Development of a variable locking angle implant for treating of Pauwels type III femoral neck fractures and mandibular angle fractures

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Abstract

Introduction: Pauwels type III fractures are generally associated with the verticality of transcervical high-energy hip fractures in younger individuals. They occur in approximately 3.6% of total body fractures and 57% of hip fractures and are the leading cause of hospitalization in elderly patients. On the other hand, young adults with femoral neck fractures are considered for hospitalization if they are younger than 65–70 years and they tend to have fewer femoral neck fractures than elderly with osteoporosis. Young adults tend to have more vertically oriented distal neck or basicervical fractures from high-energy mechanisms (commonly car or motorbike accidents). Locking plates are considered as a favourable treatment option for bone injuries and healing due to their strong biomechanical properties. Nowadays, a fair amount of locking system designs are available, but their mechanical properties and features are not entirely sufficient for the challenges the patients find themselves in. The purpose of this study is threefold. First, to both computationally and experimentally validate a novel screw locking system containing a plate and a screw by comparing it to another state-of-the-art locking system. Secondary purpose is to apply the said system in an environment of a fractured mandible to test the system in a bony environment. The last and ultimate goal of the system is to re-develop it to extend its functionality further; to compare the biomechanical stability of a standard inverted triangle configuration for treating Pauwels type III femoral neck fractures with newly proposed x-crossed screw configurations, which are the new addition to the patented locking system. When treating femoral neck fractures in both young and old individuals, artificial femoral head replacement surgery is typically not advised. Multiple screws, or a sliding hip screw with or without an antirotation screw are the most often used methods for treating vertical femoral neck fractures. So, a perfect locking system should be able to anchor itself in a healthy as well as in an osteoporotic bone, simultaneously being able to remove itself without causing any additional damage to the surrounding biological tissues. The screw's geometry, size, position, and length are the most important factors affecting the structural performance of internal fixation implants; nevertheless, the question of determining the ideal medical implant in order to guide clinical practice still exists between the surgeons.
Methods: The novel locking system was drawn in a SolidWorks software. FEA based simulations made in Abaqus were used to determine the mechanical properties of the novel locking system and the standard one prior to experimental tests. The systems containing a

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plate, and a screw were locked in the plate holes at 0○, 10○, 15○, and 20○. Cyclic bending tests and push-out tests were performed in order to determine the stiffness and push-out forces of both locking systems. A patent application was written afterwards. For testing the locking systems in the cyclic tests, a plate with four holes, 1 mm thickness, and 18 mm in length in a combination with 2.4 mm screw was used. For each sample, 5000 load cycles was conducted with a frequency of 1.4 Hz. Then, the newly designed locking system was reshaped and implemented in mandibular angle fracture. FEA simulations were made to check the biomechanical properties of the novel locking system in a new environment, simultaneously comparing it with a standard locking system for such fractures. For the femoral neck fracture problem, a left, 4th generation composite Sawbones® femur was scanned using computed tomography and later imported into Materialise Mimics software to segment the trabecular and cortical bone. The same artificial and identical bones are going to be used in later studies, in biomechanical experiments. Finally, the locking system was re-designed in SolidWorks for the osteosynthesis purpose of Pauwels type III femoral neck fractures and was later subjected to new FAE simulations, also with a comparison with a commonly used femoral neck fracture osteosynthesis method. In all of the FEA simulations, a mesh of tetrahedral elements of the second order (C3D10) was used on the models. The size of the elements was chosen based on the convergence test of the displacement results. Also, all of the materials were assumed to be homogeneous and isotropic.

Results: The novel locking system showed greater stiffness by 17.3% at the deflection angle of 20○ in cyclic tests, with lower values for other deflection angles in comparison with a similar locking system. The push-out test performance of the control locking system was somewhat superior according to the results. Same trends were displayed in simulations of a fractured mandible angle environment, while comparing the new system to the standard one. The patent application was approved, but just for the mechanism of the locking system. Considering the placement of the screws in the plate, FEA simulations for the osteosynthesis of the femoral neck fracture showed that an x-crossed-right assembly provides biomechanical stability for Pauwels type III femoral neck fractures in terms of maximum von Mises stresses and femoral head displacement. However, it falls short in ensuring full stability for maximum relative neck fracture displacement.

Conclusion: Greater stiffness of the new locking system in cyclic loading tests, together with polyaxiality of the new locking screw, could lead to easier application and improved biomechanical stability of the mandible angle fractures. More importantly, the system demonstrated its potential to be used in different human fractures such as high degree femoral neck fractures.

Acknowledgements: The work in this article is part of a project funded by the European Union – NextGenerationEU under the name FEMLOCK – Razvoj novog implantata za osteosintezu prijeloma vrata bedrene kosti" (NPOO.C3.2.R3-I1.02.0035).