

Design, finite element analysis (FEA), and fabrication of custom titanium alloy cranial implant using electron beam melting additive manufacturing

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ABSTRACT

Skull defect reconstruction is one of the most difficult challenges faced by the surgeons because of the complex shape of the skull. Skull defects are dramatically increasing with the increase in road accidents, tumors, and wars, thereby increasing the demand for reconstruction of skull. It is difficult to manufacture standard implants for skull defects especially for large and complex defects, due to the complexity and the difference in anatomy of skulls. Design and fabrication of custom cranial implant is required in these cases. The conventional technologies face multiple challenges in fabricating lightweight custom cranial implants closer to that of bone in terms of weight; the difference in the weight introduces stress-shielding effects onto the surrounding bone. In order to overcome this problem, several researches proposed lattice structure implants fabricated by additive manufacturing. However, lattice structure implants are difficult to remove later when some problems are encountered. This paper presents a methodology of design analysis and fabrication of solid lightweight custom cranial implant using additive manufacturing. A Case study is presented where, a custom cranial implant is designed and analysed using finite element analysis (FEA) and then fabricated using electron beam melting (EBM) additive manufacturing. The titanium alloy Ti6Al4V which is biocompatible and non-toxic is used as the implant material. The functionality, fitting, and aesthetic of the proposed design are evaluated. The results show the successful fabrication of thin custom cranial implant for skull defect reconstruction via EBM technology. The fabricated implant has sufficient strength, weight close to the weight of the removed bone portion while maintaining a good fit and aesthetics.

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Oblikovanje, analiza z metodo končnih elementov (MKE) in izdelava lobanjskega vsadka iz titanove zlitine z uporabo dodajalne tehnologije taljenja z elektronskim žarkom

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POVZETEK

Rekonstrukcija okvare lobanje je zaradi kompleksne oblike lobanje eden najtežjih izzivov, s katerim se soočajo kirurgi. Število okvar lobanje se z naraščanjem števila prometnih nesreč, tumorjev in vojn dramatično povečuje, s čimer se povečuje tudi povpraševanje po rekonstrukciji lobanje. Zaradi kompleksnosti in razlike v anatomiji lobanj je težko izdelati standardne vsadke za okvare lobanj, zlasti za velike in zapletene okvare. V takih primerih je treba lobanjski vsadek izdelati po meri. Konvencionalni postopki se soočajo s številnimi izzivi pri izdelavi lahkih namenskih lobanjskih vsadkov; predvsem je treba zagotoviti, da je teža vsadka primerljiva s težo okoliških kosti, saj morebitna razlika v teži ustvarja učinke napetost. Da bi to težavo premostili, so nekateri raziskovalci predlagali mrežno strukturo vsadka, izdelanega z dodajalnimi tehnologijami. Vendar pa je take vsadke v primeru težav težko odstraniti. V prispevku je predstavljena metoda analize zasnove in izdelave polnega in lahkega vsadka po meri, izdelanega z dodajalno tehnologijo. Predstavljena je študija primera, pri kateri smo lobanjski vsadek analizirali z metodo končnih elementov in ga nato izdelali s tehnologijo taljenja z elektronskim žarkom (EBM). Za material vsadka smo uporabili titanovo zlitino Ti6Al4V, ki je biokompatibilna in nestrupena. Vrednotile so se funkcionalnost, prilaganje in estetika predlaganega vsadka. Rezultati so potrdili možnost uspešne izdelave tankega lobanjskega vsadka po meri za rekonstrukcijo okvare lobanje s tehnologijo EBM. Izdelan vsadek je imel zadostno trdnost, težo podobno teži odstranjenega kostnega deleža, hkrati pa se je dobro prilagal in imel ustrezen estetski videz.

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