143 Comparison of Different Implant Placement Schemes for Personalized Restoration of an Edentulous Jaw

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Introduction

Rehabilitation of edentulous patients is one of the most difficult, relevant and still not completely solved problems in dental implantology. In 1988, the "All-on-Four" concept [1] was proposed, where a prosthesis is mounted on 4 implants placed in the anterior section of the jaw. To increase the placement base, lateral implants are tilted at an angle of 30° or 45°. The advantages of this approach include the possibility of fixing a full prosthesis of the jaw even with a small amount of bone tissue in the chewing portion and some others. However, with this, some implants may bear a larger load compared to the classical prosthetic scheme. The aim of the study is to develop an individual biomechanical model of the lower jaw (LJ) with implants and a prosthesis and to assess the stress-strain state (SSS) of the model for two different implant placement options (including All-on-Four) and different loading conditions.

Methods

The study was based on the LJ cone-beam computed tomography (CBCT) images. The conversion of CBCT images into a 3D solid-state model of the LJ was carried out using Mimics 17.0 and 3-matic 6.1 software suites. Two placement schemes with 4 implants were simulated: 1) all implants vertical; 2) lateral implants placed at an angle of 45°. The material of the jaw and implants was taken isotropic linearly elastic, the jaw elastic modulus being determined discretely for each mesh element by means of the Mimics package. Next, the model was exported to the ANSYS finite element complex, where it was supplemented with a beam model of a denture. When simulating biting, a vertical force F = 200 N [2] was applied to the nodes of the central part of the beam, while chewing - to the nodes located on the edge of the cantilever part of the beam (Fig. 1). As boundary conditions, fixing all degrees of freedom was taken in the nodes of the LJ heads and coronoids.

Results and Discussion

An assessment was made of the SSS of both the jawbone tissue in the implant sites and the implants themselves. The results of the determination of equivalent stresses with the example of chewing are shown in Fig. 2. In all cases, the maximum stress occurred in the area of the first thread of the implants. Comparison of two implant placement schemes showed that when biting, the choice of the scheme does not matter, while chewing, the parallel placement of the implants is preferable from the point of view of the stressed state of the bone tissue, but the maximum stresses in some areas of the implants are significantly higher than for the All-on-Four, being comparable with the yield strength of titanium. The values of stresses obtained in the LJ, do not exceed the limits of bone tissue strength. However, the maximum values of equivalent strains in the bone tissue under loading of the console part of the beam significantly exceeded the threshold of its damageability, which according to the H.M. Frost mechanostat theory is about 4×10^{-3} [3].

Conclusion

The presented technology makes it possible to take into account individual geometrical and mechanical characteristics of the bone structures and tissues of a particular patient when digitally planning and comparing different implantation options in the edentulous jaw. The issue of accuracy, reliability, conditions of applicability, and the possibilities of unifying a wide variety of formulas of an empirical nature for converting X-ray density into physical and further into mechanical characteristics remains studied purely. The automation of the technology considered is also hampered by the need to involve manual processing for sufficiently accurate segmentation of CT by type of tissue and optimization of the quality of mesh models.

Acknowledgements

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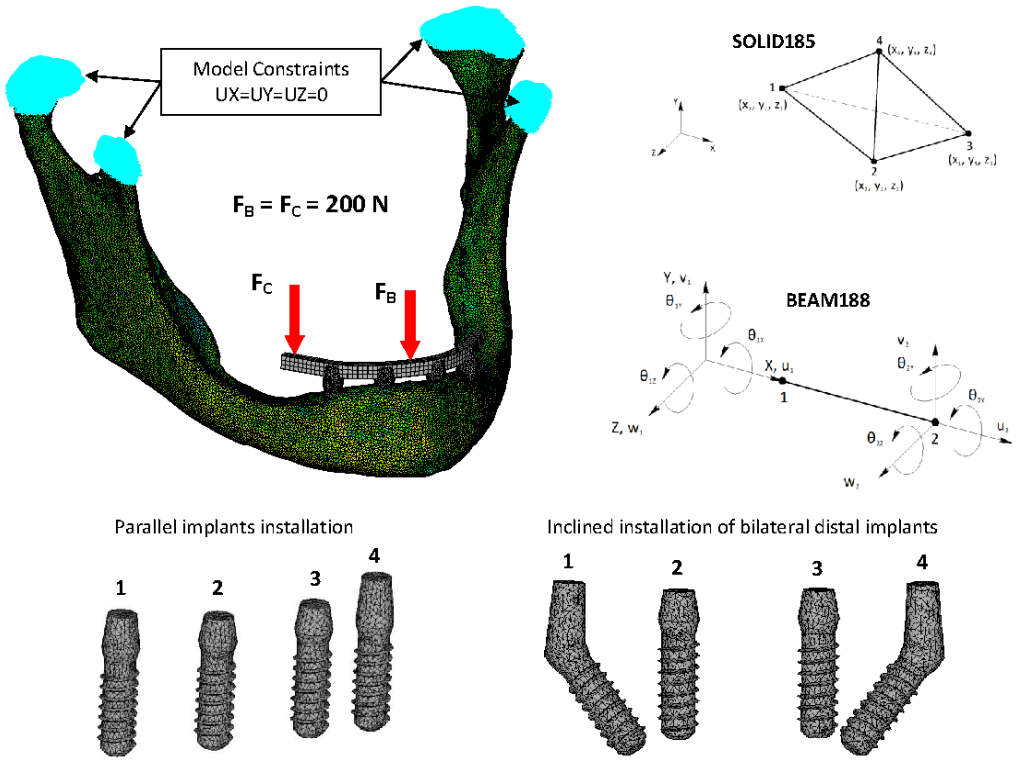

