“STUDY OF PROXIMAL TIBIA INTRAARTICULAR FRACURES SCHATZKER TYPE 5 AND 6 TREATED WITH OR WITHOUT 3D PRINTING MODEL” – A COMPARATIVE STUDY

Submitted by

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IN

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UNDER THE GUIDANCE OF

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ABSTRACT

Introduction: Complex intra-articular fractures of the proximal tibia (Schatzker types V and VI) present significant challenges in orthopaedic trauma management. Three-dimensional (3D) printing technology has emerged as a potential tool to enhance preoperative planning and surgical execution for these complex fractures. This study aimed to compare the surgical outcomes of proximal tibial Schatzker type V and VI fractures treated with or without the aid of 3D-printed models.

Methods: A prospective comparative study was conducted with 40 patients presenting with Schatzker type V and VI proximal tibial fractures, divided equally into a 3D print group (n=20) and a conventional treatment control group (n=20). Patient demographics, fracture characteristics, and surgical parameters including operating time, blood loss, fluoroscopy exposure, and number of implant trials were recorded and analysed.

Results: Both groups had comparable demographic and fracture characteristics. The 3D print group demonstrated significantly shorter mean surgical time (110.2±19.3 vs. 142.5±34.04 minutes; $p=0.001$), reduced intraoperative blood loss (275±109.4 vs. 370±155.1 ml; $p=0.03$), and decreased fluoroscopy exposure (0.22±0.15 vs. 0.34±0.06 mSv; $p=0.002$) compared to the control group. Most notably, 70% of cases in the 3D print group required zero implant trials compared to only 10% in the control group ($p<0.001$).

Conclusion: The use of 3D-printed models for preoperative planning in Schatzker type V and VI proximal tibial fractures significantly improves surgical efficiency by reducing operating time, blood loss, radiation exposure, and implant trials. These findings suggest that 3D printing technology represents a valuable adjunct in the management of complex proximal tibial fractures, potentially improving both the process and outcomes of surgical management for these challenging injuries.

Keywords: Proximal tibia fracture; Schatzker classification; 3D printing; Preoperative planning; Surgical outcomes; Intra-articular fractures; Orthopaedic trauma

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LIST OF ABBREVIATIONS

3D - Three-dimensional

2D - Two-dimensional

AO - Arbeitsgemeinschaft für Osteosynthesefragen (Association for the Study of Internal Fixation)

ARIF - Arthroscopically assisted reduction and internal fixation

BMI - Body Mass Index

CT - Computed Tomography

DICOM - Digital Imaging and Communications in Medicine

FFH - Fall From Height

IMN - Intramedullary Nail

LCP - Locking Compression Plate

MIPPO - Minimally Invasive Percutaneous Plate Osteosynthesis

MRI - Magnetic Resonance Imaging

MPTA - Medial Proximal Tibial Angle

mSv - Millisievert (unit of radiation dose)

ORIF - Open Reduction and Internal Fixation

PSI - Patient-Specific Instrumentation

ROM - Range of Motion

RTA - Road Traffic Accident

SD - Standard Deviation

STL - Standard Tessellation Language (file format for 3D printing)

TPF - Tibial Plateau Fracture

VAS - Visual Analog Scale

WOMAC - Western Ontario and McMaster Universities Osteoarthritis Index

INTRODUCTION

Proximal tibial fractures, particularly Schatzker type 5 and 6, represent some of the most challenging injuries in orthopaedic trauma due to their complex articular involvement, associated soft tissue damage, and potential for long-term complications.[1] These high-energy injuries often result from motor vehicle accidents, falls from height, or industrial accidents, predominantly affecting the working-age population and thereby having significant socioeconomic implications. The management of these fractures continues to evolve with advancing surgical techniques and technological innovations, aimed at achieving optimal functional outcomes while minimizing complications.

The Schatzker classification, introduced in 1979, remains the most widely used system for categorizing tibial plateau fractures. Type 5 and 6 fractures, characterized by bicondylar involvement with or without metaphyseal-diaphyseal dissociation, present unique surgical challenges due to their complex fracture patterns, articular surface disruption, and frequent association with severe soft tissue injury.[2] The primary goals of treatment include anatomical restoration of the articular surface, stable fixation allowing early mobilization, and preservation of the surrounding soft tissue envelope.

Traditional preoperative planning for these complex fractures has relied heavily on conventional radiographs and computed tomography (CT) scans. While these imaging modalities provide valuable information, surgeons often face challenges in fully comprehending the three-dimensional nature of the fracture patterns, particularly in cases with significant comminution and displacement.[3] This limitation can potentially impact surgical decision-making and execution, ultimately affecting patient outcomes.

The advent of 3D printing technology in orthopaedic surgery has opened new avenues for preoperative planning and surgical execution. This technology allows for the creation of accurate physical models of the fractured bone based on CT data, providing surgeons with a tangible representation of the fracture pattern.[4] The ability to physically manipulate these models before surgery offers several potential advantages, including better understanding of fracture morphology, improved preoperative planning, and enhanced surgical precision.

Recent studies have suggested that 3D-printed models may significantly impact various aspects of surgical management, including reduced operative time, decreased blood loss, and improved accuracy of reduction.[5] The tactile feedback provided by these models allows surgeons to better appreciate fracture lines, plan optimal plate positioning, and anticipate potential challenges during surgery. Additionally, these models serve as valuable educational tools for both surgical team members and patients, enhancing communication and understanding of the planned procedure.[6]

However, the integration of 3D printing technology in orthopaedic trauma comes with its own set of considerations. The time required for model production, additional costs involved, and the need for specialized expertise in model creation must be weighed against the potential benefits. Furthermore, the actual impact of this technology on clinical outcomes, particularly in complex tibial plateau fractures, requires thorough evaluation through comparative studies.[7]

The management of soft tissues in Schatzker type 5 and 6 fractures remains crucial, regardless of the planning method used. The timing of definitive surgery, choice of surgical approach, and fixation technique must take into account the status of the soft tissue envelope. The use of staged protocols, involving initial temporary external fixation followed by definitive internal fixation once soft tissue conditions improve, has become standard practice in many centers.[8]

The choice of fixation method in these fractures continues to evolve. Dual plating, whether through single or dual incisions, remains the gold standard for achieving stable fixation. However, the optimal plate configuration, timing of weight-bearing, and rehabilitation protocols continue to be subjects of debate in the orthopaedic community.[9] The potential role of 3D printing in optimizing these aspects of treatment warrants investigation.

Post-operative complications in these fractures can be significant, including wound healing problems, infection, malunion, non-union, and post-traumatic arthritis. Early identification and management of these complications are crucial for optimizing outcomes. The potential impact of 3D printing technology on reducing these complications through improved surgical precision and reduced operative time needs to be evaluated.[10]

The present study aims to compare the outcomes of Schatzker type 5 and 6 proximal tibial fractures treated with and without the aid of 3D printing technology. By analysing various parameters including operative time, accuracy of reduction, functional outcomes, and complications, this study seeks to evaluate the clinical utility and cost-effectiveness of 3D printing in the management of these complex injuries. Understanding these aspects is crucial for establishing evidence-based guidelines for the integration of this technology in routine clinical practice.

AIM

- To compare the total surgical time taken by the surgeons
- To compare the intra-operative blood loss
- To compare the fluoroscopy exposure
- To compare the use of appropriate implant sizes and the number of times it has been placed and removed from the fracture segment.

REVIEW OF LITERATURE

The usefulness of 3D printing for categorizing and scheduling surgery for complicated tibial plateau fractures was investigated by **Chen f et al. (2024)**[95]. They came to the conclusion that 3D printing improves surgical results and anatomical restoration by efficiently assisting in the preoperative planning and classification of difficult tibial plateau fractures.

S. Duan and colleagues (2024)[96] This study investigates the effectiveness of repairing these fractures with personalized plates and 3D printing technology. They came to the conclusion that accurate articular surface reduction, a large decrease in surgical time, and a reduction in intraoperative blood loss are all made possible by 3D printing technology in conjunction with bespoke plates for difficult tibial plateau fractures. By enhancing knee joint function, this approach provides a more potent therapeutic choice.

The goal of **Assink N et al. (2024)**[97] was to determine if patient-specific osteosyntheses may help medial tibial plateau fractures be properly reduced. Using specially designed osteosynthesis plates with drilling guides, this feasibility study detailed the creation and application of a patient-specific workflow for medial tibial plateau fracture surgery that enables appropriate fracture reduction, tibial alignment, and precisely positioned screws.

A study by **Jiang L et al.**[98] in 2023 demonstrated that 3D printing technology is an adequate preoperative preparation for treating tibial plateau fracture malunion. This technology allows for accurate preoperative planning to determine the optimal surgical method, plan implant placement, observe screw trajectory, and anticipate intraoperative complications.

Z. Shen and colleagues (2023)[99] “In order to treat posterolateral tibial plateau fractures (PTPF), this study compared the outcomes of traditional surgery with surgery aided by three-dimensional (3D) printing technology. In contrast to the traditional group, which recorded respective values of 115.5 ± 34.0 min, 137.0 ± 49.2 ml, and 9.13 ± 2.5 times, the 3D printing group demonstrated an operation duration of 95.8 ± 30.2 min, intraoperative blood loss of 101.1 ± 55.3 ml, and intraoperative fluoroscopy shots of 6.3 ± 2.3 times. There were notable differences between the groups that used conventional and 3D printing ($p < 0.05$). Additionally, both immediately and 12 months after surgery, the 3D printing group showed excellent radiological and functional results compared to the traditional group, however statistical significance was not reached. Additionally, there were fewer issues for the 3D printing group than for the traditional group, though not to the point of statistical significance”.

The 3D printing-assisted Schatzker IV–VI tibial plateau fracture has advantages that warrant clinical use and advancement, according to a 2022 prospective study by **He Y et al**.[100]. These advantages include reduced surgical time, perspective times, bleeding volume, and complications, as well as improved postoperative functional recovery for patients.

A 2022 prospective study by **Dust T et al.**[101] found that 3D printing has been helpful for the preoperative diagnosis of tibial plateau fractures and that the new classification systems' reliability is generally poor to fair.

N. Assink and colleagues (2022)[102] In order to determine if 3D-assisted surgery yields better clinical outcomes than surgery based on traditional imaging modalities, this systematic review set out to give an overview of current applications of 3D technology in surgical therapy of tibial plateau fractures. They came to the conclusion that throughout the past ten years, five ideas for

3D-assisted surgical therapy of tibial plateau fractures had surfaced. These include of intra-operative 3D imaging, 3D-printed surgical guides, 3D-printed hand-held fracture models for surgical planning, 3D-printed models for pre-contouring of osteosynthesis plates, and 3D virtual fracture visualization. Fluoroscopy frequency, blood loss, and operation time may all be improved with 3D-assisted surgery.

A comparison study by **Shen et al.**[103] in 2020 found that surgeons may use surgical simulation and 3D printed models to assess complex and elderly tibial plateau fractures in real time during pre- and post-operative procedures. In addition to resulting in a speedier treatment, less intraoperative blood loss, shorter fluoroscopy durations, and greater fracture reduction, this technique may be an effective way to treat this kind of fracture.

The use of 3D printing in Schatzker type IV-VI tibial plateau fracture surgery has the potential to improve the accuracy of tibial plateau fractures and postoperative knee function recovery, according to a 2020 study by **Weng N et al.**[104] Additionally, it may lessen difficulties, intraoperative fluoroscopy, and intraoperative blood loss.

Samaila EM et al. (2020)[105] looked at the educational and financial benefits of 3D printing, as well as its added value in surgical procedure planning and execution and patient communication. We recruited fifty-two patients with distal radius, tibial plateau, or calcaneus complicated articular displacement fractures. Preoperative simulations, surgery planning, and instructional activities were all made easier by 3D-printed models of articular fractures. Additionally, they lowered surgical times and expenses by roughly 15% while fortifying the informed consent procedure. They came to the conclusion that 3D-printed models of bone fractures are a big step toward more individualized treatment, with better patient-surgeon connections and education.

Moldovan F et al. (2020)[106] came to the conclusion that the 3D solution's planning capabilities are a useful tool for surgeons investigating the type of tibial plateau fractures and creating an appropriate surgical plan for surface alignment, screw fixation guides, bone fragment strength calculations, and printing surgical objects.

The surgical treatment of bicondylar tibial plateau fractures using 3D printing technology results in a thorough understanding of fracture features, precise patient-specific preoperative planning, and intraoperative guidance for actual treatments, which improves clinical outcomes, according to a prospective study done in **2019 by Wu WY et al.**[107]

According to a 2019 retrospective study by **Nie W et al.**[108] the use of 3D printing technology in the surgical treatment of bicondylar tibial plateau fractures leads to a comprehensive understanding of fracture characteristics, accurate preoperative planning tailored to each patient, and intraoperative guidance for actual procedures, all of which improve clinical outcomes.

According to a theory put up **by Foo GL et al. (2019)**[109], life-sized 3D models can help with preoperative planning for tibial plafond fractures by improving the visualization of CT scans. They came to the conclusion that 3D-printed models for preoperative planning of tibial plafond fractures are accurate and simple to utilize. The majority of surgeons think that the combination of 3D models and CT scans is more beneficial than CT scans alone.

Mishra A et al. (2019)[110] came to the conclusion that 3DP is helpful in complex trauma management because it reduces surgery time, improves result, and accurately reduces and places implants. Understanding and implementing the VPP and 3DP requires some initial learning, but with practice and experience, these get simpler.

For patients with tibial plateau fractures, **Xie L et al. (2018)**[111] found that the 3D group demonstrated a quicker union time, reduced intraoperative blood loss, and a shorter operation duration. Consequently, ORIF aided by 3D printing technology ought to be a better option for treating tibial plateau fractures than traditional ORIF.

Zheng W. and associates (2018)[112] Assessing the viability and efficacy of using three-dimensional (3D) printing technology to treat Pilon fractures was the goal of this study. In comparison to the conventional group, the 3D printing group demonstrated a considerably shorter operation time, a lower volume of blood loss, a shorter fluoroscopy time, a greater rate of anatomic reduction, and a rate of excellent and good outcome ($P < 0.001$, $P < 0.001$, $P < 0.001$, $P = 0.040$, and $P = 0.029$, respectively). Complications did not, however, differ significantly between the two groups ($P = 0.510$). Additionally, the survey indicated that overall satisfaction with the usage of 3D printing models was excellent for both patients and surgeons. They came to the conclusion that it is possible to treat Pilon fractures in clinical settings using 3D printing technology.

