

# Dissection and plastination of a lower limb in postoperative regeneration of a bicondylar fracture

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### Education

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#### ABSTRACT:

This study presents the dissection of a lower limb from a deceased individual who underwent reconstructive surgery due to a right tibial fracture affecting both the medial and lateral condyles of the proximal epiphysis (plateau fracture). The fracture was corrected using an open reduction internal fixation (ORIF) procedure, where stainless steel plates and screws were implanted. During the dissection in the area distal to the region affected by the surgery, inappropriate fixation was identified, which resulted in fragile structures that were challenging to dissect and preserve. The dissection was carried out using basic anatomical dissection instruments and the entire process has been documented with photographs in a step-by-step manner. The exposure of the surgical area involved removing the connective tissue covering the implanted hardware, revealing their positioning. Challenges arose in preserving structures located in the insufficiently fixed area, as their fragility limited complete visibility. Following the dissection, the specimen was plastinated and preserved for future educational purposes.

Despite these difficulties, the meticulous dissection and subsequent plastination of the limb yielded a durable specimen that serves educational purposes. This specimen allows demonstration of pathological changes in the tissue, provides a learning experience for

surgeons and contributes to a deeper understanding of the healing process that takes place in the postoperative period after traumatological or orthopaedic interventions.

KEY WORDS:

**plastination; orthopaedics; surgery; tibial fractures; epiphyses; postoperative period**

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## INTRODUCTION

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Understanding lower limb anatomy is essential for medical and health science students, especially those aspiring to become orthopaedic surgeons or traumatologists. To deepen their knowledge, students may dissect cadavers or use online resources. Education typically starts with basic terminology and limb orientation, progresses to surface landmarks and then explores deeper gross structures (Estai & Bunt, 2016). Dissection labs provide hands-on experience, mainly on formalin-fixed cadavers (So et al., 2017; Roxburgh & Evans, 2021). Medical imaging such as ultrasound, MRI and CT scans supplement traditional learning, while case studies enhance understanding of clinical correlations and pathologies (So et al., 2017; Pettersson et al., 2023). Clinical skills sessions often involve examining patients' lower limbs, emphasizing the importance of understanding anatomical variations for managing complications (Qazi et al., 2022). Pathology discussions, like fractures and dislocations, highlight clinical relevance, though real post-traumatic cases are rarely seen in dissecting labs (Nicola & Jewison, 2012). Learning common traumatological procedures is vital for future healthcare providers. During classes, students study the physiological positions of structures, traumatic injuries and treatment options, but postoperative conditions are seldom addressed in gross dissections, as these tissues are not preserved long-term (Dykyj & Jules, 1991). Understanding lower limb biomechanics post-surgery is crucial for physiotherapy (Esquenazi, 2014). Workshops on surgical anatomy prepare students for specialties but often do not focus on healing or postoperative complications. Integrating anatomy and pathology in postoperative education offers a more comprehensive understanding of patient recovery. Emerging technologies like plastination are increasingly used to preserve rare or postoperative cases, enhancing traumatological training (Kukulski et al., 2023).

While plastination of healed fractures remains challenging, the classification of fractures, such as bicondylar tibia fractures, is well-studied. Accurate treatment depends on proper categorization, with the Müller-AO classification being most common (Nguyen et al., 2020b; Besa et al., 2023). Soft tissue conditions, classified by systems like Gustillo-Anderson, also influence treatment outcomes (Plotnikovs et al., 2022). Fractures in the crural region are complex due to the tibia's load-bearing role and soft tissue coverage, requiring advanced imaging (CT, MRI, angiography) for planning. Treatment varies from conservative methods, such as casting and external fixation, to surgical interventions such as osteosynthesis with plates or intramedullary nailing (Nguyen et al., 2020a; Du et al., 2021). Traditional plates, once common, now see limited use due to infection risks and the rise of intramedullary nailing and angular stable plates. These interventions are typically studied during residency or workshops, but postoperative healing is rarely examined in anatomical or traumatological education, with follow-up imaging confirming implant positioning but not explored during dissections.

