Study on the Characteristics of Increased Mechanical Stiffness according to Changes in LCP shape to Reinforce Clavicle Fractures

Dae-Geun Kim[1], Soo Min Kim[2], Seongtak Kim[3], Dong-Woon Han[3]
[1]Department of Orthopedic Surgery, Soonchunhyang University Gumi Hospital,Gumi, Republic of Korea,
[2]Realistic Media Research Center, Gumi Electronics & Information Technology Research Institute (GERI), Gumi, Republic of Korea,
[3]Functional Materials and Components R&D Group, Korea Institute of Industrial Technology (KITECH), Wonju, Republic of Korea
Email of Presenting Author: kuroo25@schmc.ac.kr

Disclosures: The authors have nothing to disclose.

INTRODUCTION: The clavicle has various shapes for each individual. In addition, as high-energy trauma such as sports damage increases, the pattern of fractures is also complicated. Therefore, there is a need for a new type of metal plate with a stronger stress than the existing metal plate and an even stress distribution for rapid rehabilitation. The purpose of this study is to present a method to secure rigidity while maintaining the existing surgical protocol using six screws by modifying the structure of the locking compression plate (LCP) used to reinforce the clavicle fracture.

METHODS: In this study, in order to distribute the load concentrated on the fracture area through LCP shape control, a wing shape using a partial double curved structure was applied. The format of the image file from the CT scan of the patient's clavicle is DICOM (Digital Imaging and Communications in Medicine), and InVesalius(v.3.1.1; Center for Information Technology Renato Archer, Campinas, Brazil) software was used to read the image file and extract the three-dimensional clavicle structure. In this study, we performed FEA simulations to analyze the influence of LCP structural changes in response to external force application in an ideal environment. Since the structure of the clavicle has a very complex geometric shape, a reinforced clavicle jig was used to apply exactly the same type of external force to the LCP, and an experiment was conducted to analyze the mechanical impact of the structural characteristics of the LCP. When comparing the stress values at the FZ point as a result of FEA simulation where bending is applied, it is calculated that the stress dispersion effect is approximately ten times greater as the shape of the LCP changes from a typical to a double-curved partial wing structure.

RESULTS: As a result of testing under cantilever bending conditions using a reinforced metal clavicle jig, ultimate stress increased 3.33 times from 24.608kgf to 81.991kgf as the LCP changed from typical to double-curved partial wing shape. It can be seen that as the shape of the LCP changes, the strain at the FZ point tends to decrease, which is the same as the result in the reinforced clavicle structure. Related to the deformation of the LCP, it can be seen that the strain rate at the FZ point is rapidly reduced in the double-curved partial wing structure, and the point of maximum deformation is moved.

DISCUSSION: This new LCP design reduces the stress concentration on the fracture site and amount of stress in the fracture area while applying cantilever bending force.

SIGNIFICANCE/CLINICAL RELEVANCE: It is believed that the duration of rehabilitation protocols can be accelerated compared to when surgery was performed using a traditional LCP.

REFERENCES:
1. Postacchini, F., Gumina, S., De Santis, P. & Albo, F. Epidemiology of clavicle fractures. J. shoulder elbow surgery 11, 452–456 (2002).
2. Kim, D.-G., Kim, S. M. & Kim, Y. Numerical simulation and biomechanical analysis of locking screw caps on clavicle locking plates. Medicine 101 (2022).
3. Axelrod, D. E., Ekhtiari, S., Bozzo, A., Bhandari, M. & Johal, H. What is the best evidence for management of displaced midshaft clavicle fractures? a systematic review and network meta-analysis of 22 randomized controlled trials. Clin.orthopaedics related research 478, 392 (2020).

ACKNOWLEDGEMENTS: This work was supported by the Soonchunhyang University Research Fund (20221162) and has been conducted with the support of the Korea Institute of Industrial Technology as "Ppuri Technology based Advancement Support Program (KITECHJC-23-0016)"

IMAGES AND TABLES:

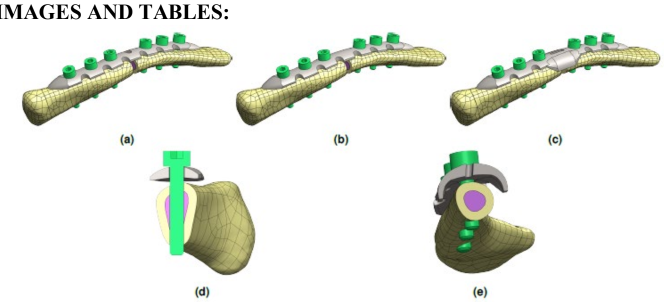

Figure 1. 3D model of customized LCP design structures for clavicle and reinforcement with artificial fracture created using Solidworks, (a) typical shape customized design(Type 1), (b) berried-hole shape customized design(Type 2), (c) double-curved wing shape customized design(Type 3), (d) cross-section area of penetration bolt at M1 hole, (e) cross-section area of double-curved wing shape LCP at FZ site.

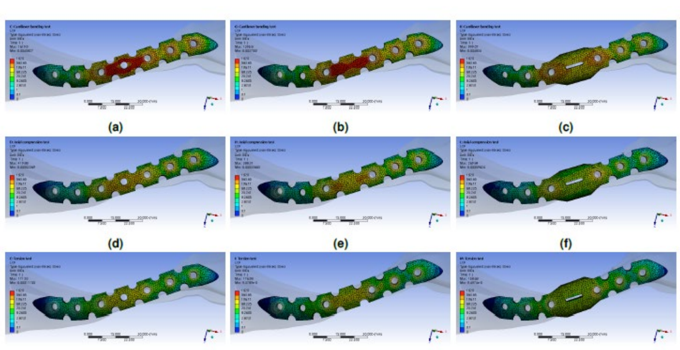

Figure 2. FEA simulation analysis results of the response to externally applied force to the LCP using the reinforced clavicle structure jig, Equivalent (von-Mises) Stress, (a) typical shaped LCP(Type 1) with cantilever bending force, (b)berried-hole shaped LCP(Type 2) with cantilever bending force, (c) double-curved partial wing shaped LCP(Type 3) with axial compression force, (d) typical shaped LCP(Type 1) with axial compression force, (e) berried-hole shaped LCP(Type 2) with axial compression force, (f) double-curved partial wing shaped LCP(Type 3) with axial compression force, (d) typical shaped LCP(Type 1) with torsion torque, (e) berried-hole shaped LCP(Type 2) with torsion torque, (f) double-curved partial wing shaped LCP(Type 3) with torsion torque.