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Biomechanical Analysis of Implant-Supported Prostheses with Different Implant-Abutment Connections

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This study evaluated the influence of implant-abutment connections on stress distribution through 3D finite element analysis. Three-dimensional models of an implant-supported fixed prosthesis in the jaw retained by four implants with different connection systems (external hex and Morse taper) were analyzed. External hex connection promoted higher microstrain values, which were concentrated on the cervical region of the distal implants extending into the trabecular bone, while Morse taper connection provided a more even distribution of the microstrain on all implants. Implant-supported fixed prostheses with external hex connections tend to concentrate strain in the distal implants, while Morse taper connection promoted a better situation. On the other hand, there was greater demand on the prosthetic screws and abutments of Morse taper connections than on external hex connections. *Int J Prosthodont 2015;28:621–623. doi: 10.11607/ijp.4258*

It has been shown that the design of the implant-abutment connection system has a profound impact on the stability of screwed joints. Norton[1] showed that Morse taper connections are significantly more stable than other implant connections when it comes to resisting extreme bending moments. Although the influence of different implant connection systems has already been studied in implant-supported partial dentures, the use of Morse taper implants in mandibular fixed implant-supported complete dentures has not yet been evaluated. The aim of this study was to evaluate, through 3D finite element analysis (FEA), the stress and strain in mandibular fixed implant-supported complete dentures with external hex and Morse taper implants under bilateral axial load. The null hypothesis was that different connection systems do not influence the biomechanical behavior of mandibular implant-supported complete dentures with four implants.

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Materials and Methods

Three-dimensional models of an edentulous mandible with four implants supporting mandibular fixed implant-supported complete dentures were created using Rhinoceros 4.0 SR8 software (McNeel) (Fig 1). The prosthetic components and implants were based on CAD models provided by the implant manufacturer (Neodent) and were cylindrical (3.75 $\times$ 13 mm) with external hex or Morse taper connection. The prosthetic framework presented a 4-mm round cross-section and a 15-mm-length cantilever. The models were exported into mechanical simulation software (Workbench 12, ANSYS).

The materials used in this study were considered isotropic, linearly elastic, and homogenous (Table 1).[2] Mesh was generated with 10-noded tetrahedral elements and refined manually. The total number of elements and nodes of the models were 561,566 and 1,041,413, respectively. The contact between the structures was considered bonded, and the trimmed surfaces of the mandible were constrained in all directions. Bilateral static loading (300 N) was applied at the cantilevers.

Results

External hex connection caused higher microstrain values (3,380.40 $\mu\varepsilon$) in the peri-implant bone tissue than Morse taper connection (2,488.00 $\mu\varepsilon$), which were concentrated in the cervical region of the distal implants and extended into the trabecular bone (Fig 2). Morse taper connection provided a more even distribution of the microstrain in all the implants.

