A finite element analysis study on the stress effect in the knee joint based on the fibular osteotomy level and varus deformity

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INTRODUCTION: Proximal fibular osteotomy (PFO) was found to relieve pain and improve knee function in patients with medial compartment knee osteoarthritis (OA). The treatment effect on medial knee OA can be expected when the medial load is reduced without actually correcting the alignment of the knee joint. Therapy re-distributes the load applied from the inside to the outside and alleviates the load applied on the inside through fibula osteotomy. However, there is lack of quantitative evidence regarding changes in the biomechanical properties of the knee in response to fibular OT. Therefore, the clinical effect of fibular osteotomy using the finite element (FE) method was evaluated to calculate the exact change in stress inside a knee joint with varus deformity. We also sought to establish a clinical basis by identifying the surgical effect, according to the position of the fibular osteotomy, and the most appropriate level of osteotomy.

METHODS: In order Tto construct a bone model forto be used in finite element analysis (FEA), Ccomputed Ttomography (CT) and Mmagnetic Rresonance Iimaging (MRI) images data of the right lower extremity of an 45- year-s old Korean woman in an intact condition were used. UsingThrough radiology image data, the bone, cartilage, and meniscus were constructed as 3D models, and ligaments were also attached in accordance with the position. One1 body weight was added to the force, and the increase in the varus angle was expressed by changing the force ratio applied into the medial and lateral directions. Accordingly, 12 analysis models were constructed with osteotomy atin different positions and force ratios were constructed.

RESULTS: : In the I21 model, the peak von Mises stress in the medial and lateral menisci were 5.000 MPa and 3.058 MPa, respectively. In the P21 model in which proximal fibula osteotomy was performed, the peak von Mises stress results were 4.537 MPa and 2.915 MPa in the medial and lateral directions, respectively. In the M21 model with osteotomy at the middle level, the peak von Mises stress results were 4.579 MPa and 2.905 MPa in the medial and lateral directions, respectively. In the D21 model with osteotomy at the distal level, the peak von Mises stress results were 4.579 MPa and 2.911 MPa in the medial and lateral directions, respectively. In the I31 model with increased varus angle, the medial and lateral stress measurements were 5.562 MPa and 2.574 MPa, respectively, and in the I41 model, the medial and lateral stress measurements were 5.941 MPa and 2.257 MPa, respectively.

DISCUSSION AND CONCLUSION: A comparison of the peak von Mises stress results between the I21 and the P21, M21, and D21 models that underwent fibula osteotomy showed that the meniscus and cartilage stress in the medial direction significantly decreased, and that in lateral direction tended to decrease slightly. In particular, compared with the I21 model, the stress of the medial tibial cartilage decreased from 17.3% to 17.4% in the P21, M21, and D21 models, and the stress of the lateral femur cartilage decreased from 5.6% to 5.8%, showing a difference in the amount of change in the medial and lateral directions. When the force was increased on the medial compartment before OT, the stress decreased more significantly during fibula osteotomy.