Fig. 1: Mandible finite element model in the biting and chewing processes modeling and model constraint conditions (top left); finite elements types used to create the model (top right); implants placement schemes (below)

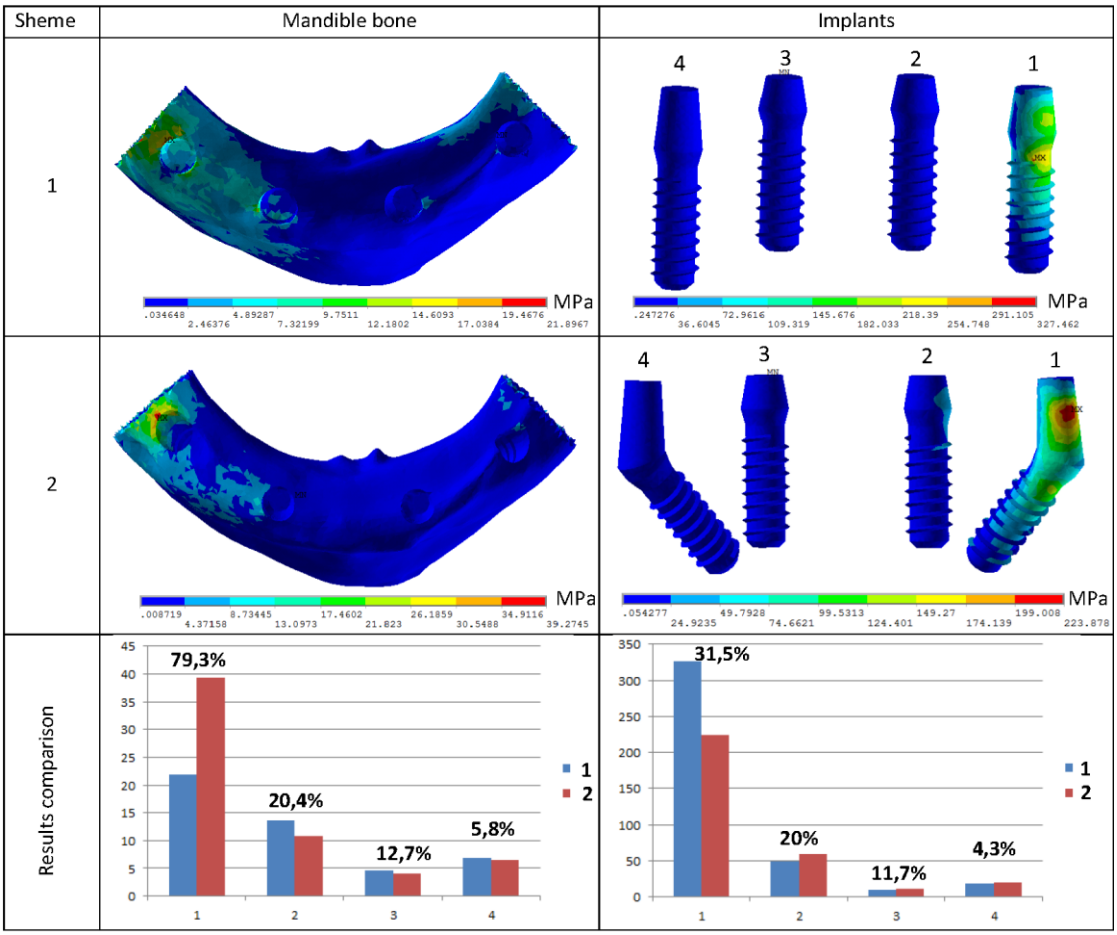

Fig. 2: The von Mises stresses in the lower jaw and implants when chewing. On histograms - the maximum stress values: blue bars – scheme 1, brown – scheme 2; the percentage indicates the difference between the schemes.