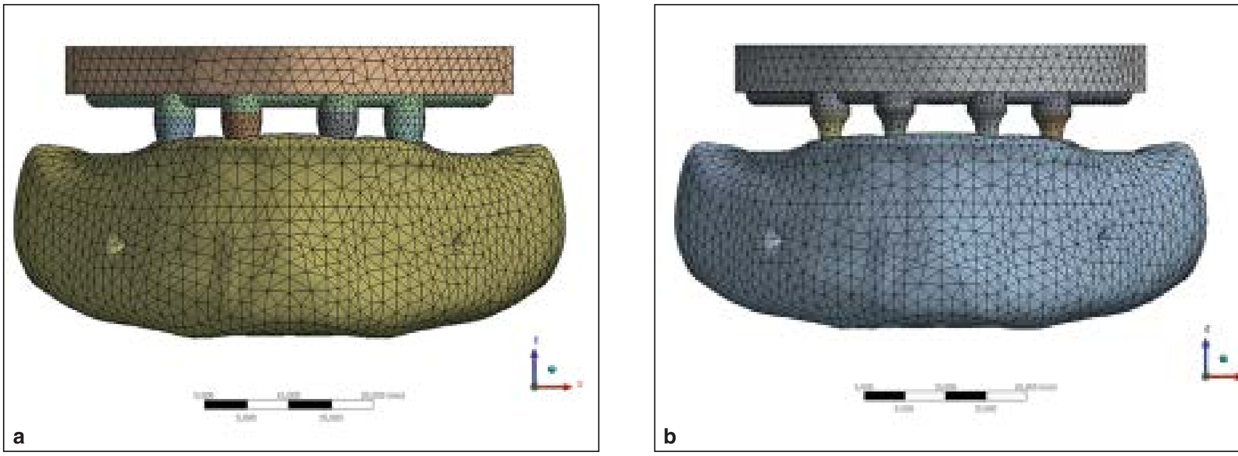

Fig 1 Frontal view of finite element model. **(a)** External hex connections. **(b)** Morse taper connections.

Table 1 Properties of Materials Used

	Young modulus (GPa)	Poisson ratio
Cortical bone	13.7	0.30
Cancellous bone	1.37	0.30
Implant, abutment, prosthetic screw, prosthetic framework (CP Ti)	110	0.33
Acrylic resin	3.8	0.30

Table 2 Von Mises Stress Values (MPa) for Each Prosthetic Component of the External Hex and Morse Taper Connections

	External hex	Morse taper
Right distal abutment	208.14	323.50
Right distal prosthetic screw	157.40	170.21
Right medial abutment	121.70	339.43
Right medial prosthetic screw	234.25	335.05
Left medial abutment	120.58	243.78
Left medial prosthetic screw	231.16	298.57
Left distal abutment	207.38	233.44
Left distal prosthetic screw	172.42	154.18

In regard to the prosthetic components, it was possible to verify that the distal abutments of the external hex system presented the highest stress values, while for the prosthetic screws the medial abutments presented the highest stress values (Table 2).

Discussion

According to Frost's mechanostat theory,[3] bone physiology is influenced by local deformation produced by mechanical stress. This theory suggests that high values of bone deformation (greater than 3,000 $\mu\varepsilon$) could increase microdamage, surpass the repair mechanism, and result in a fatigue failure. This pathological strain value was observed in the external hex connection and could lead to bone resorption. The highest values of strain were observed in the cervical region of the distal implants, which is in agreement with the findings of Ogawa et al,[4] who suggested that the distal implants have a greater risk for mechanical overload.

The biomechanics of external connections evidences the greater flexibility, release, and transfer of the stress field for the bone. These aspects justify the increase of the strains next to the loaded region and the lower tendency of stress dissipation along the medial implants. A common clinical failure is related to the reduced height of the hexagon creating a bigger rotation center, reducing the resistance for rotational movements, which could lead to loosening or fracture of the prosthetic screw or bone resorption. On the other hand, the lower stress values in the abutments and prosthetic screw could be attributed to this weak connection acting as a fail-safe mechanism, dissipating deleterious forces. Taper joint connections presents better sealing capabilities for closing the microgap, and consequently better stability of the joint,[5] which may result in higher stress values in the prosthetic components.

FEA presents some limitations, such as the assumptions that living tissues are homogenous and linearly elastic and that the contacts between the structures are bonded, that could influence the obtained results. It is of great importance that the clinician understand this method, its applications, and its limitations, to more confidently interpret results of FEA studies and relate them to clinical situations.

