Abstract

Segmental or complete mandibulectomy are often advised for patients suffering from large odontogenic tumours in the mandible. The precise relationship between the risk of pathological failure and the odontogenic tumours are not clearly understood yet. Using finite element (FE) analysis, this study is primarily aimed at investigating load transfer across the tumour affected mandibles during a complete mastication cycle. Geometry and material properties were based on subject-specific CT-scan data. Before analysis of a diseased mandible with tumour, it seemed necessary to investigate the load transfer across a healthy mandible to determine the deviations in stress and strain distributions. Based on the condition of the host bone, segmental reconstruction or complete mandibular reconstruction is advised. A FE based novel multiscale framework using numerical homogenisation technique has been employed in order to evaluate effective orthotropic material properties of $0^{o}/90^{o}$ Ti lattice structures with different strut diameters and inter-strut distances. Moreover, the complete mandibular constructs were assigned with the effective orthotropic material properties of the designed lattice structures and simulated under a complete mastication cycle. It is observed that notable influence of the strut diameter and inter-strut distance was evident on the principal strain distributions of the constructs. Moreover, for $0^{o}/90^{o}$ strut orientation, scaffold architecture, with 0.6 mm strut diameter having 0.5 mm inter-strut distance and 0.2 mm strut diameter having 0.3 mm inter-strut distance, appeared to be suitable for the design of the complete mandibular constructs. Two different types of patient specific customized Ti reconstruction plates, solid and plate with holes, with different types of fixation screws, dental roots and crowns were designed for further study. The FE models of the reconstructed mandibles were simulated under a mastication cycle to analyse the influence of the combination of fixation screws and reconstruction plates, on the load transfer across the reconstructed mandibles. The lattice structures with 0.6 mm strut diameter having 0.5 mm inter-strut distance were further chosen for fabrication using an extrusion-based 3D printing. Based on the physicochemical assessments of the sintered scaffolds, it could be concluded that extrusion-based 3D printing is an excellent alternative as compared to those high-cost incurring laser-based additive manufacturing processes. Moreover, osteogenic peptides were grafted on the pristine Ti surfaces using a silane chemistry based novel vapour deposition process. *In vitro* assessments of the surface modified scaffolds, using human amniotic derived mesenchymal stem cells, showed enhanced cell adhesion and viability. *In vivo* subcutaneous study in rat models of the surface modified Ti scaffolds also showed enhanced tissue integration in terms of Collagen I deposition as revealed by Masson's trichrome staining of the tissue-integrated scaffold sections, around the periphery of the tissue-integrated struts as compared to those of pristine scaffolds. The study has established that the FE based design of the scaffolds were successfully fabricated using 3D printing and showed enhanced tissue integration abilities while grafted with osteogenic peptides on their surfaces.

Keywords: odontogenic tumour, mandible, segmental mandibulectomy, mandibular reconstruction, finite element analysis, multiscale numerical homogenization technique, bone graft, 3D printing, surface modification, *in vitro* assessment, subcutaneous tissue-integration.