In order to treat tibial plateau fractures, **Lou Y et al. (2017)**[113] compared traditional surgery with surgery aided by 3D printing technology. The 3D model group experienced an average operation duration, blood loss, and number of intraoperative fluoroscopies of 85.2 ± 0.9 minutes, 186.3± 5.5 ml, and 5.3± 0.2 times, respectively, while the traditional surgery group experienced these same outcomes: 99.2±1.0 minutes, 216.2 ±6.9 ml, and 7.1 ± 0.2 times. The difference between the 3D model group and the standard surgery group was statistically significant ($P < 0.05$). The 3D printing group has demonstrated superior clinical efficacy through follow-up. Both the patient and physician questionnaires had average scores of 7.3 ± 0.1 and 8.5 ± 0.1 points, respectively. The clinical viability of using 3D printing technology to treat tibial plateau fractures was proposed by this study.

Giannetti S. et al.(2017)[114] Our study aimed to assess the results of internal fixation and minimally invasive reconstruction for patients with displaced tibial plateau fractures (TPFs) with and without the use of pre- and intra-operative real size 3D printing. They came to the conclusion that there was a notable decrease in surgical time for patients who underwent operations using 3D-model printing. Furthermore, using a method without a 3D model exposed the surgeon and patient to more radiation.

According to **Yang P et al. (2016)**[115], 3D printing technology can be used to precisely plan osteotomy procedures, lower the risk of postoperative deformity, minimize intraoperative blood loss, speed up operation times, and substantially enhance treatment outcomes.

Bizzotto N. et al.(2015)[116] 102 patients (distal radius fractures, radial head, tibial plateau, astragalus, calcaneus, ankle, humeral head, and glenoid) had 3D printing done on them during the study period. Surgeons utilized the medical models to understand the articular surface yielding and fragment dislocation. Additionally, the patient was shown models in order to obtain their informed permission prior to surgery. They came to the conclusion that 3D printing articular fractures is a novel technique that provides a tangible, preoperative assessment of the fractures that is extremely helpful for intervention planning and patient education.

Huang H. and associates (2015)[117] With the aid of a 3D-printed navigational template and a library of 3D implants, this study sought to increase the surgical accuracy of plating and screwing for complex tibial plateau fractures. They came to the conclusion that the discrepancies between the ideal and actual screw trajectories in terms of screw length, entrance point, and projection angle were not significantly different. With the help of the patient-specific navigational template and the library of 3D models of implants, the optimal and precise preoperative planning of plating and screwing may be accomplished in the actual surgery. We have demonstrated via our clinical applications that this technology enhances the precision and effectiveness of customized internal fixation surgery.

In a prospective cohort research, **Zhi et al. (2015)**[118] reported using 3D printing to improve the clinical outcomes of knee surgery for a knee with complex fractures and deformities. To compare clinical results, surgery time, total blood loss, radiation exposure, and length of hospital stay, 22 patients with complex knee fractures and deformities participated in the study. When compared to surgery planned using traditional radiologic pictures, the authors found that using 3D printing technology for surgical planning allows for better preoperative planning and enhances surgical accuracy, safety, and overall surgical time required.

EM and associates (2010)[119] This study aimed to discuss the use of virtual 3D reconstruction and segmentation software for preoperative planning of fractures of the tibial plateau. They came to the conclusion that segmentation was successful in every instance. Surgeons may find this software's 3D planning features useful in determining the type of injury in tibial plateau fracture patients and in creating a suitable surgical strategy. The time commitment for the segmentation analysis and 3D reconstruction, however, might be a current barrier to its application in a clinical situation.

Wicky S. and others (2000)[120] The purpose of this study was to evaluate the accuracy of spiral CT and plain film CT exams in the pre-operative surgical plan in 22 instances and to compare their diagnostic efficacy with 3D reconstructions of 42 tibial plateau fractures. They came to the conclusion that spiral CT 3D reconstructions enable a more precise pre-operative surgical plan and provide a better and more exact representation of the tibial plateau fracture.

Blaser PF and associates (1998)[121] In comparison to traditional X-rays, the purpose of this prospective study is to ascertain how much 3D CT contributes to the classification of fractures and how it can help surgeons with preoperative planning and surgical reconstruction. Results analysis has demonstrated that 3D CT is preferable in terms of planning (easier and more acute), classification (more accurate), and precise assessment of the lesions (number of fragments), demonstrating its indisputable benefit to the surgeon.

BRIEF HISTORIC PERSPECTIVE

In 1822, Sir Ashley Cooper was the first to record proximal tibia fractures.[11] The lateral tibial plateau fracture was commonly thought to be caused by jaywalking at the time, as evidenced by Cotton and Berg's (1929) use of the terms "bumper" and "fender" to describe the fracture. The earliest recognition of the fracture that falls often cause emerged in the decade following World War II.[12] The most common treatment for these fractures in the 1950s was closed reduction and cast; however, “Perey et al.[13] described open reduction with screw fixation in more severe cases as early as 1952. Many works of literature from the early 1950s and beyond supported the notion that the prevention of post-traumatic osteoarthritis required strict fixation, early mobilization, and anatomical reduction of the joint surfaces”.[13–15] Surgeons started using ORIF (Open Reduction Internal Fixation) as a frequent treatment option in the 1950s thanks to the work of Danis and Müller.[16] At the same time, Prof. Ilizarov's development of a circular external fixator created new opportunities for fracture care.[17]Both treatment modalities were refined over the next decades, and the more advanced external fixators with a hexapod shape were first used in 1990. Within same time range, there was also hope for better treatment thanks to the emergence of pre-contoured, less invasive locking plates.[18] The optimum course of therapy for tibial plateau fractures is currently unknown; external circular fixators, screws, and plates are all used.[19]

ANATOMY

The “tibia is one of the two bones that comprise the leg. [20] It is the weight-bearing bone that is larger and stronger than the fibula. The tibia forms the knee joint proximally with the femur, and the ankle joint distally with the fibula and talus. As it passes medially from just below the knee joint to the ankle joint, the interosseous membrane joins the tibia and fibula”.[21]

The medial and lateral condyles, which are situated on the proximal half of the tibia, comprise the inferior section of the knee joint. The intercondylar area, situated between the two condyles, is where the menisci, anterior collateral ligament, and posterior collateral ligament attach.

Structure and Function

With the “medial part of the tibia carrying the majority of the load, the tibia, the second biggest bone in the body, is mostly utilized in the leg for weight bearing. [22] Eleven muscles originate or insert here, allowing for dorsiflexion and plantarflexion at the ankle joint and extension and flexion at the knee joint”.

Tibial Osteology :

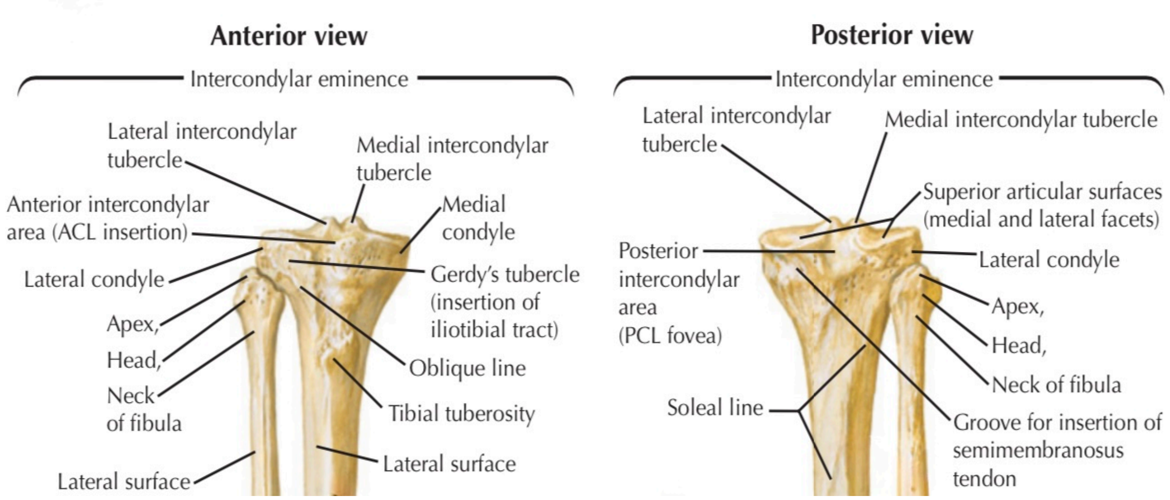

Figure 1: Anatomy of Tibia

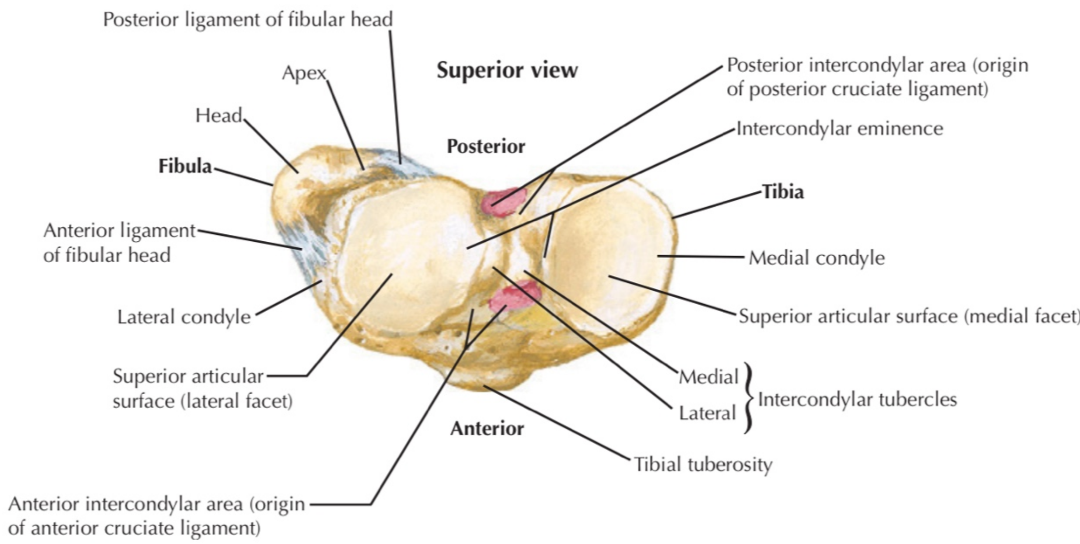

Figure 2: Upper End of Tibia

Proximal Study[22]

- "The lateral proximal side of the tibia, called the lateral condyle, is where it articulates with the femur.
- The proximal medial facet of the tibia that articulates with the femur is called the medial condyle.
- The superior articular surface of the lateral condyle is known as the lateral tibial plateau.
- The superior articular surface of the medial condyle is known as the medial tibial plateau.
- The intercondylar region

  Anterior area: situated between the lateral and medial condyles anteriorly. the anterior cruciate ligament's attachment site.

- The posterior region is situated between the lateral and medial condyles. the posterior cruciate ligament attachment site.
- The tibial spine's intercondyloid eminence, which is made up of a medial and lateral tubercle, is situated in between the articular facets. The menisci and cruciate ligaments attach to the depression behind the intercondyloid eminence”.

The medial condyle is larger than the lateral condyle, however it does not protrude as much. The oval-shaped top articular surface is concave across all diameters. The concavity is deepened and the medial intercondylar tubercle is covered by the upward-extending lateral border. Just below the articular edge is a rough strip that forms a barely perceptible ridge that divides the posterior side of the condyle from the medial surface of the shaft.

The shaft, which bears a small round facet for articulation with the upper end of the fibula on its inferior surface, is overhung by the lateral condyle, especially at its posterolateral section. The upper surface is covered by the articular surface for the femur's lateral condyle. Its generally circular shape is slightly hollowed in the middle, and its medial border extends upward to the lateral intecondylar tubercle. The tuberosity of the tibia creates a continuous surface in front by joining the anterior surfaces of the two condyles. [23]

Blood Supply and Lymphatics

“The tibia receives its blood supply from the periosteal vessels and the nutritional artery. The nutritional artery penetrates the bone posteriorly distal to the soleal line, branching off from the posterior tibial artery. The anterior tibial artery is the source of the periosteal vessels”.[24]

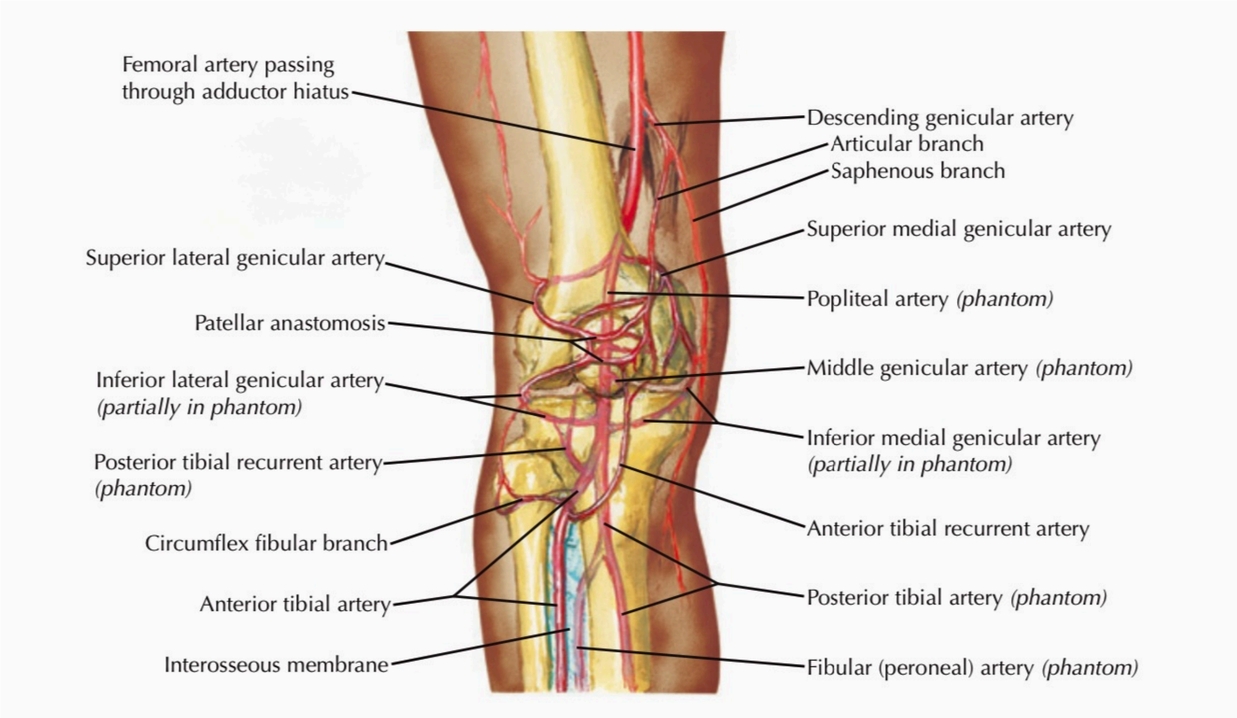

Figure 3: Blood supply of Proximal Tibia

Nerves

The tibia is supplied by branches of every major nerve that supplies nearby compartments. [25] While the deep fibular nerve supplies branches to the tibia's anterior aspect in the leg's anterior compartment, the tibial nerve supplies branches to the tibia's posterior side in the leg's posterior compartment.

