Numerical Simulation and Biomechanical Analysis of Locking Screw Caps on Clavicle Locking Plates

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INTRODUCTION: The risk of displaced and comminuted midshaft clavicle fractures is increased in high-energy traumas such as sport injuries and traffic accidents. Open reduction and plate fixation have been widely used for midshaft clavicle fractures. Among various plates for clavicle shaft fractures, superior locking compression plates (LCPs) have been mostly used. In plate fixation, nonunion caused by implant failure is the most difficult complication. The most common reasons for metal plate failure are excessive stress and stress concentration caused by cantilever bending. These causes were easily addressed using a locking screw cap (LSC).

METHODS: The clavicle 3-dimensional image was made from a computed tomography scan, and the clavicle midshaft fracture model was generated with a 10-mm interval. The fracture model was fixed with a superior LCP, and finite element analysis was conducted between the presence (with LSC model) and absence (without LSC model) of an LSC on the site of the fracture. The stresses of screw holes in models with and without LSCs were measured under 3 forces: 100 N cantilever bending force, 100 N axial compression force, and 1 N·m axial torsion force. After the finite element analysis, a validation test was conducted on the cantilever bending force known as the greatest force applied to superior locking plates.

RESULTS: The mean greatest stress under the cantilever bending force was significantly greater than other loading forces. The highest stress site was the screw hole edge on the fracture site in both models under the cantilever bending and axial compression forces. Under the axial torsional force, the maximum stress point was the lateral first screw hole edge. The ultimate plate stress of the with LSC model is completely lower than that of the without LSC model. According to the validation test, the stiffness, ultimate load, and yield load of the with LSC model were higher than those of the without LSC model.

DISCUSSION: Therefore, inserting an LSC into an empty screw hole in the fracture area reduces the maximum stress on an LCP and improves biomechanical stability.

SIGNIFICANCE/CLINICAL RELEVANCE: By using a LSC, it is believed that displacement of LCP may be prevented, thereby preventing nonunion of fracture site.

REFERENCES:
1. Postacchini, F., Gumina, S., De Santis, P. & Albo, F. Epidemiology of clavicle fractures. J. shoulder elbow surgery. 2022; 11, 452–456.
2. Chiu YC, Huang KC, Shih CM, et al. Comparison of implant failure rates of different plates for midshaft clavicular fractures based on fracture classifications. J Orthop Surg Res. 2019;14:220.
3. Zhang F, Chen F, Qi Y, et al. Finite element analysis of dual small plate fixation and single plate fixation for treatment of midshaft clavicle fractures. J Orthop Surg Res. 2020;15:1–7.

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IMAGES AND TABLES:

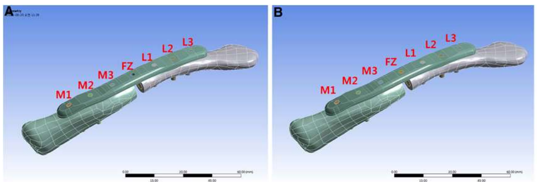

Figure 1. There were schematics of 2 simulation models. (A) Without LSC model. (B) With LSC model. LSC = locking screw cap.

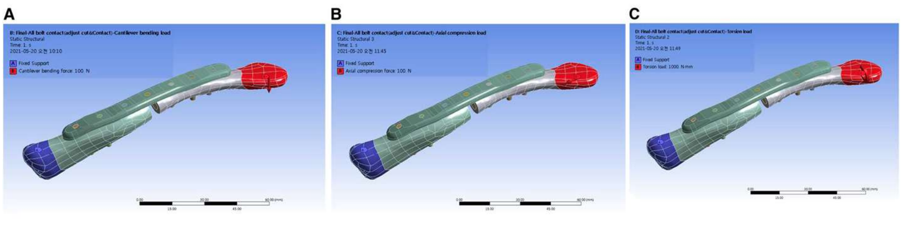

Figure 2. Three loading conditions with boundary conditions were applied to the acromial end. (A) Cantilever bending load. (B) Axial compression load. (C) Axial torsion load with count clockwise.

Points	Cantilever bending load (MPa)		Axial compression load (MPa)		Axial torsion load (MPa)	
	Without LSC	With LSC	Without LSC	With LSC	Without LSC	With LSC
M1	15.40	15.54	0.78	0.78	3.60	3.81
M2	36.71	36.28	5.32	5.34	10.10	10.60
M3	91.01	90.17	21.91	21.94	24.43	24.95
FZ	874.11	412.66	244.51	116.88	46.90	61.03
L1	82.13	80.01	24.99	24.33	33.47	33.57
L2	39.88	40.22	11.50	11.56	24.71	25.34
L3	16.17	15.79	3.99	3.82	5.20	4.43
Avg. M	47.71	47.33	9.34	9.35	12.71	13.12
Avg. L	46.06	45.34	13.49	13.23	21.13	21.11
Avg. ratio (M/L)	1.04	1.04	0.69	0.71	0.60	0.62
Max	874.11	494.26	252.22	114.15	86.03	83.23
FZ reduce (%)	52.79		52.20		–30.11	
Max reduce (%)	43.46		54.74		3.25	

Avg. = average, FZ = fracture zone, L = lateral, LSC = locking screw cap, M = medial.

Table 1. Stress analysis results by FEA.