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Finite Element Analysis of Mini-Plate Stabilization of Mandible Fracture

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Abstract : The aim of the presented investigation is to recognize the possible mechanical issues of mini-plate connection used to treat mandible fractures and to check the impact of different factors for the stresses and displacements within the bone-stabilizer system. The mini-plate osteosynthesis technique is a common type of internal fixation using metal plates connected to the fractured bone parts by a set of screws. The selected two types of plate application methodology used by maxillofacial surgeons were investigated in the work. Those patterns differ in location and number of plates. The bone geometry was modeled on the base of computed tomography scans of hospitalized patient done just after mini-plate application. The solid volume geometry consisting of cortical and cancellous bone was created based on gained cloud of points. Temporomandibular joint and muscle system were simulated to imitate the real masticatory system behavior. Finite elements mesh and analysis were performed by ANSYS software. To simulate realistic connection behavior nonlinear contact conditions were used between the connecting elements and bones. The influence of the initial compression of the connected bone parts or the gap between them was analyzed. Nonlinear material properties of the bone tissues and elastic-plastic model of titanium alloy were used. The three cases of loading assuming the force of magnitude of 100N acting on the left molars, the right molars and the incisors were investigated. Stress distribution within connecting plate shows that the compression of the bone parts in the connection results in high stress concentration in the plate and the screws, however the maximum stress levels do not exceed material (titanium) yield limit. There are no significant differences between negative offset (gap) and no-offset conditions. The location of the external force influences the magnitude of stresses around both the plate and bone parts. Two-plate system gives generally lower von Misses stress under the same loading than the one-plating approach. Von Mises stress distribution within the cortical bone shows reduction of high stress field for the cases without the compression (neutral initial contact). For the initial prestressing there is a visible significant stress increase around the fixing holes at the bottom mini-plate due to the assembly stress. The local stress concentration may be the reason of bone destruction in those regions. The performed calculations prove that the bone-mini-plate system is able to properly stabilize the fractured mandible bone. There is visible strong dependency between the mini-plate location and stress distribution within the stabilizer structure and the surrounding bone tissue. The results (stresses within the bone tissues and within the devices, relative displacements of the bone parts at the interface) corresponding to different models of the connection provide a basis for the mechanical optimization of the mini-plate connections. The results of the performed numerical simulations were compared to clinical observation. They provide information helpful for better understanding of the load transfer in the mandible with the stabilizer and for improving stabilization techniques.

Keywords : finite element modeling, mandible fracture, mini-plate connection, osteosynthesis
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