Muscles

"Insertion of the Tibia Muscles

• Quadriceps femoris inserts anteriorly on the tibial tuberosity.

• Tensor fasciae latae inserts on the lateral tubercle of the tibia, also referred to as the Gerdy tubercle

• The popliteus inserts on the soleal line of the posterior tibia; the sartorius, gracilis, and semitendinosus insert anteromedially on the pes anserinus; and the horizontal head of the semimembranosus muscle inserts on the medial condyle".

Originating Muscles at the Tibia

• "Extensor digitorum longus begins at the lateral condyle of the tibia; tibialis anterior originates in the top two-thirds of the lateral tibia.

• On the soleal line, the posterior portion of the tibia is the origin of the soleus and flexor digitorum longus.

The lateral and medial condyles of the femur articulate directly with the medial and lateral tibial plateaus. There is a minor difference in the tibial and femoral articular widths. Whereas the medial plateau is more concave and slightly distant to the lateral plateau, the lateral plateau is more proximal and slightly convex. About 60% of the total stress distributed across the knee is supported by the medial plateau. Because the lateral tibial condyle is proximal, the plateau has a minor varus shape in relation to the tibial diaphysis. Compared to the lateral, the medial tibia can be more congruent with the femoral condyle because of the medial plateau's concavity. The anterior plateau is more proximal and the posterior plateau is more distal due to the tibial plateau's approximately 15° posteroinferior inclination. The posterior tibial slope of the medial plateau is higher than that of the lateral plateau. Menisci made of fibrocartilage and articular hyaline cartilage cover parts of the surfaces of the tibial plateau. Its meniscus covers the lateral plateau more than the medial plateau. The medial and lateral spines make up the intercondylar eminence. The non-articular intercondylar eminence divides the proximal tibia into the medial and lateral plateaus. The posterior cruciate ligament attaches posteriorly on the proximal tibia, and the anterior cruciate ligament attaches to the medial spine".[26]

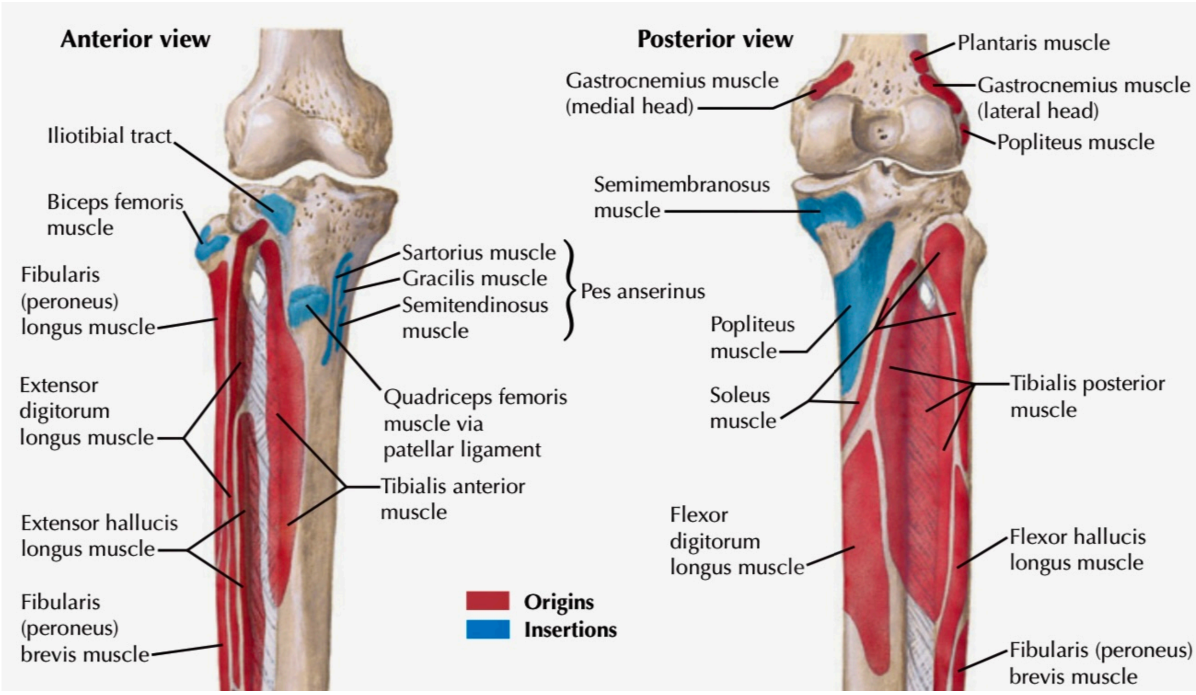

Figure 4: Muscular Attachments of Tibia

PROXIMAL TIBIAL FRACTURES (TIBIAL PLATEAU FRACTURES)

"Tibial plateau fractures are a common orthopedic condition. One part of the knee joint, the articular surface of the tibia, is affected by these fractures. Plateau fractures can be low energy with little to no displacement or complex with significant concomitant damage".

EPIDEMIOLOGY

Fractures affecting the "tibial articular surface account for little more than 1% of all long bone fractures, 56.9% of all proximal tibia fractures/dislocations, and 8% of all fractures in the elderly.[28, 27] 10.3 per 100,000 is their annual incidence".[29] According to estimates, polytrauma is present in 16–40% of patients who are admitted with a tibial plateau fracture.[30] Similar to other periarticular injuries, the age distributions for men and women are bimodal. Men make up

70% of fracture cases, and the most common patient group is men between the ages of 40 and 44.[27] Comminuted fractures occur more commonly in men.[28] The most prevalent age range for tibial plateau fractures in females is 55 to 59 years old. The incidence shifts from males to females beyond age 60, with females accounting for 61% of cases.[27] Because life expectancy is increasing and many wealthy countries have a large aging population, “it is expected that the incidence of low-energy tibial plateau fractures would continue to climb”.

“The fracture distribution according to the AO classification has been published by Albuquerque et al. Reports state that AO types 41-B3 and 41-C3 are the most common fracture forms, making up 57% of all tibial plateau fractures. Unicondylar fractures account for about two-thirds of tibial plateau fractures. An approximate frequency of 17% for open fractures has been reported”.[31]

MECHANISM OF INJURY

“The mechanism of injury seen in tibial plateau fractures is significantly influenced by age. The majority of tibial plateau fractures in the elderly are caused by low energy falls. This injury is occurring more frequently as a result of osteoporosis and an older population. Osteoporosis and osteopenia play a major role in the observed fracture processes and patterns. In older adults, lateral fracture patterns are more prevalent than medial fracture patterns. Both the quality of the bone and the forces acting on it determine the subsequent fracture patterns. [32] Fracture patterns are impacted by reduced bone density because it reduces the force necessary for injury. These patients usually have more compression fractures even though their energy injury mechanisms are lower. High-energy approaches are used by most younger people. Men are more likely to exhibit gender. Sports, motor vehicles, and height falls can all result in injuries. Low energy falls are responsible for 22% of injuries, while pedestrians hit by motorized vehicles account for 30% of all injuries”.[33]

The force that caused the injury and its direction often have an impact on the fracture pattern. Compressive, axial, or angular stresses can cause the condyles to fail. Axial stress frequently contributes more to the process of injury and produces more energy than angular forces. More axial force usually results in more severe fractures with higher soft tissue injury, comminution, and fragment displacement. A cadaver study34 that looked at the causes of damage found that split depression fractures were caused by a combination of axial and valgus forces, joint compression fractures were caused by axial forces, and the common lateral split fractures were caused by pure valgus forces. “The proximal tibia is more susceptible to valgus stress because of anatomical predispositions that result in 5-7° of knee valgus in normal anatomic alignment and a higher frequency of lateral side impacts as an injury mechanism”.

AETIOLOGY AND PATHOPHYSIOLOGY

“An axial load, with or without a varus or valgus load, is the primary mechanism of damage. Fractures of the tibial plateau can be medial, lateral, or bicondylar. The most frequent injuries are to the lateral portion of the tibial plateau, which can result from a direct hit to the lateral aspect of the knee. More force is needed to inflict injuries to the medial plateau, which are caused by high-energy mechanisms such as motor vehicle crashes, falls from great heights that land on the feet, and other direct trauma sources. Bicondylar fractures are more prevalent than isolated medial plateau fractures when high-energy mechanisms like these are involved. The elderly or other populations with osteoporotic illness are more susceptible to tibial plateau fractures caused by low energy mechanisms”.[29]

“The tibia, which bears the weight of the leg, is located medially to the fibula. The proximal part of the bone compromises the distal part of the knee joint. The two articular surfaces that comprise the tibial plateau are the medial and lateral tibial condyles, which are also referred to as the medial and lateral plateaus. In the knee, the thicker medial tibial condyle supports 60% of the weight. It has a concave shape and is located slightly more distally than the lateral tibial condyle. The lateral tibial condyle is more convex, thinner, weaker, and closer to the body than the medial tibial condyle. The intercondylar eminence, a bone structure located between the two condyles, is where the anterior cruciate ligament is attached. Deep fascia separates the lower leg into four compartments, each of which has muscles and neurovascular systems. The front, lateral, superficial, and deep posterior compartments that border the tibia can all experience compartment syndrome following a tibial fracture. Tibial plateau fractures can harm not only the knee joint's ligaments and menisci, but also these tissues. Lateral meniscus tears are more common when Schatzker type II fractures are present, as well as when there is an articular surface depression larger than 10 mm, whereas medial meniscus tears are more likely when Schatzker type IV plateau fractures occur. Studies have shown that anterior cruciate ligament injuries account for 25% of Shatzaker type IV and VI fracture patterns. Schatzker type IV fracture-dislocations are often associated with vascular damage.[35, 36] Vascular injury can also arise with Schatzaker type IV tibial plateau fractures and proximal tibial fractures. The popliteal artery travels behind the knee and branches off into the anterior and posterior tibial arteries".

The three-column theory of tibial plateau fractures states that zero-column fractures are just articular fractures. "A single column fracture is an isolated articular depression with a column fracture, whereas two-column fractures are either anterolateral with separate posterolateral depression fractures or anteromedial with different posteromedial fractures".

CLASSIFICATION

"Over time, the classification of fractures to the proximal tibia has evolved. A morphological approach based on anteroposterior radiographs was proposed by Schatzker et al. (1979) to differentiate six types of fractures, from simple split fractures to complex fractures (Figure 5).[37] The AO/OTA (Arbeitsgemeinschaft für Osteosynthesefragen/Orthopedic Trauma Association) adopted this descriptive classification for its comprehensive classification in 1990 when it acquired international support (Figure 6).[38] Three primary types of fractures are distinguished by the AO/OTA classification: A, B, and C. Avulsion fractures of the intercondylar eminence and extraarticular fractures are included in Group A. Meyers and McKeever have classified isolated avulsion fractures of the eminence into different categories.[39] Only one tibial condyle had split or depression fractures in Group B. Bicondylar and comminuted tibial head fractures are included in Group C".

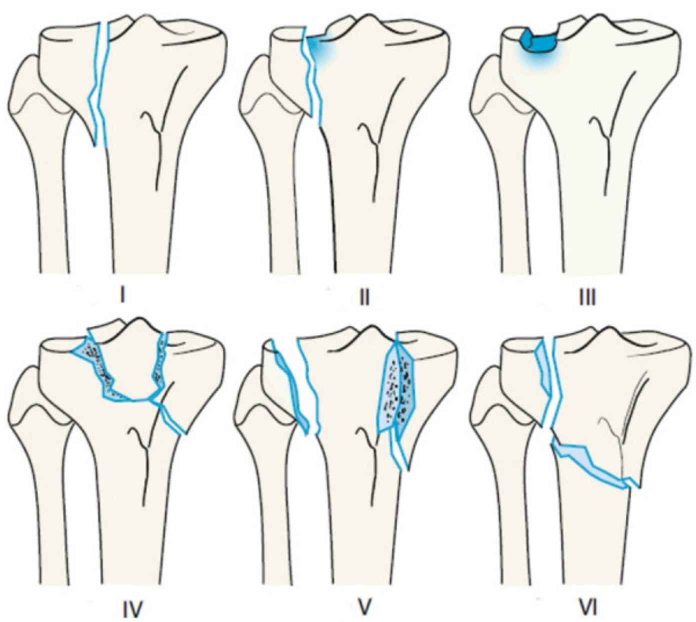

Figure 5: "Schatzker's classification of proximal tibia fractures. (I) Wedge-shaped pure cleavage fracture of the lateral tibial plateau. (II) Splitting and depression of the lateral tibial plateau. (III) Pure depression of the lateral tibial plateau; Schatzker IIIa: with lateral depression; Schatzker

IIIb: with central depression. (IV) Medial tibial plateau fracture with a split or depressed component. (V) Wedge fracture of both lateral and medial tibial plateau. (VI) Transverse tibial metadiaphyseal fracture, along with any type of tibial plateau fracture (metaphyseal-diaphyseal discontinuity)”.

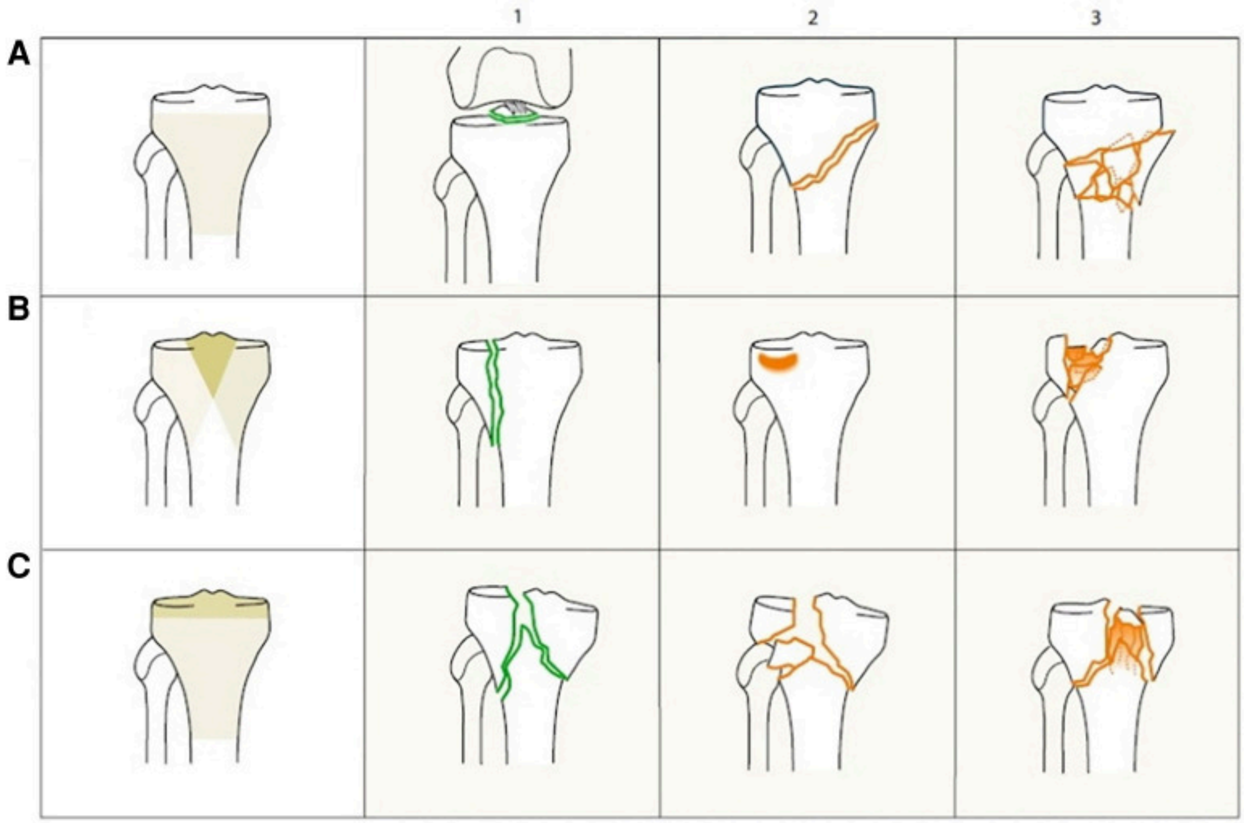

Figure 6: “AO/OTA classification of proximal tibia fractures. 41-A extra-articular fracture. 41-A1 avulsion. 41-A2 extraarticular simple. 41-A3 extraarticular, wedge or multifragmentary. 41-B partial articular fracture. 41-B1 pure split. 41-B2 pure depression. 41-B3 split-depression. 41-C complete articular fracture. 41-C1 articular simple, metaphyseal simple. 41-C2 articular simple, metaphyseal wedge or multifragmentary. 41-C3 articular multifragmentary”.

