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Numerical Analysis of Mandible Fracture Stabilization System

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Abstract : The aim of the presented work is to recognize the impact of mini-plate application approach on the stress and displacement within the stabilization devices and surrounding bones. The mini-plate osteosynthesis technique is widely used by craniofacial surgeons as an improved replacement of wire connection approach. Many different types of metal plates and screws are used to the physical connection of fractured bones. Below investigation is based on a clinical observation of patient hospitalized with mini-plate stabilization system. Analysis was conducted on a solid mandible geometry, which was modeled basis on the computed tomography scan of the hospitalized patient. In order to achieve most realistic connected system behavior, the cortical and cancellous bone layers were assumed. The temporomandibular joint was simplified to the elastic element to allow physiological movement of loaded bone. The muscles of mastication system were reduced to three pairs, modeled as shell structures. Finite element grid was created by the ANSYS software, where hexahedral and tetrahedral variants of SOLID185 element were used. A set of nonlinear contact conditions were applied on connecting devices and bone common surfaces. Properties of particular contact pair depend on screw - mini-plate connection type and possible gaps between fractured bone around osteosynthesis region. Some of the investigated cases contain prestress introduced to the mini-plate during the application, what responds the initial bending of the connecting device to fit the retromolar fossa region. Assumed bone fracture occurs within the mandible angle zone. Due to the significant deformation of the connecting plate in some of the assembly cases the elastic-plastic model of titanium alloy was assumed. The bone tissues were covered by the orthotropic material. As a loading were used the gauge force of magnitude of 100N applied in three different locations. Conducted analysis shows significant impact of mini-plate application methodology on the stress distribution within the miniplate. Prestress effect introduces additional loading, which leads to locally exceed the titanium alloy yield limit. Stress in surrounding bone increases rapidly around the screws application region, exceeding assumed bone yield limit, what indicate the local bone destruction. Approach with the doubled mini-plate shows increased stress within the connector due to the too rigid connection, where the main path of loading leads through the mini-plates instead of plates and connected bones. Clinical observations confirm more frequent plate destruction of stiffer connections. Some of them could be an effect of decreased low cyclic fatigue capability caused by the overloading. The executed analysis prove that the mini-plate system provides sufficient support to mandible fracture treatment, however, many applicable solutions shifts the entire system to the allowable material limits. The results show that connector application with the initial loading needs to be carefully established due to the small material capability tolerances. Comparison to the clinical observations allows optimizing entire connection to prevent future incidents.

Keywords : mandible fracture, mini-plate connection, numerical analysis, osteosynthesis
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