In this study, a lower limb was dissected post-surgery. Healing in a not well-fixed area was examined and preserved via plastination for educational purposes. Dissection also revealed stainless steel plates in the postoperative period, which were maintained in their position

after plastination. The focus was on preserving and studying postoperative conditions of surgical intervention.

## **MATERIALS AND METHODS**

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The donation of the body for anatomical examination took place according to the binding legal regulations. The cadaver was fixed with 10% formalin via the femoral artery at 1.2 bar pressure, and formalin was circulated in the body to reach the tissues. The cadaver was then placed into a 10 % formalin bath for 3 months. The preservation process was performed in accordance with the routine protocol of the Department of Anatomy, Histology and Embryology at the University of Debrecen, Hungary. After preservation, the lower limbs connected to the pelvis were separated at the level of the iliac crest, and the pelvis was halved in the sagittal plane. Dissection involved basic scalpels, scissors and forceps. Scar tissue covering the implanted plates and screws was removed with surgical scalpels. A Pean clamp was used to retract muscles and tendons.

An anatomical dissection of a complete lower limb from a deceased individual who had surgical intervention for a tibial fracture was conducted for educational purposes. The detailed medical history was unknown, but we were informed that the deceased had undergone knee surgery. The exact type of intervention was determined after exposing the surgical area. The deceased likely suffered a plateau fracture of the medial and lateral tibial condyles, known as a bicondylar tibial plateau fracture. The fracture had been corrected with open reduction and internal fixation (ORIF), during which two buttress steel plates and several screws were implanted.

After dissection, the specimen was dehydrated by immersion in acetone at -20° C for approximately 3 weeks. Then the specimen was placed in a vacuum chamber (at atmospheric pressure) with liquid silicone (S10/S3 BIODUR® Products GmbH, Heidelberg, Germany) until vacuum removed the remaining air, allowing the silicone to infiltrate the specimen. This step took approximately 4 weeks in the case of the complete lower limb. After impregnation, the specimen was kept at room temperature in a chamber for 7 days while excess silicone drained from the tissues. Silicone droplets were removed and the surface of the specimen was wiped every day. During this process, anatomical structures were positioned and separated for the best possible visualization of obscured structures. For the final step, the dissected specimen was placed in the S6 (BIODUR® Products GmbH, Heidelberg, Germany) gas chamber for curing for 10 days at room temperature. The curing process hardened the silicone and ensured that the specimen was stable and retained its shape. The curing process preserved the status of degraded tissues as well.

## RESULTS

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Anatomical dissection revealed a lower limb with bicondylar tibial plateau fracture treated via ORIF with steel plates and screws, following prior knee surgery. Unfortunately, such interventions can lead to numerous complications despite the greatest precautions. Complications such as infection, swelling, bone damage, secondary displacement of the fracture and acute compartment syndrome may occur (Rudran et al., 2020; Amin et al., 2021; Milenkovic et al., 2021). In severe cases, the implanted hardware can cause inflammation, vascular occlusion and knee arthrofibrosis (Choo & Morshed, 2014; Kugelman et al., 2017).

During the dissection of the lower limb, our primary goal was to expose the surgical area in such a way as to preserve the important anatomical structures while ensuring that the implanted screws and plates were clearly visible to demonstrate features of the healing process. Finally, our objective was to prepare the specimen for plastination so that it could be used for educational purposes for a longer duration.

The dissection proceeded normally for the regions above the knee, and we successfully preserved all significant anatomical structures. During the exposure of the knee region, we found several screws and two buttress steel plates on either side of the proximal epiphysis of the tibia (Fig. 1A). Among the placed hardware, we found several screws that protruded significantly 7 mm above the plane of the plate (Fig. 1B). In the case of one screw, it was observed that the tip of the screw significantly exceeded the bony substance (Fig. 1B). While this is an expected consequence of the healing process (Amin et al., 2021) the extent of the protrusion of the screw was surprising. Moreover, the tip of one screw was positioned towards the popliteal artery and vein, although the surrounding tissue was well dissectible in this area (Fig. 2).