“Schatzker classification cannot be used to classify 10% of all tibial plateau fractures. In particular, fractures connected to dislocations or instability in the knee. Moore first identified the importance of focusing on the fracture mechanism and associated injuries, such as neurovascular and ligamentous injuries, in 1981, particularly in cases of fracture dislocations.[40] A better three-dimensional comprehension of fracture patterns was part of this strategy (Figure 7)”.

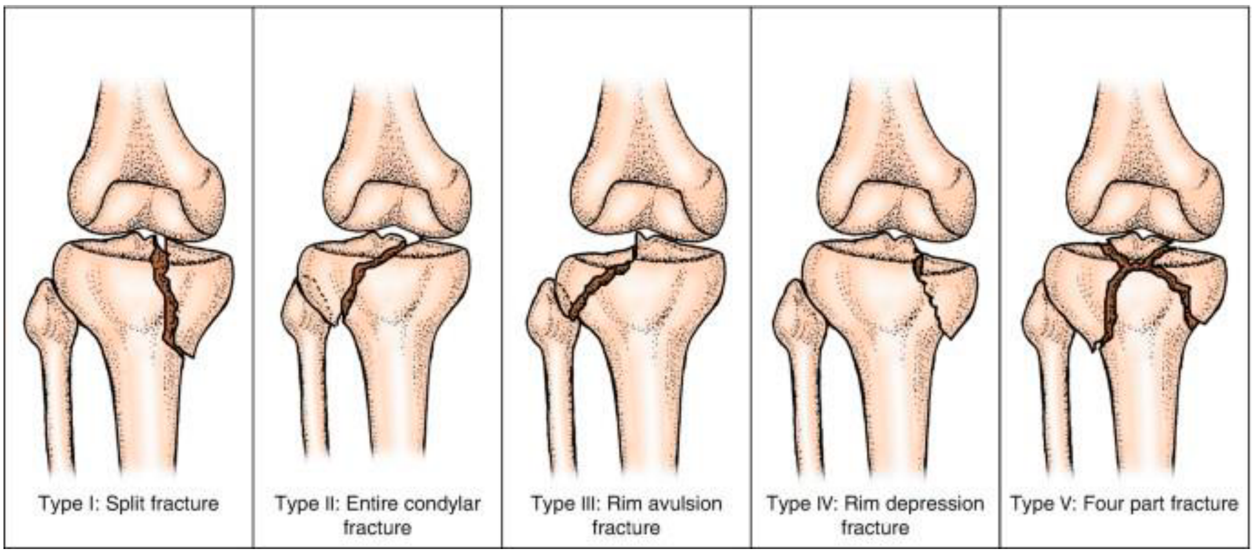

Figure 7: “Moore's classification of proximal tibia fractures. (I) Posteromedial split. (II) Entire condyle. (III) Rim avulsion. (IV) Rim impression (V) Four part fracture.”

“Type I refers to a medial tibial condyle dorsal split fracture, which is frequently accompanied by an anterior cruciate ligament (ACL) rupture.

Type II fractures split the tibial condyle medially (IIa) or laterally (IIb), and they also split the intercondylar eminence from the tibial shaft by a second fracture line.

Avulsion of the eminence, Segond fragment, and lateral tibial rim fracture are all included in Type III summary of capsular avulsion fractures. Ruptures of the ACL are frequently linked to this kind of fracture.

Type IV refers to the ligament rupture as well as the depression of the bony tibial edge.

A comminuted fracture, including an avulsion fracture of the tibial eminence, is referred to as type V. In this instance, the cruciate ligaments that are linked may frequently remain continuous ("redeeming fracture of eminence")".

"In 1984, Tscherne et al.[41] presented a new categorization that integrated aspects of Schatzker and Moore's categories. Their method distinguishes between fracture dislocations, comminuted fractures, and plateau fractures. Because there is less bone density laterally, tibial plateau fractures (P) more commonly impact the lateral plateau than the medial due to axial trauma.[42] There are different classifications for plateau fractures: split (P1), depression (P2), split-depression (P3), and bicondylar (P4) fractures. These are regularly observed in osteoporotic bone and are expected to become more common as the population ages. Shearing and rotating motion are the causes of fracture dislocations (L). The femoral-tibial complex's ligamentous abnormalities are frequently linked to these fractures. Comminuted fractures (C) are mostly caused by high-energy trauma impacts and can cause significant harm to the tibial plateau, including bone loss and soft tissue damage".[43]

"Similar to other fracture sites including the spine and calcaneus, computed tomography has led to the development of new classifications based on three-dimensional reconstruction. The 10-segment notion of Krause et al.[46] and the three-column technique of Luo and colleagues,[44] which was later improved by Hoekstra et al., are two noteworthy recent classifications that stand out. [45] Axial CT cuts performed below the physiological tibial plateau joint line serve as the primary basis for the three-dimensional fracture analysis principle employed in these models. The concepts of fracture fixing are diverse; Luo et al. concentrated mostly on restoring the stability of the damaged columns, whereas Krause's categorization gives priority to rebuilding the damaged joint surface".

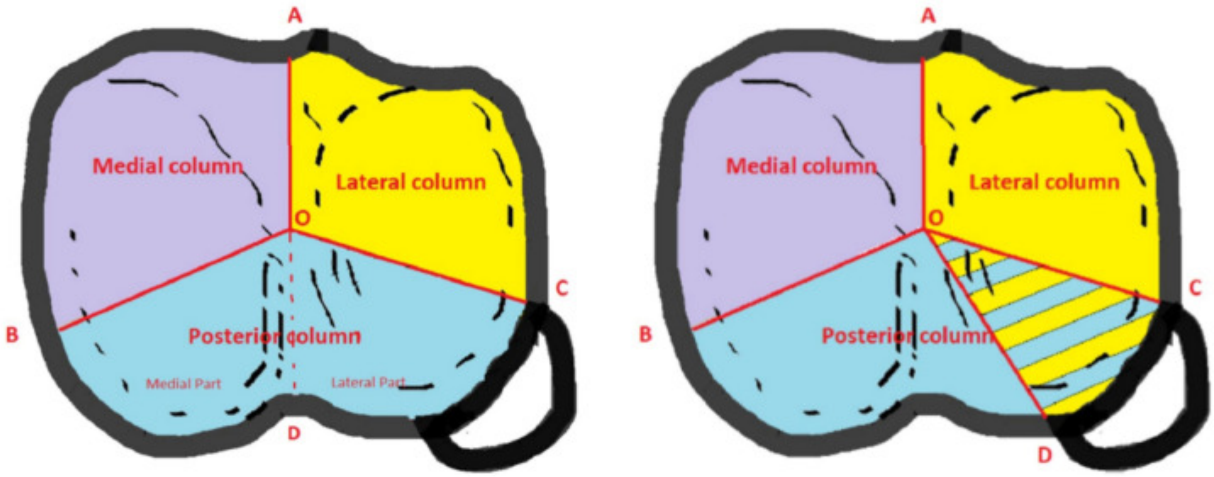

Figure 8: 3-column concept of Luo and Hoekstra's modification.

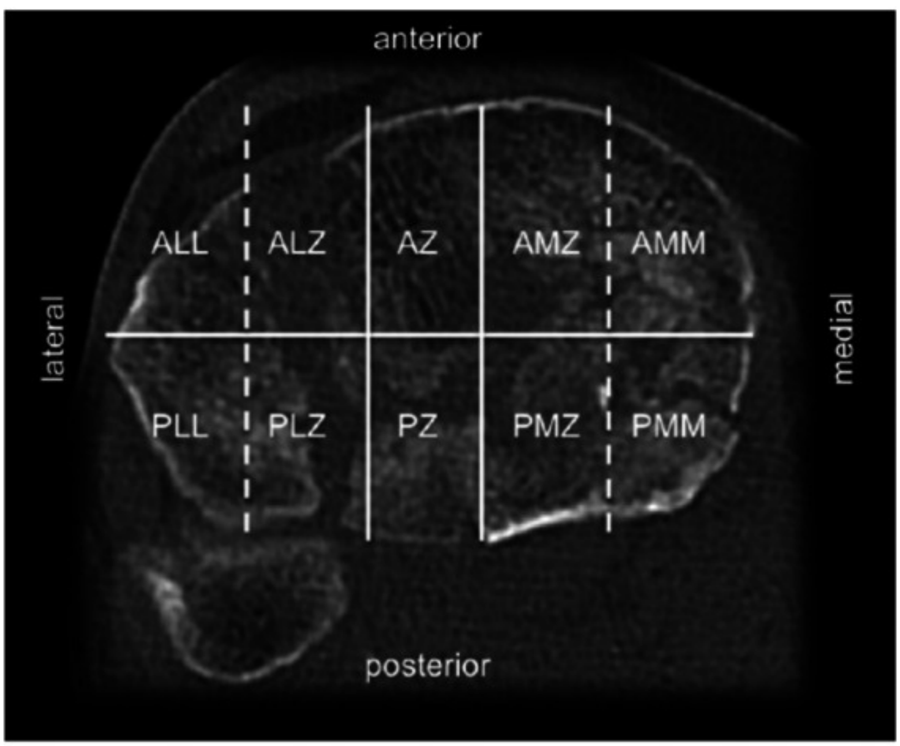

Figure 9: 10-segment classification according to Krause Segments:

The “ideal classification of proximal tibial fractures has not yet been found. The OTA/AO and Schatzker's classifications have worldwide recognition, but they do not consider accident mechanisms and concomitant injuries. Furthermore, being based on anteroposterior roentgenograms, they do not use the additional information provided by computed tomography or magnetic resonance imaging and hence are underrating certain fracture types. More recent classifications based on computed tomography try to improve three-dimensional understanding. In addition to an improved detection of posterior fracture types these classifications facilitate the choice of approach”.[46]

Associated soft tissue injuries[26]

Soft tissue injury may arise from fractures of the tibial plateau. The overall incidence of soft tissue injuries has been estimated to be between 73 and 99% based on MRI investigations. Only one patient showed no soft tissue injury at all, according to Gardner et al.'s analysis of the MRIs of 103 patients who had surgery for a tibial plateau fracture. Lateral and medial meniscus pathology were present in 44% and 91% of patients, respectively, while cruciate or collateral ligament injuries were present in 77% of patients. “In a study of individuals with nonoperative tibial plateau fractures, similar results were found: 90% had substantial soft tissue injury, 80% had meniscal tears, and 40% had ligament disruptions”.

Ligament injury

According to MRI studies, between 40 to 77 percent of people have ligamentous damage overall. Total ACL tears are estimated to occur 11–44% of the time, posterior ACL tears 8–40% of the time, lateral collateral ligament injuries 29% of the time, medial collateral ligament injuries 32%

of the time, and posterolateral corner injuries 45–68% of the time, according to MRI studies that have been published in the literature. Higher energy fracture patterns (type IV–VI) are more likely to result in ligamentous damage.

Meniscal injury

"Based on preoperative MRI, the incidence of meniscal damage linked to tibial plateau fractures has been reported to range from 49 to 91%. Numerous studies have demonstrated a direct correlation between the degree of condylar enlargement and lateral articular depression and the prevalence of soft tissue injuries".

CLINICAL EVALUATION

History

Getting a thorough medical history is essential in every tibial plateau fracture case. To ascertain the amount of the damage and whether urgent medical intervention is necessary, it is critical to assess the mechanism of injury. "Low energy falls or twisting injuries are more likely to have a reduced risk of neurovascular damage or compartment syndrome, but falls from a height, auto accidents, and pedestrians struck by a vehicle are more likely to have higher risk and may require more urgent or emergent care. Although knowing where the damage came from may be helpful, the fracture pattern is essential in determining the treatment plan and any potential outcomes. It is helpful to know the location and severity of the pain, the time and date of the incident, any associated injuries, and any therapies that were used. Medical comorbidities (e.g., pulmonary disease, diabetes, vascular disease, cancers, renal disease, nutritional deficiencies, previously poor DEXA scan results, use of immunosuppressive medications, and smoking history) and the patient's ambulatory status prior to the injury should all be assessed. Medical comorbidities and certain medications may influence bone quality, inhibit wound healing, and increase the risk of postoperative infection. The patient's level of activity, social support network, mental health, and employment position will all influence an appropriate surgery and rehabilitation plan".

Physical examination

"As part of the first evaluation of tibial plateau fractures, the physical examination should try to rule out soft tissue damage, open fractures, compartment syndrome, and neurovascular injury. It is advised that a circumferential evaluation of the skin covering and a neurovascular baseline state be performed. A circumferential examination and palpation of the skin and soft tissues is necessary to ascertain whether a soft tissue injury is open and to assess its severity. The size, type, and location of blisters from fractures, contusions, and edema can be used to further assess the degree of soft tissue damage. Selecting surgical methods and timings requires careful consideration of soft tissue assessment".

The symptoms of compartment syndrome include stiff, non-compressible extremities and pain with passive stretching. It is crucial to monitor for compartment syndrome during the patient's stay because it can manifest days after an injury or operation. Depending on the findings of the clinical evaluation, compartment pressure measurements may be useful at the time of presentation and may need to be repeated in patients with high energy fracture patterns or those who are not responding. "If the diagnosis is made in conjunction with elevated compartment pressures or if the physical examination makes the diagnosis obvious, a fasciotomy will be necessary".

