Effects of High Tibial Osteotomy on Tibiofemoral Articular Contact Pattern and Stress/Strain Distribution During Stand-to-Sit Movement

Kao-Shang Shih[1], Yu-Ting Chen[2], Kuan-Hsien Wu[2], Jing-Huei Siao[2] and Tung-Wu Lu[2,3,4*]
[1] Department of Orthopedic Surgery, Shin Kong Wu Ho Su Memorial Hospital, Taiwan
[2] Department of Biomedical Engineering, National Taiwan University, Taiwan
[3] Department of Orthopaedic Surgery, School of Medicine, National Taiwan University, Taiwan
[4] Health Science and Wellness Research Centre, National Taiwan University, Taiwan
Email: twlu@ntu.edu.tw

Summary

This study examined the effects of high tibial osteotomy (HTO) on tibiofemoral contact patterns and stress/strain distribution during stand-to-sit movement. Using biplane fluoroscopy and finite element analysis, we observed a reduction in medial contact area and a redistribution of stress post-surgery. These findings suggest that HTO may alter joint loading and contribute to improved stability, warranting further investigation into its long-term biomechanical effects.

Introduction

High tibial osteotomy (HTO) is a surgical intervention for medial compartment knee osteoarthritis (OA) that aims to restore joint alignment and delay total knee arthroplasty. While its clinical benefits are well recognized, its biomechanical effects during functional activities such as stand-to-sit (STS) remain unclear [1]. This study investigates the impact of HTO on tibiofemoral articular contact patterns and stress/strain distribution during STS movement to improve understanding of post-surgical joint mechanics and guide rehabilitation strategies.

Methods

Fifteen patients with knee OA (age: 58.07 ± 9.51 years) performed stand-to-sit (STS) exercises before and after HTO. Knee motions were captured using a biplane fluoroscopy system, and 3D models of bones and cartilage were reconstructed from CT and MRI scans. A validated 3D/2D image registration method was used to determine joint kinematics [2], and finite element analysis was conducted to evaluate stress and strain distribution. Paired t-tests were used to compare pre- and post-surgery conditions ($\alpha = 0.05$).

Results and Discussion

Altered tibiofemoral contact patterns during STS movement were observed before and after HTO. Compared to the pre-surgery condition, the post-surgery condition exhibited significantly reduced contact areas in the medial compartment for knee flexion between 35° and 75° (Figure 1a). No significant changes were observed in the lateral compartment (Figure 1b). Stress distribution also shifted post-surgery, with reduced peak stress in the medial compartment and a more uniform distribution across the tibial cartilage (Figure 2). This shift suggests that HTO may alleviate excessive loading in the medial compartment, potentially slowing the progression of cartilage degeneration.

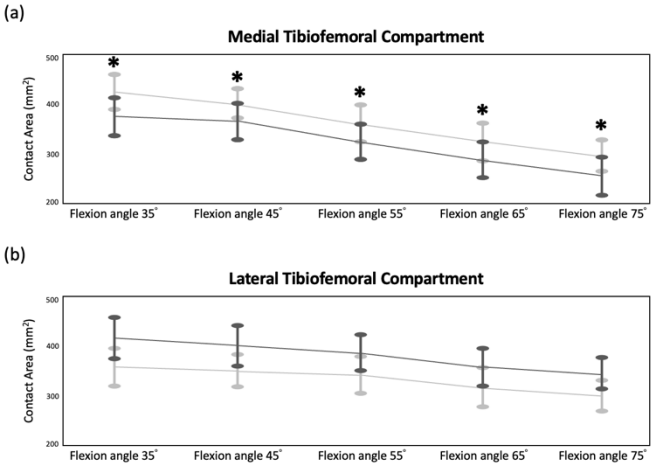

Figure 1: Tibiofemoral compartment contact areas during stand-to-sit movement

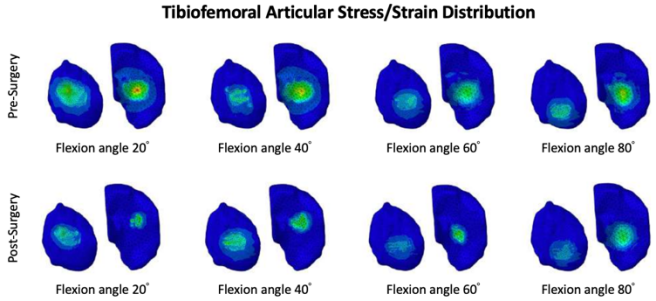

Figure 2: Tibiofemoral articular stress and strain distribution during stand-to-sit movement

Conclusions

HTO appeared to reduce medial compartment contact area and redistribute stress, which may help alleviate excessive loading and slow cartilage degeneration. The more uniform stress distribution suggests a potential improvement in joint stability, providing insights for optimizing surgical outcomes.

Acknowledgments

The authors are grateful for the financial support from the National Science and Technology Council of Taiwan (111-2221-E-341-003- and 112-2221-E-341-001-).

References

[1] Liu et al. (2019). *J Healthc Eng*, **2019**: 8363128.
[2] Lin, C. C. et al. (2018). *Med Phys*, **45(8)**, 3637-3649.