UNIVERSITI TEKNOLOGI MARA

BIOMECHANICAL ANALYSIS OF PARIETAL-TEMPORAL IMPLANT: EFFECTS OF IMPLANT MATERIALS, PORE SHAPES AND PORE SIZES

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ABSTRACT

Cranial implants are designed to shield the brain before and after neurosurgery or trauma, thus their durability is crucial clinical value. The mechanical response of each implant cannot be practically described experimentally due to the rise in patient-specific implants. However, computational models such as finite element analysis (FEA) have a great chance of accurately forecasting the mechanical behaviour of implants designed specifically for a certain patient. FEA has been used extensively for the solid cranial implant, yet there has been relatively little research on FEA for porous implants. Thus, this study aimed to analyse the biomechanical behaviour of the solid implant and porous implant by varying implant pore shape (pentagonal and hexagonal), pore size (900 and 1200 μm), and materials (titanium, hydroxyapatite, and zinc-hydroxyapatite) through a finite element method. In the first phase of this research, the three–dimensional (3D) human skull model was developed from the 245 DICOM images with a thickness of 1 mm of a 15-year-old girl patient with a right parietal-temporal defect. The defective skull images underwent the segmentation technique using a threshold method with a Hounsfield unit of 226 HU to 3071 HU via the Mimics software. The excessive bone such as the neck area was removed using a split mask tool and the region of interest was exported as Standard Tessellation Language (STL) file. Next, the 3D skull model was loaded into 3 Matic software. The smooth curve was created around the defect region and then the skull was mirrored at the midplane. The guiding curve was then constructed from the starting point to the ending point to match the mirrored skull's form. Finally, the solid implant was obtained through the surface construction approach. After the Boolean operation got a precise implant, the pentagonal and hexagonal pore shapes with pore sizes of 900 and 1200 μm was constructed on the solid implant. Finally, the biomechanical behaviour of each implant model loaded by 50 N force exerted at the implant's centre and 15 mmHg intracranial pressure at the internal surface of the skull was evaluated in terms of von Mises stress and deformation using the finite element method. The skull was fixed at the bottom and the connection between the implant and skull was assumed perfectly bonded. From the analysis, the maximum von Mises for Ti6Al4V, HA and ZnHA of Hex PS900 were 2.65 MPa, 2.07 MPa, and 2.04 MPa, respectively whereas Hex PS1200 were 5.45 MPa, 5 MPa, and 4.93 MPa, respectively. Regarding the deformation, it can be seen that the maximum deformation of the ZnHA implant was significantly higher than the HA implant, with a percentage difference of around 26.62% to 27.67%. Meanwhile, the percentage difference in the maximum deformation between all models of HA and Ti6Al4V implants was 34.24% to 37.70%. It was found that the von Mises stress was much more affected by the implant pore sizes, followed by implant pore shapes and, lastly, implant materials. In contrast to the von Mises stress, the implant materials had a significant effect on the deformation, while pore shapes and pore sizes did not have any effect on the deformation. Subsequently, the safety factor for each implant design was calculated and there was no implant fracture or failure since the safety factor values of all implants were greater than one. The HA implant of Hex PS900 was discovered to be the best implant of all. So, this research provides a unique cranial implant design in terms of pore shape and pore size and broadens the selection of safe materials for lightweight and durable cranial implants. These discoveries may influence surgeons' decisions when developing and manufacturing cranial implants for improved clinical outcomes.

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