For high-energy injuries (fracture-dislocations, metaphyseal-diaphyseal dissociation patterns, etc.), a thorough neurovascular evaluation is crucial. Lower extremity amputation rates can approach 86% when diagnosis and surgical intervention are postponed for more than eight hours, despite the fact that vascular injury is normally rare. 48, 47 Important aspects of neurovascular assessment include testing for distal pulses, such as the posterior tibial and "dorsalis pedis, capillary refill, extremity color and temperature, and sensory patterns in the distribution of the tibial, superficial peroneal, saphenous, and sural nerves. Comparing the results with those of the other side is essential. Any changes in sensation or pulses can be investigated with an ankle-brachial index (ABI) measurement. In any event, for certain high-energy fractures, getting an ABI might be considered. The negative predictive value is quite strong (almost 100%) for ABIs greater than 0.8." A CT arteriogram and/or a consultation with a vascular surgeon should be scheduled for further vascular assessment if the ABI is less than 0.9.[47]

"A thorough physical examination for a possible tibial fracture should involve evaluating the knee as a whole and comparing it to the contralateral, presumably intact, knee. The following should be given particular attention":

• "Skin: To check for an open fracture, cuts, or puncture wound, the skin should be inspected circumferentially.

• Knee effusion: In the event of a substantial effusion, the knee may be aspirated in order to assess the presence of lipids or bone marrow components, which could indicate an intraarticular fracture, as well as for hemarthrosis.

• Neurovascular exam: It is important to evaluate distal pulses, motor function, and sensation. In the unlikely event that there is a pulse difference between the extremities, there should be a low threshold for measuring Ankle-brachial indices.

• Parts: Each compartment needs to be felt for; a hard, tense compartment may indicate compartment syndrome, which can be assessed further by taking an intracompartmental pressure reading.

• Laxity tests: When varus/valgus stress testing is performed at the joint line, more than 10 degrees of laxity indicate a tear in the collateral ligaments. A displaced fracture is indicated by laxity below the joint line.

• Range of motion: Because of discomfort, it can be exceedingly challenging to evaluate strength and range of motion.

If radiographic evaluation leaves uncertainty regarding instability, varus and valgus stress testing can be required. When deciding whether to proceed with surgery, valgus instability is crucial, particularly in cases with lateral tibial plateau fractures. In the event of instability, surgical fracture reduction and fixation may be necessary to treat the issue".[49, 50]

RADIOLOGICAL EVALUATION

A "significant portion of surgical planning involves imaging. The imaging modalities that are used include MRI, CT with 3D reconstruction, and plain radiography".

PLAIN RADIOGRAPHS

"The first diagnosis of tibial plateau fractures is usually made using plain radiographs. For minor fractures, this is sometimes the only imaging modality needed. Anteroposterior (AP) and lateral images of the knee are usually obtained for plain radiograph evaluation. An image acquired 10 to 15° caudally from a conventional 90° AP view is called a "tibial plateau view" in order to match with the plane of the plateau. This is to offset the 15° posteroinferior slope of the plateau surface. Because it can be seen as a single radio dense line, this view of the proximal articular surface allows for a better assessment than the lateral and AP views of the articular depression. [51] It is also necessary to take radiographs of the whole tibia. Oblique views are no longer widely employed since computed tomography (CT) scans have effectively taken the place of oblique views, despite the fact that they have also been used to assess fracture lines and the degree of displacement. Interestingly, studies suggest that plain radiographs alone may not detect inadequate fractures in patients with osteopenic fractures".[52]

"Traction radiographs are helpful for better examining the fracture anatomy on both conventional and CT scans when there is substantial displacement. This can be obtained by manual traction or external fixators. Contralateral radiographs can serve as a template for reduction, condylar width, coronal alignment, and the posterior slope of the plateau in the sagittal plane when dealing with severely comminuted fractures".

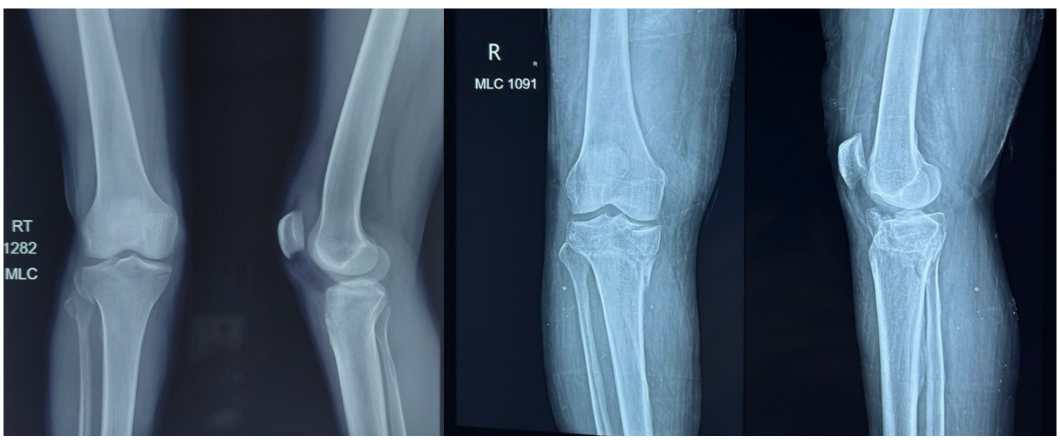

Figure 10: Radiograph of knee in AP and LATERAL views

COMPUTED TOMOGRAPHY (CT) SCANS

"These days, CT scans are frequently utilized to assess tibial plateau fractures. Axial CT slices are especially helpful in detecting posteromedial fracture lines. Axial CT scans and reconstructions provide important information about the anatomy of fractures and aid in preoperative planning. According to a number of studies, using CT scans enables surgeons to more precisely classify fractures, which aids in the development of the optimal treatment strategy. [53, 54] CT facilitates more accurate imaging of articular displacement and comminution than traditional radiography.[55] CT also enables better assessment of the location and orientation of fracture lines, the degree of depression, and the size and orientation of articular segments—all of which are critical for preoperative planning".

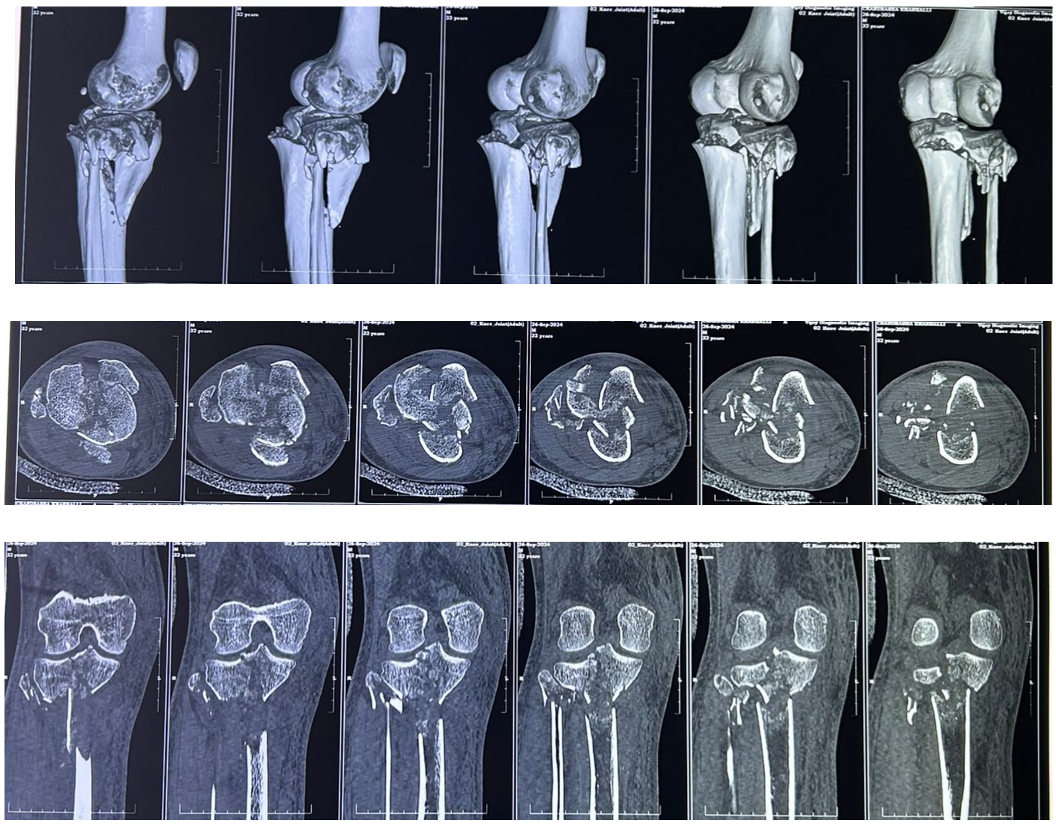

Figure 11: CT scan of knee with 3D Reconstruction.

MAGNETIC RESONANCE IMAGING (MRI)

"Magnetic resonance imaging (MRI) is increasingly being used to evaluate tibial plateau fractures. Some people believe that soft tissue injuries should be appropriately evaluated and treated, especially when they involve fractures, as high energy mechanisms are more likely to produce meniscal and ligamentous pathology.[56] MRI is more sensitive than CT in detecting meniscal and ligamentous injuries, which are both commonly observed in tibial plateau fracture cases.[57] MRI is the gold standard for detecting occult fractures, which are not evident on normal radiographs".

TREATMENT MODALITIES

"There are three aims in the therapy of proximal tibial fractures:"

- ✓ "Joint surface reconstruction: The tibial joint surface needs to be restored as precisely as possible. If the uneven levels continue, there's a chance that the impact force will be higher and the erosion process will speed up, which could result in secondary osteoarthrosis, especially in the area where the joint can bear its maximum weight without meniscal cover.
- ✓ Rebuilding the knee axis and creating a "height stable" tibial plateau: It can occasionally be challenging to attain perfect articular congruency, particularly in cases of severely comminuted fractures. Moreover, there is disagreement on the acceptable step-off in articular surface. In the tibial plateau, articular incongruities alone appear to be comparatively easily tolerated in comparison to other joints. Meniscus retention requires additional attention in addition to joint stability and coronal alignment.[58] A bad outcome is significantly linked to joint instability, or "pseudolaxity," which is caused by a lower height of the tibial head rather than a ligamentous lesion.[59]

  Mechanical overstressing of one condyle as a result of the lower limb's improper mechanical axis (varus—valgus deformity with lateral displacement of the mechanical axis) could be another cause for posttraumatic accelerated degeneration. Anteroposterior axis deviation might cause genu recurvatum or limited extension because of a higher posterior slope.

- ✓ Early mobilization: Extended joint immobilization deteriorates the already compromised nourishment of the cartilage. A further consequence of extended immobility is arthrofibrosis”.

The kind of fracture and any related soft tissue injury must be considered in any treatment approach. Both access and operational planning require the creation of stable soft tissue environments. Therefore, significant edema and contusion should be treated with immobilization and decongesting methods such as elevation and lymph drain pumps. The possibility of compartment syndrome should be taken into account, as it would require immediate diagnosis and treatment. The decision to decompress all tibial compartments should be made as soon as possible.[44]

NONSURGICAL TREATMENT

“Nonsurgical treatment may be an option for some fractures and in specific clinical circumstances. Since hinged bracing allows movement while maintaining coronal support, it is now desired to attain instantaneous passive range of motion with non-weight bearing for 6–12 weeks. Undisplaced or minimally displaced fractures, less than 5° of varus/valgus instability, delayed presentation, patients with serious medical conditions that preclude surgery, elderly patients with low functional status where deformities would be tolerated, and nonambulatory patients are all candidates for nonsurgical treatment. When deciding which patients may benefit from nonsurgical therapy, the ability to predict the post-treatment risk for deformity, malalignment, and instability is essential. Angular malalignment is poorly tolerated by patients, and it can result in articular cartilage overload, cosmetic issues, and an increased risk of knee instability. These conditions can cause patients to feel unbalanced and raise their risk of falling. Determining the patient's risk for instability can be aided by learning more about their demographics, comorbidities, activity level, and limb alignment. Imaging factors that are helpful in assessing the risk for instability include the degree of articular depression, bone quality, fracture type, condylar width, and extent of fracture comminution”.

“Examining the fracture pattern can aid in your decision-making even more. While smaller fragment Schatzker II fractures may be managed nonsurgically, larger lateral split depression fractures and all medial plateau fractures have a considerably higher tendency to collapse into valgus and varus deformity, respectively. Operation is recommended for nearly all unicondylar medial tibial plateau fractures with displacement and displaced bicondylar fractures”.[60, 61]

“Surgical treatment is frequently used to improve reduction, obtain early mobility, and ensure precise limb alignment. Nevertheless, despite articular incongruities and displacements, the clinician would be well advised to keep in mind that nonsurgical treatments can produce good results for patients who are either unable or reluctant to undergo surgery”.[62]

SURGICAL TREATMENT

The majority of tibial plateau fractures are now treated surgically, while most were treated nonoperatively with cast immobilization until the 1950es. Restoring knee function, axial alignment, articular congruity, and joint stability are the goals of surgical treatment for a fractured tibial plateau. Fixation must be able to reduce issues, allow for early motion, and maintain stability following surgery.

INDICATIONS

"Operational therapy is recommended for tibial plateau fractures when near-anatomic alignment cannot be consistently achieved based on fracture pattern, physical exam findings, and radiographic data. In young, active individuals with no comorbidities, two fracture types that need surgical attention are shaft dissociation patterns and bicondylar plateau fractures. Furthermore, most medial and lateral plateau fractures require surgical therapy unless the fractures are little displaced and proper tibial/knee alignment can be achieved without fixing. An additional recommended signal for surgery is the extent of articular depression. This indicator is the subject of great debate, and the literature has a wide range of cutoffs. Articular depression cutoffs range from >2.5 to >10 mm, and untreated cases provide unsatisfactory outcomes. [63, 64] Unfortunately, the accuracy and constancy of the degree of articular depression are questioned. Independent observers measure articular depression at least 12 mm differently 10% of the time, according to Martin et al. [65] Whether or whether there is more articular depression than a predetermined threshold should not be the sole factor used to determine whether or not surgery should be performed".

Due to the high incidence of meniscal disease and poor functional outcomes, some articles have suggested that surgery should be recommended in cases of varus/valgus instability exceeding 5° and a condylar width expansion more than 5 mm. [63, 66]

"Patients who are older, less active, or inactive, or who have comorbidities that increase their risk of surgery, require extra careful consideration when deciding whether to proceed with operative management. To choose the appropriate course of action, each patient's risk-benefit analysis must be taken into account. Small abnormalities won't affect elderly or sedentary people as much if their functional demands are lower".

