Support instruments provide remarkable stability in medial closed-wedge distal femoral osteotomy: A finite element analysis

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Disclosures: The authors declare no potential conflicts of interest regarding this research, authorship, or publication. This work was jointly funded by the Tokyo Women's Medical University and Olympus Terumo Biomaterials Corp.

INTRODUCTION:
Medial closed wedge distal femoral osteotomy (MCWDFO) is an effective treatment for valgus osteoarthritis of the knee with femoral deformity. However, lateral hinge fracture may increase the risk of non-union and loss of correction. Few studies have assessed the mechanical impact of hinge fracture in MCWDFO. The aim of this study was to evaluate the influence of hinge fracture and support instruments on MCWDFO using finite element analysis.

METHODS:
Computed tomography (CT) data of patients with knee OA who had undergone CT scanning at our institute were adopted. Five femur models were developed using Mechanical Finder 11.0 FEA software (Research Centre of Computational Mechanics Inc.). This study was approved by the Institutional Ethics Commission, and informed consent was obtained.
We produced a 1 mm osteotomy gap as a simulated postoperative bi-plane MCWDFO. Referencing the report on bone mineral density (BMD) status by Keyak et al. [1], the density distribution was calculated with the following formula using the software: BMD (g/cm3) = (CT value [Hounsfield Unit] + 1.4246) × 0.001/1.058. The mean femoral BMD was 0.529 ± 0.065.
A load of 2,400 N was applied to the femoral head at an angle of 15° relative to the femoral axis, and a load of 1,200 N was applied to the greater trochanter at an angle of 20° [2].
We simulated the following models: only a medial locking plate (MLP) (group A); an MLP with a lateral support screw (group B); and an MLP with a lateral support plate (group C) (Fig. 1). The equivalent stress around the hinge was evaluated and the percentage of the plastic deformation zone was calculated for the hinge area in the no-hinge fracture model. The equivalent stress of the MLP and the degree of displacement were calculated using the hinge fracture model.
Data normality was checked using the Kolmogorov–Smirnov test. Repeated measures ANOVA was performed using a paired t-test (Bonferroni correction) to compare the three groups. A p-value of <0.05 was considered indicative of statistical significance.

RESULTS SECTION:
The percentages of the plastic deformation zone in groups A, B, and C were 18.0 ± 11.7%, 3.3 ± 2.4%, and 2.3 ± 2.8%, respectively.
The percentages tended to be lower in groups B and C than in group A, although there were no significant differences between the groups. In the hinge fracture model, the mean equivalent stress of the MLP in group C was significantly less than that in group A ($p < 0.05$) (Fig. 2).
In terms of the mean degree of displacement, group A showed more than 1 mm of displacement, which was significantly larger than that of the other groups ($p < 0.05$) (Fig. 3).

DISCUSSION:
The main findings of the present study were that the support screw and plate provided significant stability to the hinge fracture site and reduced the equivalent stress of the main plate in MCWDFO with hinge fractures. The support instruments also limited the plastic deformation at the hinge area with the hinge intact model. The support plate tended to show greater stability than the screw, although the two instruments had no significant difference.
The study used a simplified 3D model that did not account for all soft tissues, applied a single loading condition, and only evaluated one plate system. Therefore, the results may not be generalizable to all patients and all clinical situations.
Although such limitations, this study provided that the support instruments, both screws and plates, provided stability to the hinge site and reduced the equivalent stress of the main plate in MCWDFO with hinge fracture.

SIGNIFICANCE/CLINICAL RELEVANCE:
In both plates and screws, the support instruments provided stability to the hinge site and reduced the equivalent stress of the main plate in the MCWDFO with hinge fractures.

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IMAGES AND TABLES: