

Effect of Osteochondral Defect Size on Contact Pressures in Human Knee Joints: Experimental and Finite Element Analyses

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Introduction: Osteochondral defects (OCD), involving simultaneous damage to articular cartilage and underlying subchondral bone, present intricate challenges in joint pathology [1]. These defects are associated with pain, functional limitations, and joint degeneration. Understanding the biomechanical nuances that govern the effects of OCD on joint health is crucial for informed clinical decision-making and tailored interventions [2-3]. The knee joint's intricate biomechanics and susceptibility to loading underscore the importance of comprehending how OCD size and location influence contact pressures. Bridging the gap in this knowledge has implications for optimizing treatment approaches. Therefore, the purpose of this study is to systematically investigate the effects of OCD size and location on knee joint contact pressures, utilizing a combined approach involving biomechanical testing and finite element analysis (FEA)

Methods: Six human cadaveric knees (three left, three right) were prepared meticulously, retaining critical anatomical structures. OCD of varying sizes (3, 5, 7, and 10 mm) was introduced on both medial and lateral femoral condyles. Biomechanical testing involved axial loading (0-600 N) at full extension and 30 degrees of flexion using custom apparatus and Tekscan sensors. Finite element analysis (FEA) employed a 3D knee joint model validated against micro-CT scans. Circular defects simulating experimental sizes were positioned based on anatomical considerations. FEA encompassed material properties, constraints, and contact interactions. The model was validated against experimental data involving a 600 N load during full extension and 30 degrees of flexion.

Result: The study found that increasing defect size led to a significant increase in contact pressures on the MFC and LFC, with the highest pressures observed near the 3 mm defect size. The location of the peak contact pressure points on the MFC and LFC also shifted with an increase in defect size (**Fig 1**). Furthermore, FEA analysis revealed that the pressure distribution on the femoral cartilage varied significantly with defect size, with the 3 mm defect size being the most critical in affecting overall contact pressure distribution (**Fig 2**).

Discussion: The study delved into how distinct OCD sizes influence contact pressures and distribution in human knee joints' femoral condyles—notably, more significant defects correlated with elevated pressures, posing risks of escalated cartilage damage and joint degeneration. Raised edges accompanying defects compounded uneven force distribution due to reduced contact area, further exacerbating cartilage deterioration. Shifts in peak pressure points with varying defect sizes underscored the surgical planning's complexity, emphasizing the need to consider these dynamics for optimal implant or graft placement. Finite element analysis (FEA) validated these findings, aligning peak pressure values with the literature. While magnitudes vary across studies, the trend of more significant defects yielding higher pressures is consistent. FEA pressure distribution analysis highlighted the critical impact of 3 mm defects on overall contact pressure distribution. Clinically, early intervention to halt cartilage defect progression and joint degeneration is crucial. Strategies like microfracture, autologous chondrocyte implantation, and osteochondral grafting offer the potential for restoring cartilage and enhancing joint function, with optimal outcomes tied to defect size, location, and contact pressure distribution. Nevertheless, study limitations included static loading conditions and cadaveric specimens' divergence from living joints. Furthermore, the study's focus on size and location calls for additional research into factors like patient age, activity level, and joint health, intricately weaving the tapestry of cartilage defects, contact pressures, and joint function.

Significance/Clinical Relevance: The findings of this study hold significant clinical implications for the management of articular cartilage lesions within the knee joint. Understanding how OCD size and location influence contact pressures on femoral condyles informs tailored interventions. Larger defects were associated with heightened contact pressures, with potential consequences of exacerbating cartilage damage and accelerating joint degeneration. Moreover, the study's observation of peak pressure point shifts emphasizes the need for precise surgical planning to optimize outcomes. Surgeons can strategically position implants or grafts based on defect characteristics.

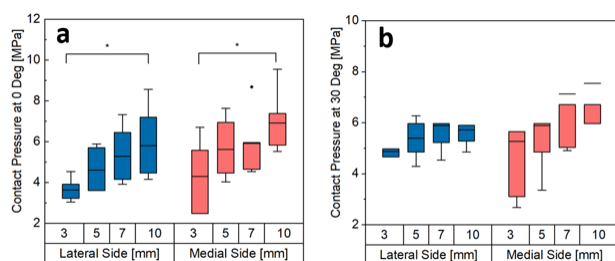


Fig 1. Maximum contact pressure box plots for medial and lateral femoral condyles with different defect sizes. (a) The figure shows that medial and lateral femoral condyles at 0 degrees of full extension and (b) 30 degrees of full flexion with different defect sizes (3, 5, 7 and 10 mm).

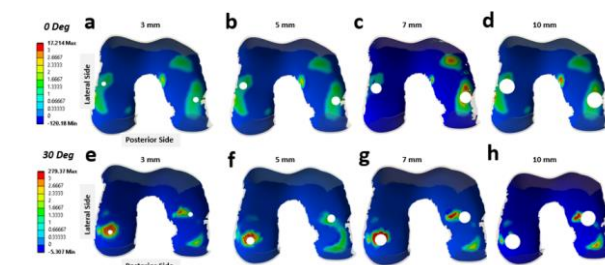


Fig 2. A finite element analysis (FEA) contact pressure analysis for the medial and lateral cartilage of the femoral knee with chondral defects of varying sizes (d = 3, 5, 7, and 10 mm) at 0 (a-d) and 30 degrees (e-h) of full extension and flexion of the knee joint. The pressure distribution and contact pressure magnitudes (in MPa) for each defect size and knee angle are displayed, highlighting the differences in peak contact pressure and pressure distribution patterns between the medial and lateral condyles

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