Temporary external fixation

For high-grade unstable fractures, a temporary external fixation can be required to relieve proximal tibial compression and restore regular anatomical geometry. This procedure is particularly recommended after a lot of traumas and high-energy trauma impacts.[67] The "span-scan-plan" protocol begins with external fixation using monolateral carbon fiber “fixation systems ("span"), which allow radiographic access to the fracture and enhance radiological imaging interpretation while avoiding the need for pin placement in the area of the subsequent surgical approach”. Simultaneous soft tissue injuries and fracture features ("plan") largely determine the ultimate surgical strategy (time, approach) after MDCT and/or MRI imaging ("scan").[68] For open fractures, lavage and debridement are necessary. However, a second look therapy is typically needed after 48 hours. Rebuilding these tissues is advised as part of the initial surgical procedure when an injury (such as a ruptured patellar tendon or a fractured tibial tuberosity) limits knee extension. A future loss of reduction may occur even with external fixation if the extension mechanism is not sufficiently repaired.

Definitive external fixation

Unlike ORIF with “similar stabilization, definitive external fixation frequently combines limited-access internal fixation, which reduces soft tissue injury and permits early range of motion, with a small wire external fixator that compresses against the fracture segments. Severe open fractures and very comminuted fractures are signs of definitive external fixation when internal fixation is not an option. External fixation can also be employed with minimal internal fixation, such as lag screws squeezing the articular fragments. Numerous studies that compare ORIF with external fixation reveal varying rates of infections and aftereffects. [69] Krupp et al.[70] on the other hand, observed that external fixation had considerably greater incidence of overall morbidity, knee stiffness, infections (7% vs. 13%), and malunion when compared to open reduction for bicondylar tibial plateau fractures”.

Pin site placement for external fixation

“Surgeons differ in their assessment of the significance of pin site placement, as does the literature. In order to prevent pin penetration into the joint, it is customary to insert pins at least 14 mm distal to the joint line and outside the area where subsequent plates would be placed.[71] On the other hand, there are conflicting new data regarding the potential impact of this on infection rates”.

Limited open/percutaneous fixation of the articular segment combined with external fixation: [72]

This is indicated by highly contaminated open fractures or fractures that are significantly comminuted. The plan is to utilize subchondral lag screws or wires to stabilize the reduction after the articular surface has been reduced percutaneously or with tiny incisions. After that, either “an external fixator or a hybrid ring fixator is employed. It improves knee range of motion and lessens soft tissue damage. Patients are allowed to bear weight once the fixator has been worn for two to four months and the callus has formed”. This therapeutic method has been connected in several instances to a high likelihood of malunion.

Staged or Sequential fixation: “If the patient has other major injuries that require damage control orthopedics, or if there is a significant soft tissue injury, bridging external fixation with delayed ORIF[73] may be used as a temporizing approach.[74] Two 4.5 or 5 mm half pins are inserted into the center of the distal femur and the middle of the distal tibia to apply the external fixator. axial traction is then used to reduce the fracture, and the fixator is locked in a mild flexion. For the purpose of controlling the flexion-extension and varus-valgus forces, bars should be positioned in two planes. With the benefits of a lower infection rate and fewer difficulties with wound healing, external fixators allow soft tissue resuscitation before permanent fixation. The primary drawback of this method is the lingering stiffness in the knee".

Open reduction internal fixation (ORIF)

The most common surgical technique for tibial plateau fractures is open reduction internal fixation (ORIF). "Numerous surgical procedures have been recorded for the surgical therapy of tibial plateau fractures. Posteromedial and anterolateral surgery are the two methods most commonly used to reduce and internally repair tibial plateau fractures. They can be used singly or in combination, depending on the fracture pattern. The twin incision technique is safer and equally effective at reducing infection rates as the extensile techniques, with no appreciable increase in infection rates". [75] Other posterior approaches have also become more prominent and have been documented in the literature. The fracture pattern largely dictates the approach and fixation technique. For direct view and access to a greater amount of the articular surface, especially in the central region, direct anterior techniques can be helpful in addition to parapatellar arthrotomy. It is important to keep in mind that while using a direct anterior method, soft tissue dissection should only proceed medially or laterally from the incision. It is not recommended to use anterior midline methods with large medial and lateral dissections because of the plateau's devascularization.

Plates and screws are the most often utilized implants for tibial plateau fractures. Manufacturers offer locking plates and pre-contoured periarticular plates that fit against the proximal tibial surface. The various uses of the plates will depend on their anatomical location and fracture pattern. A plate positioned anterolaterally in a split depression fracture can support the weaker lateral cortex by acting as a buttress for the lateral tibial condyle. On the other hand, the posteromedial plate's location resists shearing pressures by acting as an antiglide mechanism. "Precontoured medial plates are also available from some manufacturers. Recent years have seen a decrease in plate thickness, with medial and lateral plates often averaging 3.5 mm rather than the prior 4.5 mm. The plates may then fit into the bone more securely, and the corresponding 3.5 mm screws can be positioned nearer the articular surface to help support the smaller pieces. Furthermore, the plates allow for "rafting," which is the insertion of subchondral screws through the plate head parallel to the articular surface, significantly reducing postoperative articular depression. [76] Screw placement has less of an impact on mediation than plate position. To make sure the plate is firmly positioned in this important region, a screw can be positioned near the peak of the fracture. The plate position needs to be very close to the peak of the fracture".

"Lateral plates alone may be used to treat bicondylar and Schatzker type VI fractures in specific circumstances. These plates must be able to resist axial, rotational, and bending forces. The insertion of locking screws in the plate has in some situations substantially facilitated the removal of dual plating. However, the propensity for bending forces to result in a varus deformity must be considered when using a single lateral plate in a bicondylar fracture pattern.

Dual plating has often been avoided by lowering the varus collapse using fixed angle devices, however this may not be sufficient to support an unstable medial column sufficiently on its own. Although its application in unicondylar fractures for buttress or antiglide plates is questionable, locking technology is available for the majority of implants made especially for the tibial plateau".

More caution is needed because medial or lateral plating may not be adequate to sustain posterior plateau pieces. It has been shown that the posterior segment is more commonly implicated than previously believed, and that neglecting to diagnose and treat it can lead to misalignment and functional instability. [77] and [78] Although it is simply a secondary cause, this could possibly be the reason why certain fractures fail even after fixation. [79] Effective treatment of these fractures may be possible with the use of the three column concept80.

Void filling

Cancellous bone volume is lost in articular depression fractures (Schatzker II and III) due to the compression of cancellous trabeculae. Below the smaller portion of depressed tibial plateau articular fragments, there is a zone of bone void. Therefore, it is necessary to give these components enough support in order to reduce the possibility of redisplacement. Metaphyseal void material can be used to fill up these fracture patterns, reducing risk and increasing stability.

"A variety of products are available to help close these gaps. Even though autograft bone can be used, it is not widely available, requires more time during surgery, and may result in donor site morbidity. Vascular injuries, deep infections, neurologic injuries, deep hematomas, iliac wing fractures, chronic discomfort, abdominal contents herniating through pelvic donor sites, temporary pain or numbness, superficial infections, seromas, and minor hematomas are among the range of complications".

Their two primary benefits are the increased availability of allografts from bone banks and the absence of donor site morbidity. "Autografts provide osteogenesis, osteoinduction, and osteoconduction as advantages and characteristics, but the majority of allografts only provide osteoconduction and poorer osteoinduction. As a result, the healing process after autograft is usually faster than that after allograft". Donor illnesses may spread, however this risk is significantly reduced by tissue testing and donor screening.[26]

Nowadays, several commercially available graft options are used to treat tibial plateau fractures. In terms of mechanical properties, phase-changing cements have recently shown promising results, surpassing both autologous and allogenic bone grafts. Calcium phosphate cement was substantially stiffer than cancellous bone and shown significantly less displacement at 1000 N in a split depression fracture cadaver model study.[81]

Minimally invasive percutaneous plate osteosynthesis (MIPPO)

MIPPO speeds up the healing process because it disrupts soft tissues like the periosteum and its vascularity less. Additionally, it enables percutaneous submuscular implant placement and indirect fracture reduction.[82] Farouk et al. compared the post-procedure bone blood supply in MIPPO with conventional plate osteosynthesis in a cadaver study. Perforating and nutritive arteries remained intact, and the MIPPO group showed improved periosteal and medullary perfusion when compared to the standard plating group.[83] "ORIF enables direct observation, reduction, and fixation, but at the cost of stiffness, deep infections, substantial soft tissue dissection, and a higher chance of wound disintegration".[84] The advantages of both ORIF and MIPPO procedures can be integrated in surgery by making a tiny incision close to the joint line for direct joint viewing and fixation, and then using percutaneous minimally invasive techniques for plate placement and fastening. Percutaneous guides can help guarantee that shaft screws are inserted into these plates precisely and effectively, even though some surgeons prefer to employ feel and fluoroscopy.

Intramedullary nailing

Intramedullary nailing (IMN) has many advantages when it comes to fixing fractures. These include least intrusive exposure, longer implants to bridge more complex fractures, biologically friendly implant placement, and load-sharing fixation that allows for early weight bearing. Due to intrinsic nail design flaws that prohibited the nails from correctly aligning with the metaphyseal and epiphyseal segments, prior implants highlighted concerns about malreduction from intra-articular fractures.[85] "Recent developments in implants have inserted multiplanar interlocking screws clustered near the ends of nails to improve purchase in proximal segments and to enable locking the interlocking screws to the nail, creating a fixed angle construct that theoretically improves stability. These new advancements enable the formation of a stable articular block by safely stabilizing proximal intra-articular tibial fractures with intramedullary nailing. This is often achieved by either placing independent lag screws proximally and outside of the intended nail route, or by applying buttress plating using nailing-compatible techniques

(Figure 12). Intramedullary nailing may be advised, especially in patients who are more susceptible to wound problems, have segmental injuries, or have tibial fracture patterns with diaphyseal extension.[86] Wound effects are more likely to occur in people with peripheral vascular disease, diabetes, morbid obesity, thin skin, and damaged soft tissues. Before nailing, C-type articular fractures must be converted to A-type fractures by anatomic reduction and stable stability of the articular surface. When the tibial tubercle is included in the fracture pattern or when reconstructing the articular surface beyond the intended nail trajectory is not practical, nailing may not be the best option. Fractures involving fragments of the tibial tuberosity are not excellent candidates because the nail might generate a large anteriorly oriented deforming stress".[86]

With arthroscopic support, internal fixation and reduction can produce outcomes that are comparable to those of open surgeries. "Especially in Schatzker I to III.[87] fractures

Primary Total Knee Arthroplasty: This can be a possibility for some patients with specific fracture patterns".

Bicondylar tibial plateau fractures are particularly challenging to treat in terms of fracture shape, early mobilization, and postoperative reduction maintenance.

APPROACHES TO PROXIMAL TIBIA[88]

- ✓ ***"Lateral Approach***

• "Anterolateral Approach: This is the most widely used technique for treating tibia plateau fractures, and most trauma surgeons employ it. For Schatzker's type III, V, and VI fracture patterns, this method is usually applied.

• Posterolateral Approach: This method is applied to coronal fractures in which the posterolateral pieces have been displaced or to fractures that cannot be treated using the anterolateral approach. The first method of fibular osteotomy was published by Lobenhoffer and colleagues, and since then, other modifications have been developed. You can use this method in a lateral, supine, or prone posture".

- ✓ ***"Medial approaches***

This method is typically applied to fractures of Schatzker type IV. However, this method is now only utilized for Schatzker type V fractures due to the intricacy of fractures increasing and the emergence of the dual plating technique".

- ✓ ***"Direct Posterior Approach***

Only avulsion fractures of the posterior cruciate ligament (PCL) or shear fractures of the posterior plateau may be treated with the direct posterior approach. This method is applied in the three-column fixation concept to address the posterior column fracture component of any kind of injury".

CHOICE OF TREATMENT

Medial Plateau Fractures These fractures damage the medial tibial plateau. Often, soft tissue, ligament, and neurovascular injury accompany these fractures. The majority of the time, a posteromedial surgical technique is preferred. The proximal extension parallel to the pes anserinus tendons should be positioned as posteriorly as possible following the medial incision, which started 1 cm posterior to the posteromedial edge of the tibia, "in order to reduce the posterior fragment. The tendons may be severed and either retracted or repaired at the end of the therapy. The medial gastrocnemius is dissected from the tibia. A buttress plate is necessary to improve stability after open reduction".

The repair of associated soft tissue damage is determined on an individual basis. Meniscal injuries should usually be repaired. Sutures or screws can be used right away to repair a ligament osseous avulsion. Further ligament repairs should be delayed until knee range of motion and bone healing have improved.[89]

Bicondylar Tibial Plateau Fractures

These fractures damage the lateral and medial tibial plateaus. Anterolateral and posteromedial internal fixation with open reduction are the two most used techniques for treating these fractures. In addition to providing the advantages of direct visualization, reduction, and stabilization of medial and lateral articular and metaphyseal fragments, the two-incision technique reduces extraneous soft tissue dissection, which may lessen wound complications and deep sepsis that have been documented with a single anterior incision. [90, 91]

Anatomical reduction is required to restore the alignment of the limbs and the joint surface. It is frequently insufficient to maintain axial alignment following single lateral plating with conventional plates for bicondylar tibial plateau fractures. [92] “The medial fragment is frequently comminuted or not reducible in high-energy fractures. After that, the screws from a lateral plate are unable to engage this piece. Independent medial fixation is therefore required. Bilateral dual plating is usually recommended as the sole practical therapy for this kind of fracture; however, a second plate can be needed to secure the posterior column. "Three column fixation," a novel fixation approach for difficult tibial plateau fractures, is especially useful for multiplanar posterior column fractures. The medial column is usually addressed initially using a posteromedial approach. Precautions must be taken to avoid screw fastening pieces with unreduced lateral fracture”.

Treatment of Three column fracture[93]

"This most complex kind of fracture may be caused by a variety of stresses operating in various combinations on the knee during flexion or extension. The principles of treatment are similar to those of two-column injury therapy, which deals with individual columns. To ascertain the major acting force and the location of the knee at the time of injury, the authors of the revised Three Column Fixation concept (uTCC) by Luo et al. recommend measuring the pTSA (medial and lateral) and mTPA as previously mentioned. For example, in an injury where a dominant varus force is acting on the knee in flexion, as indicated by a negative medial Tibial Plateau Angle, the so-called primary buttressing plate should be positioned posteromedially (=compression side) as the first step. It may be necessary to use more tiny buttressing plates to manage separate secondary column fractures. The opposing (tension) side should be stabilized with a supporting plate; this is frequently done as the last stage of restoration. There may occasionally be further ligament ruptures or bone avulsions on the tension side that need to be surgically repaired".

