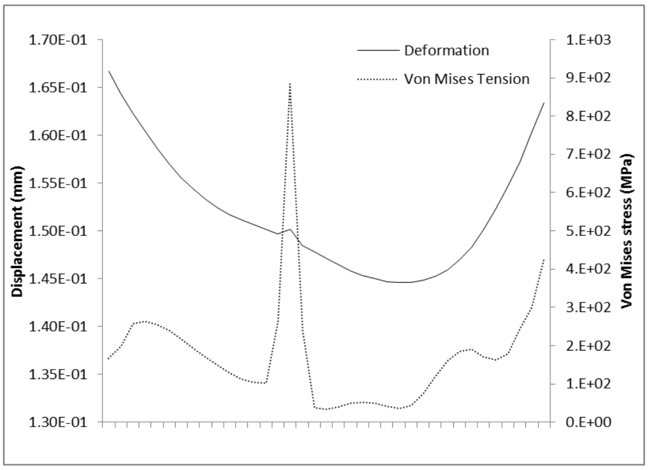

Figure 2: Equivalent stress and displacement in fossa component.

These values occur near the holes and at the contact point between the fossa and the condyle component. Maximum displacement was around 0.145 mm in the center of the fossa component. Displacement in the component is high.

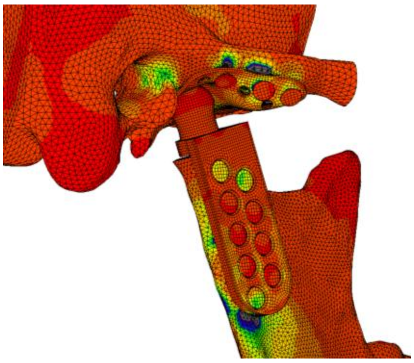

Figure 3: Minimum principal strains in mandible and cranium bones.

Strain distribution around the bone is shown in figure 3.

The results revealed the most critical strain occurring near the screws and contact point in the fossa. In the mandible, the critical region is around the first and second screws, and the contact region at the end part of the condyle component. This region was in agreement with previous observation in surgical procedures.

CONCLUSIONS

The results revealed some critical stress in the TMJ components. These results suggest some fractures in the fossa component and the formation of fibrous tissue around the fossa. In the condyle component the screw fixation presents a critical behavior.

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