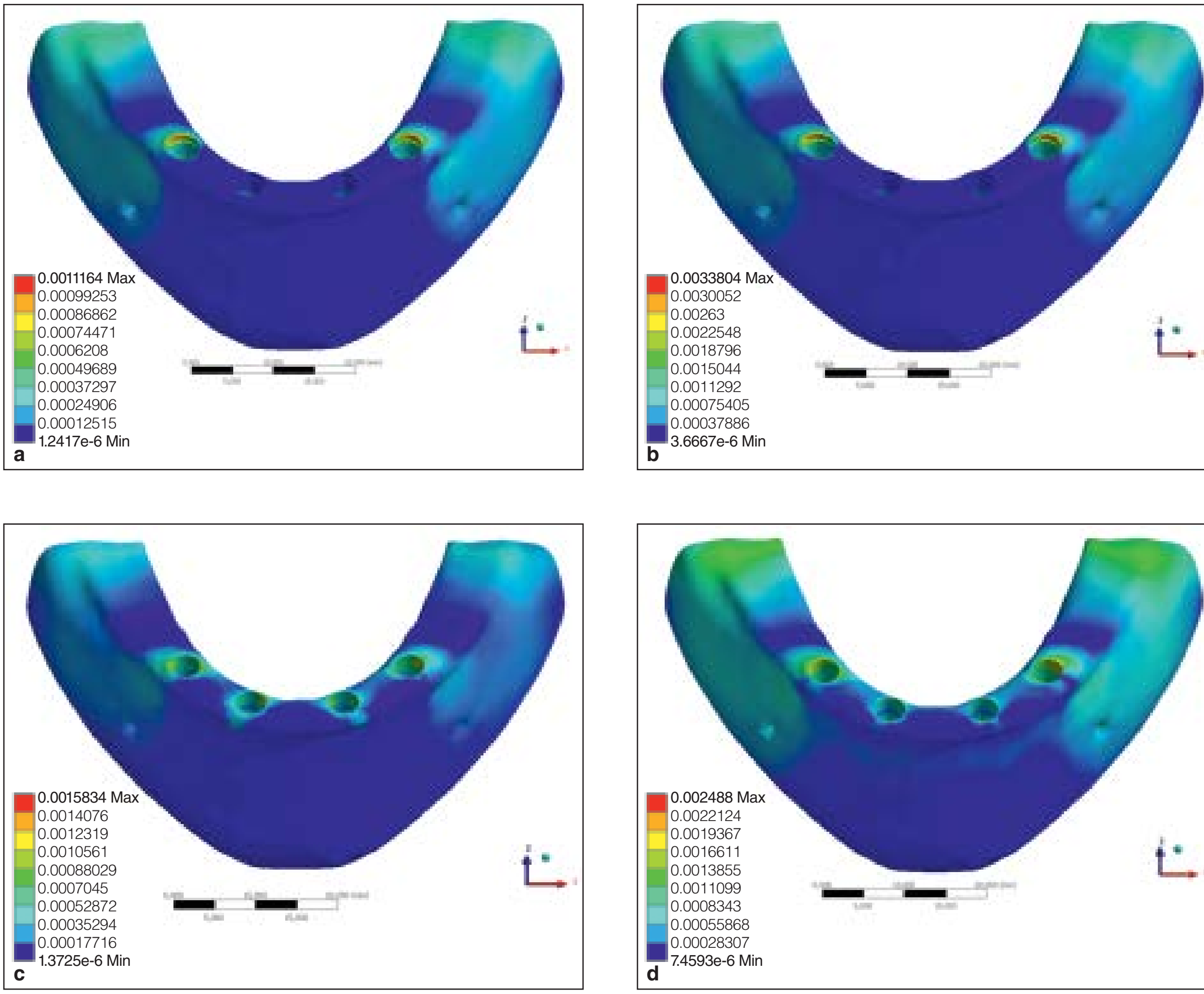

Fig 2 Bone strain (με) for the different analyzed situations. **(a)** External hex, 100 N. **(b)** External hex, 300 N. **(c)** Morse taper, 100 N. **(d)** Morse taper, 300 N.

Conclusions

Implant-supported fixed prostheses with external hex connections tended to concentrate strain in the distal implants, while Morse taper connection promoted a more even distribution among all implants.

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