"While Luo et al.'s uTCC focuses on the reconstruction of the mechanical axis and joint stability, Krause and colleagues' 10-segment technique focuses on the reconstruction of the joint surface. However, as compression is usually the main source of articular surface injury, these concepts do not contradict each other. More thorough examination of the joint imprint site has proven advantageous, though, because certain techniques allow for sufficient buttressing of a split-wedge fragment but fail to provide significant exposure of the central joint segments. Luo's extended posterior approach, for example, only visualizes the joint surface up to the edge of the plateau, but it allows buttressing of the medial and posterior column from the head of the fibula's medial border to the posterior border of the medial collateral ligament. In conjunction with an enlarged anterolateral approach (anterolaterocentral, posterolaterocentral according to Krause et al.), the central articular surface can be rebuilt".

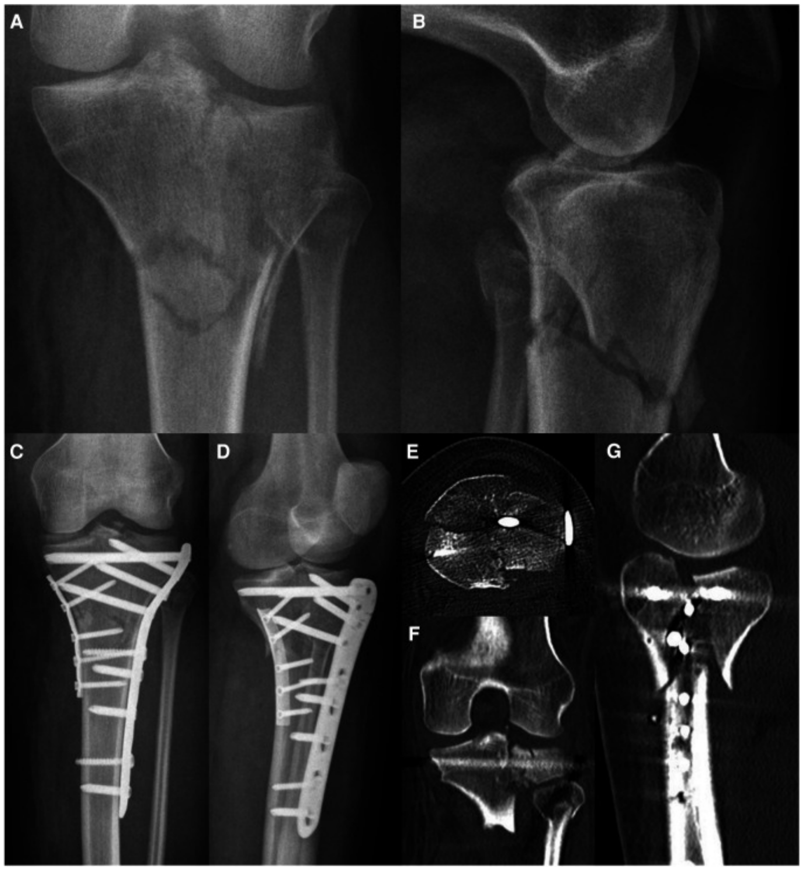

Figure 12: "3-column fracture (Schatzker VI, AO 41-C3, Moore V, 3-column-fracture) displayed by AP (A) and lateral (B) x-ray. Postoperative AP (C) and lateral (D) x-ray as well as axial CT cut (E), coronal (F) and sagittal (G) reconstruction after first surgery abroad (ORIF by double plate fixation via anterolateral and medial approaches) reveal a persisting dislocation of a large posteromedial fragment causing an articular step-off of more than 5 mm".

THREE-DIMENSIONAL PRINTING IN ORTHOPAEDIC SURGERY[94]

"The design theory and manufacturing processes underlying a wide range of products in all major industries have been completely transformed by three-dimensional (3D) printing, also known as additive manufacturing". This technology offers significant opportunities for simple prototyping, small production runs with real-time refinement, and customization. This potent technology has enabled the creation of intricate, geometric designs, as well as one-off manufacturing, that would be impossible with conventional production techniques. Furthermore, a central industrial location with room to keep substantial stocks is typically needed for traditional manufacturing. This workflow has been altered by on-demand manufacturing, which is made possible by 3D printing and does not require a significant production and storage space. With the introduction of desktop 3D printers, the technology entered homes and became a crucial part of commercial manufacturing. Customers can see how their own designs are transformed from a raw material to a final product with the right tools and matching software.

Basics of Three-dimensional Printing in Medicine

Additive and subtractive manufacturing are the two primary forms of product manufacture. To create the final product, additive manufacturing combines layers of solids, liquids, or powders. Subtractive manufacturing, on the other hand, creates the final structure by cutting, milling, or molding the starting material from a base product. Although there are many different 3D printing techniques, they all follow a similar sequential procedure.

"Using a de novo design or cross-sectional imaging from CT and/or MRI scans stored in the digital imaging and communications in medicine format, a digital representation of the final product is first created. Using regions of interest that distinguish between tissues and surrounding anatomical features, this method allows software to fine-tune these pictures during the segmentation process, accurately defining the shape of the object to be printed. A standard triangle language file is created by computationally transforming the contours" of segmented regions of interest. The American Society for Testing and Materials validated the additive manufacturing file in 2011, enabling users to incorporate other aspects of the 3D-printed product (such as material qualities, surface texture, and color) into the design.

"In order for the printer to convert the digitally supplied coordinates of the file into a series of two-dimensional cross-sections, the standard triangle language" or additive manufacturing file must next be translated into a code, usually the G-code. Because they serve as the foundation for each layer that the printer fuses together to produce the finished 3D item, these cross-sections are crucial.

"Material extrusion, material jetting, binder jetting, powder bed fusion, directed energy deposition, stereolithography, sheet lamination, and vat polymerization are among the several techniques accessible after the finished product is prepared for printing. One of the most popular printing techniques is material extrusion, also known as fused deposition modeling, which starts with solid materials. This method creates a hardened layer by allowing small beads or streams of material to emerge from an extruder in a hot liquid or semiliquid state that is quickly cooled. Orthopaedic implants are frequently made using powder bed fusion techniques, which have shown success with metal-based goods". A tiny coating of powder is applied to the printer's building platform, where a thermal energy source—either an electron beam or a laser—fuses the relevant area as specified by the original design. Until every layer or slice of the structure has been correctly fused to produce the intended end product, this process is repeated.

Conventional (subtractive) manufacturing produces waste and scrap by milling or cutting away a base product to get the required structure. On the other hand, additive manufacturing reduces raw material waste, with reported rates below 5%. Because of this benefit, additive manufacturing has become a wellliked and effective substitute; also, using traditional methods usually results in more costly and time-consuming bespoke items. Despite having its own set of drawbacks, 3D printing's rising acceptance and growth across sectors has significantly reduced costs, improved accessibility, and expanded its uses in a number of sectors, including healthcare.

Orthopaedic Applications

Anatomic Models

Anatomical models printed in three dimensions are helpful for education as well as for preoperative planning in complicated instances. With a precise 3D model of the anatomy, surgeons may see and feel what they will experience in the operating room. Surgeons who were categorized "as inexperienced, having operated on fewer than 15 similar fractures, altered their preoperative plan more than 70% of the time after using the 3D model when more than 100 orthopaedic surgeons were asked to select a locking plate for a complex tibial fracture after examining radiographs, CT scans, or a 3D-printed model". More over 70% of seasoned surgeons favored using 3D models in their practice if they were accessible, despite the fact that they did not switch their choices as often. 3D models not only help with hardware selection but also enable prebending of specific plates prior to surgery. This method has demonstrated potential in the treatment of clavicle fractures and allows the plate to conform to the unique anatomy of each patient to enable precise reduction.

The mirror imaging method, which prints anatomical representations of the contralateral uninjured side for help in preoperative planning, has made use of three-dimensional printed models. Surgeons can optimize plate selection using the undamaged 3D model and replicate their reduction approach using the broken 3D model. Excellent results have been seen when this approach is applied to calcaneal, pilon, ankle, and clavicle fractures.

Medical education can benefit greatly from the use of three-dimensional printed models. Realistic 3D patient models that depict common diseases seen in the operating room can help resident surgeons hone their technical abilities. Overall, trainees who were asked to rate "the clinical usefulness of 3D-printed models in preparing their surgical strategy for percutaneous screw fixation of a posterior column fracture expressed great satisfaction, claiming that the models improved their comprehension of both the surgical technique and regional anatomy". 3D-printed anatomic models have been used to enhance patient education, which could result in better perioperative comprehension and compliance from patients.

Even while 3D-printed anatomic models are becoming more and more popular, third-party payers do not yet fund their use, despite the fact that using them results in much shorter operating times. For low and high usage rates, "the net savings range from $19,384 to $129,589 and $77,536 to $518,358 at an average of $62 operating room time per minute. The predicted cost reductions might even be enough to pay for the upkeep of a 3D printing lab, even at low volumes of about 63 models annually".

Prosthetics and Orthotics

"Most braces and orthotics are available only in a limited number of sizes and are designed to fit a large fraction of the population. Although fully customizable prosthetics have proven to be effective, the manufacturing process is complex and adds to the overall cost and time required to make these prosthetics".

New Noncustom Implants

"Three-dimensional printing technology can be used to produce orthopaedic implants that are not customized. Several new implant types for hip and knee arthroplasty have entered the market as a result of the streamlined 3D printing production process. Three-dimensional printed acetabular cups are thinner and less expensive than traditionally manufactured cups".

“Patient-specific Instrumentation”

“Customized surgical guides for orthopaedic surgery have been manufactured with the aid of 3D printing technology. Although it has been proposed that PSI reduces operative time and improves alignment, studies of total knee arthroplasty (TKA) demonstrated mixed results. To preserve a high standard of patient care with a growing case load, an in-depth investigation into the economic efficiency of PSI is valuable”.

Patient-specific Custom Implants

“Although standard implants are made to fit most of the general population, a personalized fit is required in cases with variations in anatomy and cases in which no already produced implant would suffice (e.g., severe bone loss for trauma, cancer, and infection). Custom implants are arguably the most ground-breaking aspect of 3D printing for orthopaedic surgery; surgeons can now design and implant custom devices. Although this technology has the potential to revolutionize patient care, we must also exercise caution and obey the mantra “just because you can, doesn't mean you should.”

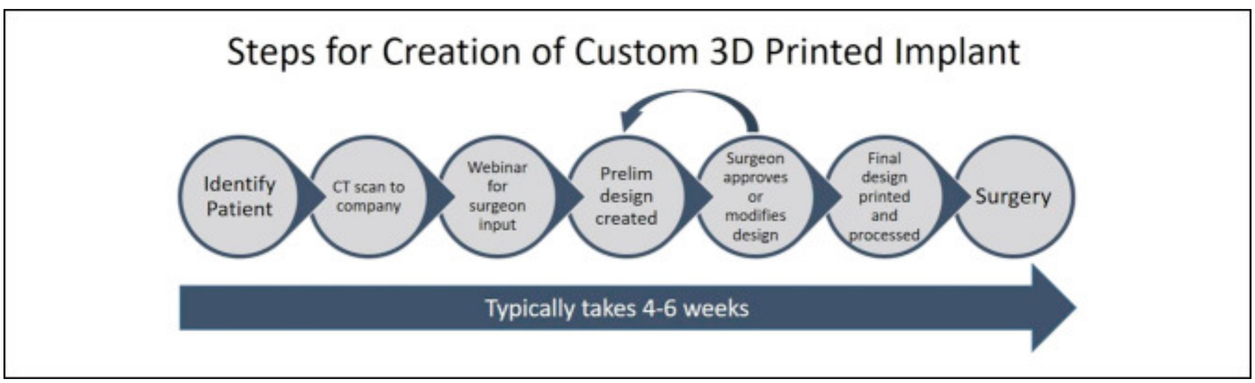

Figure 13: Design process of a custom three-dimensional printed implant.

3D Printing Applications in Tibial Plateau Fracture Treatment:

Preoperative Planning

- “Creates exact anatomical replicas of the patient's fracture from CT scan data
- Allows surgeons to visualize complex fracture patterns in three dimensions
- Helps plan optimal screw and plate placement before surgery

Patient-Specific Guides

- Custom surgical guides can be 3D printed to match the patient's anatomy
- Ensures accurate placement of screws and implants
- Reduces surgical time and improves precision

Custom Implants

- Patient-specific implants can be designed and printed for complex cases
- Better anatomical fit compared to standard implants
- Particularly useful in cases with bone loss or unusual anatomy

Clinical Benefits:

- Reduced operating time
- More accurate reduction of fractures
- Better surgical outcomes
- Lower risk of complications
- Improved patient understanding of their condition
- Better surgical precision

Limitations:

- Additional cost for printing
- Time needed for design and printing
- Requires specialized expertise
- May not be available at all facilities

Best Candidates:

- Complex fracture patterns
- Unusual anatomy
- Young, active patients
- Cases requiring precise reconstruction
- Revision surgeries

Recovery Benefits:

- More accurate joint reconstruction
- Better post-operative alignment
- Potentially faster rehabilitation
- Improved long-term outcomes

This technology represents a significant advance in orthopedic surgery, allowing for more precise, personalized treatment of tibial plateau fractures. The ability to plan and execute surgery with patient-specific tools has shown promising results in improving surgical outcomes.

MATERIAL AND METHODS

- We have done a “Comparative study” conducted in BLDE (DEEMED TO BE UNIVERSITY) Shri B. M. Patil Medical College, Hospital & Research Centre, Vijayapura from April 2023 to March 2025.

- In our study, 40 patients were involved, of which 2 groups were made consisting of 20 patients each of with and without 3D print of whom 35 (87.5%) were male and 5 (12.5%) were female.

- **Inclusion criteria:**

1. Patients age more than 18 years
2. Intra articular Tibial Plateau fractures SCHATZKER TYPE 5 AND 6.
3. Polytrauma

- **Exclusion criteria:**

1. Open Intra articular Tibial fractures

METHODOLOGY:

This prospective comparative study was conducted at the Department of Orthopaedics, B.L.D.E. (Deemed to be University) Shri B. M. Patil Medical College, Hospital & Research Centre, Vijayapura, between April 2023 and March 2025. The study included patients diagnosed with Schatzker type 5 and 6 proximal tibial intra-articular fractures. All patients received detailed information about the study, and written informed consent was obtained prior to enrollment.

Patient Evaluation and Selection

A comprehensive initial assessment was performed for all patients, which included detailed history taking with particular emphasis on the mechanism of injury, associated comorbidities, and pre-injury functional status. Clinical examination focused on the assessment of soft tissue status, neurovascular examination, and evaluation of associated injuries. Standard radiological evaluation included anteroposterior and lateral radiographs of the affected knee, along with computed tomography (CT) scans with 1mm slice thickness for detailed fracture pattern analysis.

Preoperative Workup

All patients underwent a standardized preoperative workup including complete blood count, renal and liver function tests, blood glucose levels, coagulation profile, blood grouping and Rh typing, and infectious disease screening (HIV, HBsAg, HCV). Cardiac evaluation was performed through ECG and 2D echocardiography, and chest X-rays were obtained as part of the pre-anesthetic assessment.