During dissection of the distal (crural and plantar) regions, tissues below the knee were fragile, likely due to transient acute compartment syndrome (Cleveland Clinic, 2024) or circulatory issues from popliteal artery compression (Fig. 3A). This limited our ability to fully dissect deeper vascular and nerve structures; the anterior tibial and fibular (peroneal) muscles were partially disintegrated, and the superficial fibular (peroneal) nerve was difficult to isolate (Figs. 3A, 3B). The plantar surface posed additional challenges: poor formalin fixation led to inadequate preservation, causing muscle tissue damage during dissection (Fig. 4A). In contrast, the opposite limb's sole was well-preserved (Fig. 4B), supporting the circulatory insufficiency theory, as formalin hadn't penetrated deeper layers. Despite this, vascular and nerve structures remained intact, though superficial plantar muscles were severely damaged. We did not dissect the popliteal artery or its branches to identify the cause of obliteration, prioritizing preservation of anatomical structures.

After dissection, we proceeded with limb plastination. We documented the knee before (Fig. 5A) and after plastination (Fig. 5B). The specimen's volume reduction was notable due to high fluid content in inadequately fixed areas, but this did not affect the macroscopic structures or hardware placement. Plastination preserved fragile regions and clearly displayed the hardware's position relative to the knee. Similarly, the entire limb was documented before (Fig. 6A) and after plastination (Fig. 6B), with all dissected and challenging areas well preserved. The postoperative surgical site remained unchanged throughout the process.

## DISCUSSION

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The crural region consists of two long bones, the tibia and fibula. The tibia is more load-bearing, being one of the strongest yet most frequently fractured bones in the lower limb (Muller et al., 2023). Its anteromedial surface is subcutaneous, making it vulnerable to fractures and open injuries from direct impacts (Ramponi & McSwigan, 2018). In traumatology, orthopaedic surgery, and other medical fields, a detailed understanding of lower limb anatomy is essential. Many anatomical atlases and online resources provide theoretical knowledge, but their idealized representations are less applicable practically. Therefore, specimens preserved via formalin or plastination are valuable for hands-on learning. While some articles focus on pathological cases for education (Goh et al., 2024), most address internal organ deviations like cerebral infarctions, cardiac tamponade, or neoplasms (Alpar et al., 2005). Fewer studies cover limb pathologies, mainly joint abnormalities and vascular visualization (Graf et al., 1991). Publications on limb trauma or surgical abnormalities are scarce, indicating that pathological limb changes and their preservation are only sporadically documented.

Our plastinated lower limb specimen offers an excellent demonstration of a significant surgical intervention for students. Careful dissection aimed to keep the surgical area visible while maintaining surrounding anatomical relationships. Preserving degraded tissues below the knee was challenging, extending dissection time, but plastination preserved these regions well, enhancing specimen longevity. However, plastination reduces water content (Monteiro et al., 2022), which may influence postoperative condition assessments. Nonetheless, it does not hinder topographical analysis of implants used in trauma surgery and allows study of tissue degradation.

For medical education, it is vital for students and residents to understand both normal anatomy and changes during postoperative recovery. This specimen facilitates study of external fixation, osteosynthesis plates and intramedullary nailing. Although some efforts exist to present pathological or postoperative changes (Simank et al., 1997), such studies are limited, especially regarding post-surgical limb alterations. Despite advances in imaging and 3D printing for surgical planning, understanding degenerative postoperative processes remains challenging (Chen et al., 2024). This plastinated specimen provides valuable

insights for students to master anatomy and to discuss pathological conditions such as fractures and healing processes. Such dissections deepen anatomical knowledge, broaden clinical perspectives and support future studies in various specialties.

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## **Ethical Approval**

This study was performed in line with the principles of the Declaration of Helsinki. Cadaver donation for anatomical dissection happened according to the binding legal regulations of the University of Debrecen.

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