Introduction: Surgical managements of proximal extra-articular tibia fractures using the conventional plates are subjected to lacking secondary reduction ability when using unilaterally [1]. However, with the introduction of the anatomically pre-shaped locking plate like LCP_PLT (LCP Proximal Lateral Tibia), now unilateral plating with minimally invasive approach has been becoming a gold standard technique for unstable extra-articular proximal tibial fractures [2-3]. Although, studies on its biomechanical stability of the locking plating and conventional plating have been widely performed, comprehensive evaluation of the locking plate regarding its static and dynamic stability are rare, especially the strain distributions of locking plates under physiological loading control were never known. In this study, we investigated stiffness and fatigue characteristics of LCP_PLT to understand its clinical feasibility. Strain gauges were also employed to find the strain/stress distribution in the system.

Materials and Methods: To minimize specimen variations, two composite synthetic tibiae (large left 3rd-generation tibia, model 3302, 405 mm; Sawbones, Vashon Island, WA, USA) were prepared with 3 cm defect regions to simulate proximal extra-articular tibia fractures. Both defect tibia models were reduced with 13-hole LCP (LCP-PLT, model 422.229, Synthes, USA). Three 40 mm screws were placed distal to the osteotomy through the third-fifth locking holes; three 90 mm, 75 mm, 50 mm screws and two 70 mm screws were placed proximally through the A-E holes, all of which were performed by an experienced trauma orthopaedic surgeon. One of the tibia/LCP construct was then mounted to the holding fixture with acrylic cement and subjected to axial compression load at 0.2 mm/sec until failure by using the Material Testing System 858 (MTS System Inc., MN, USA) (Figure 1). Femoral component (G-size, model 5272-17-01; NEXGEN system, Zimmer, USA) jig was used to simulate the physiological loading from the knee joint [4]. To evaluate the static stability of the tibia/LCP construct, we collected the load and displacement data at a rate of 20 Hz and the slope (stiffness) was obtained from the load-displacement curve. Five strain gauges were attached to the plate near and adjacent to the defect region to measure the strain. During the testing, axial strains were simultaneously recorded using Strain Measurement System (AI1600, MN, USA) (Figure 1). Femoral component (G-size, model 5272-17-01; NEXGEN system, Zimmer, USA) jig was used to simulate the physiological loading from the knee joint [4]. To evaluate the static stability of the tibia/LCP construct, we collected the load and displacement data at a rate of 20 Hz and the slope (stiffness) was obtained from the load-displacement curve. Five strain gauges were attached to the plate near and adjacent to the defect region to measure the strain. During the testing, axial strains were simultaneously recorded using Strain Measurement System (AI1600, CAS, USA). During fatigue test, the specimen was subjected to axial cyclic load of 50-500 N for 5×105 cycles (5Hz) to simulate 10 months in vivo [5]. Fatigue failure was defined as a plate or screw breakage or a loosening of the screws in the plate or bone [3].

Results: Stiffness and failure load of the LCP were 141.6 N/mm and 1032.5 N, respectively. The displacement at 600 N which is close to the body weight was 4.39 mm. The stiffness of LCP in this study was 2.3 times higher than the traditional buttress plate, while 58% lower than dual plating found in the literature. There was no failure due to fatigue after 5×105 cycles (Table 1). The highest axial strain (ε) was presented at the defect region and the second highest region was shown at upper adjacent region to the defect (No. 2). This is thought to be due to the higher bending moment at the upper part of the LCP.

Discussion: In this study, we compared the static stability of LCP constructs to the previous investigation using double plating (DP) and unilateral plating (BP) [6]. LCP construct showed more than two-times higher biomechanical rigidity than that of BP construct using conventional buttress plate, although the DP construct is stiffer than LCP construct. Additional study of the fatigue test presented that LCP construct may have sufficient biomechanical stability during the bone healing processes, since 10-month following fracture treatment is sufficient for the healing of the comminuted fracture [6]. To investigate axial strain (ε) of the LCP under static loading condition, five strain gauges were attached to the LCP near to the defect and adjacent regions. As our expectation, defect region (No. 3) showed the highest axial strain but the second highest region was shown at upper adjacent region to the defect (No. 2). This is thought to be due to the higher bending moment at the upper part of the LCP.

In conclusion, unilateral plating using LCP may be able to allow more stable fixation of the proximal extra-articular tibia fracture during the bone healing process as compared to the conventional buttress plates, both in static and dynamic loading.


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Table 1: Stiffness and displacement of the defect-composite tibia treated by LCP in comparison with previous studies.

Table 2: Axial strains and stresses on the LCP around the defect region (30-mm gap) at 600N axial compression.

Figure 1: Composite tibiae were axially compressed using femoral component jig (A) and five strain gauges were attached to the plate near to defect and adjacent region (B).