3D Model Preparation Protocol

For the study group, CT scan data (1mm slice thickness, 1mm reconstruction interval) was acquired and stored in DICOM format. The data processing followed a systematic protocol:
The DICOM files were initially imported into INVESALIUS software, where region of interest (ROI) selection and data segmentation were performed. The segmented data was then exported as an STL file. Further refinement of the model was accomplished using MESHMIXER software, which involved smoothening of surfaces and removal of artifacts and unwanted structures. The refined 3D model was then processed through 3D SLICER software for slicing and conversion to gcode format. The final printing was executed using a CR-10 3D printer with appropriate support structures. Post-processing of the printed model was performed to ensure

optimal quality for surgical planning.

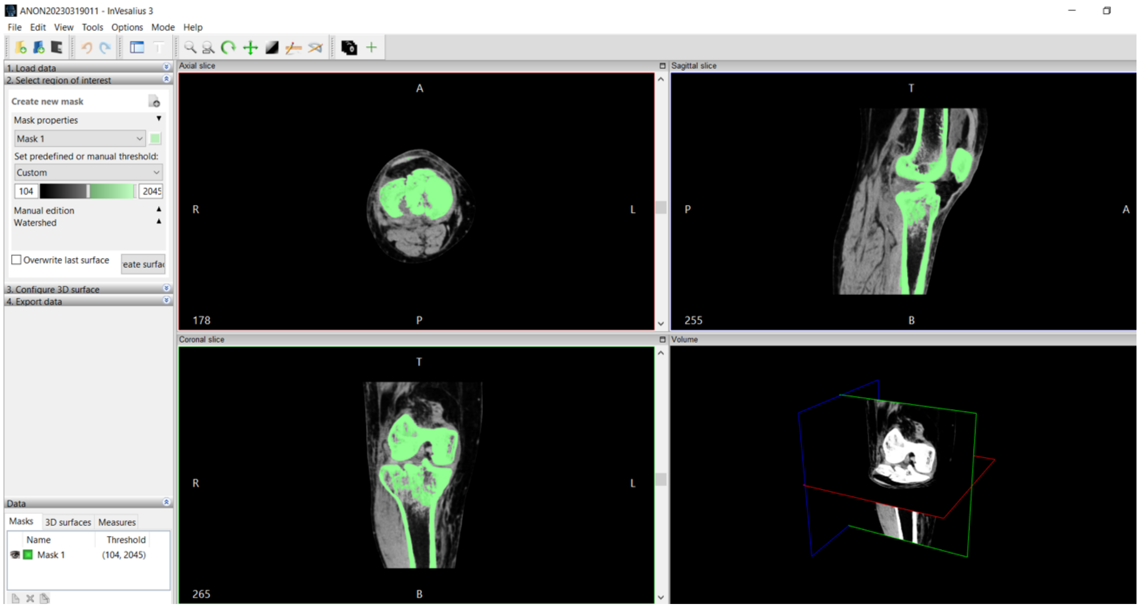

Figure 14: Region of interest (ROI) selection done with INVESALIUS software.

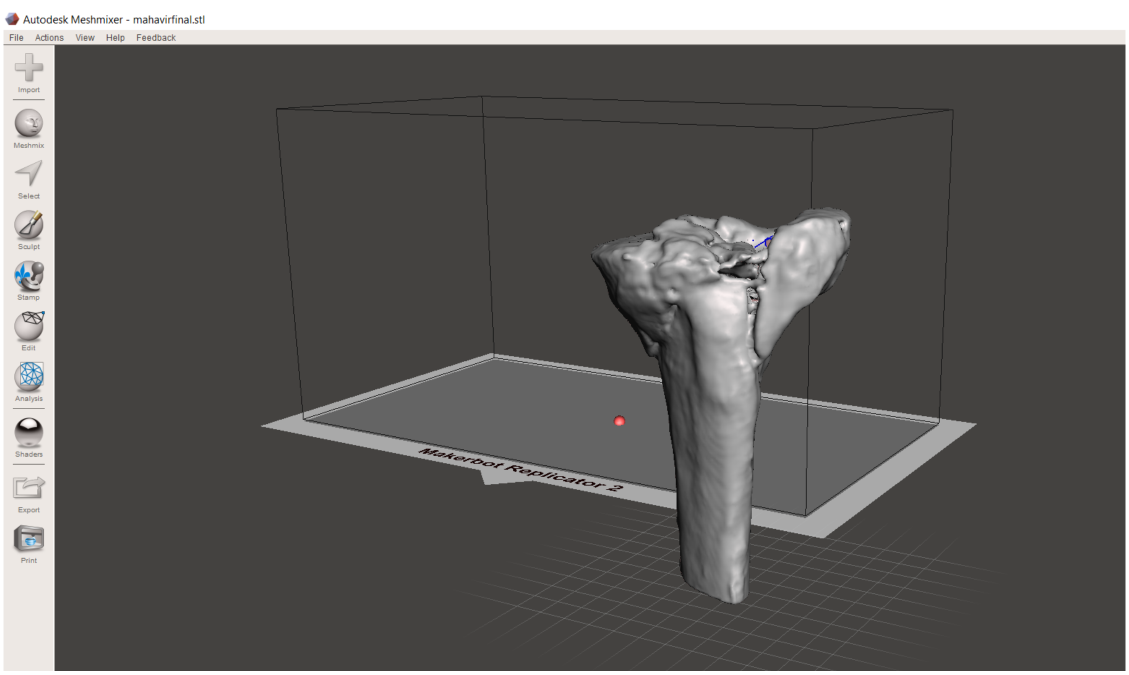

Figure 15: Refinement of model done with MESHMIXER software

Preoperative Planning

In the study group, the 3D-printed models were utilized for detailed preoperative planning. This included selection of appropriately sized implants and simulation of reduction manoeuvres using the physical model. The control group underwent conventional preoperative planning using radiographs .

Surgical Procedure and Data Collection

All surgeries were performed by the same team of experienced orthopaedic surgeons. Intraoperative data collection included surgical time (measured from skin incision to closure), blood loss (measured by weighing surgical sponges and collection in suction bottles), and fluoroscopy exposure time. These parameters were recorded and compared between the groups with and without 3D model assistance.

Approaches for proximal tibia

- Anterolateral approach
- Medial / posteromedial approach
- Posterior approach

Position of patient

- Supine
- Lateral decubitus position

Implants used

- 4.5 T- buttress plate
- Proximal lateral tibia plate
- Proximal medial tibia plate
- 3.5 Proximal posteromedial tibia plate

Figure 16: Locking compression plates

SAMPLING

Sample size: 40

As per study by Shen Shen et al Using G*Power ver 3.1.9.4 software for sample size calculation, The operation time(min) Without 3D Printing (Mean=152.50, SD=29.63) and With 3D Printing (Mean=127.25, SD=8.03), this study requires a total sample size of 40(for each group 20, assuming equal group sizes), so to achieve a power of 94% for detecting a difference in Means: Inequality, two independent means (two groups)(t-test) with 5% level of significance.

Formula used $\mathbf{n=z^2\,S^2/d^2}$

Where,

Z= Z statistic at α level of significance

d2= Absolute error

P= Proportion rate

q= 100-pC

STATISTICAL ANALYSIS

Data was entered in excel sheet and analyzed using SPSS version 21. Results were presented in tabular and graphical forms Mean, median, standard deviation and ranges were calculated for quantitative data. Qualitative data were expressed in terms of frequency and percentages. Student t test (Two Tailed) was used to test the significance of mean and P value <0.05 was considered significant.

CASE ILLUSTRATIONS

CASE 1: A 41 year old male diagnosed with right proximal tibia fracture (schatzker type 5) and underwent ORIF with plating. This patient was planned with a CT scan with 3D MODEL.

Figure 17 (A) : Pre-operative x-ray

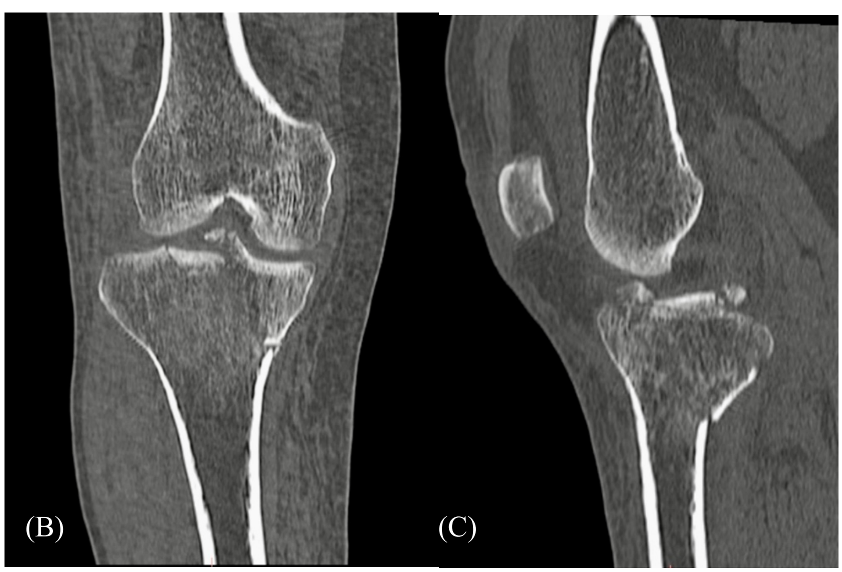

Figure 17 (B) : CT Coronal View & Figure 17 (C): CT Sagittal View

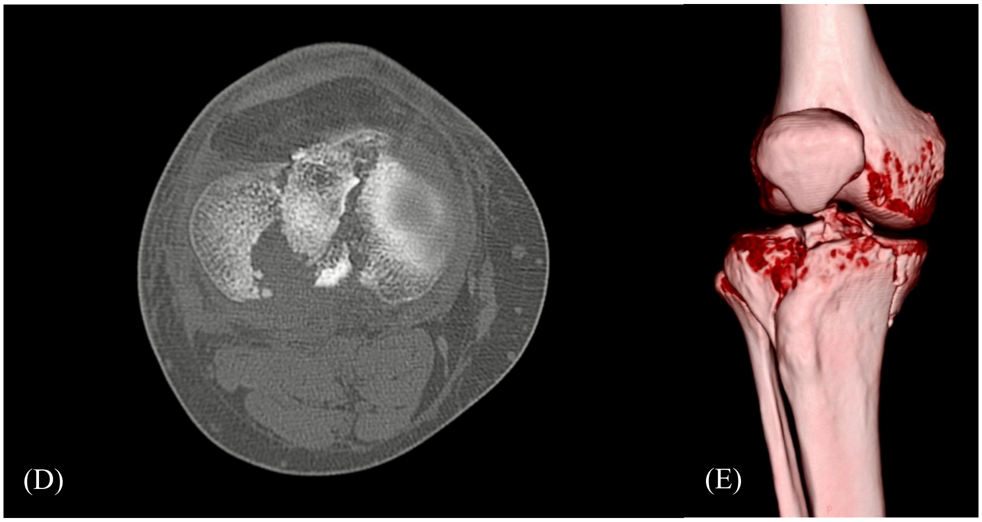

Figure 17 (D) : CT Axial View & Figure 17 (E): CT 3DView

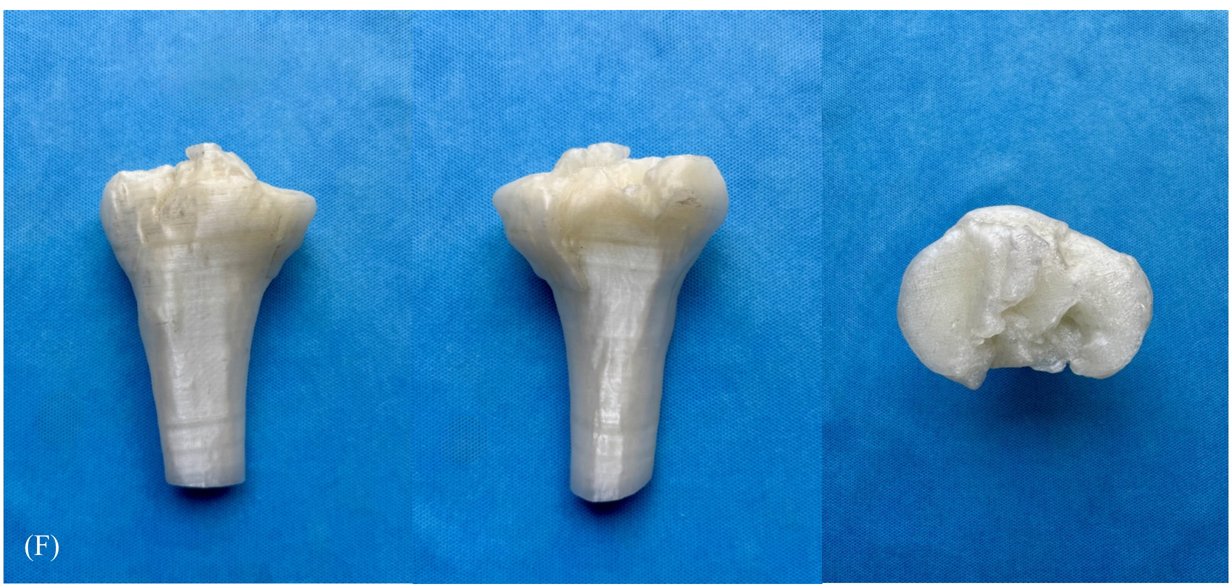

Figure 17 (F) : Pre op 3D bone model

Figure 17 (G) : bone model post planning

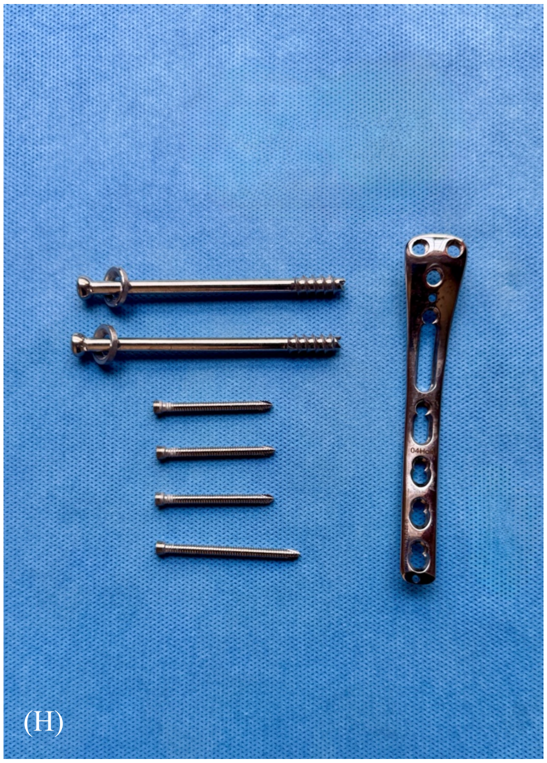

Figure 17(H): Implants planned preop

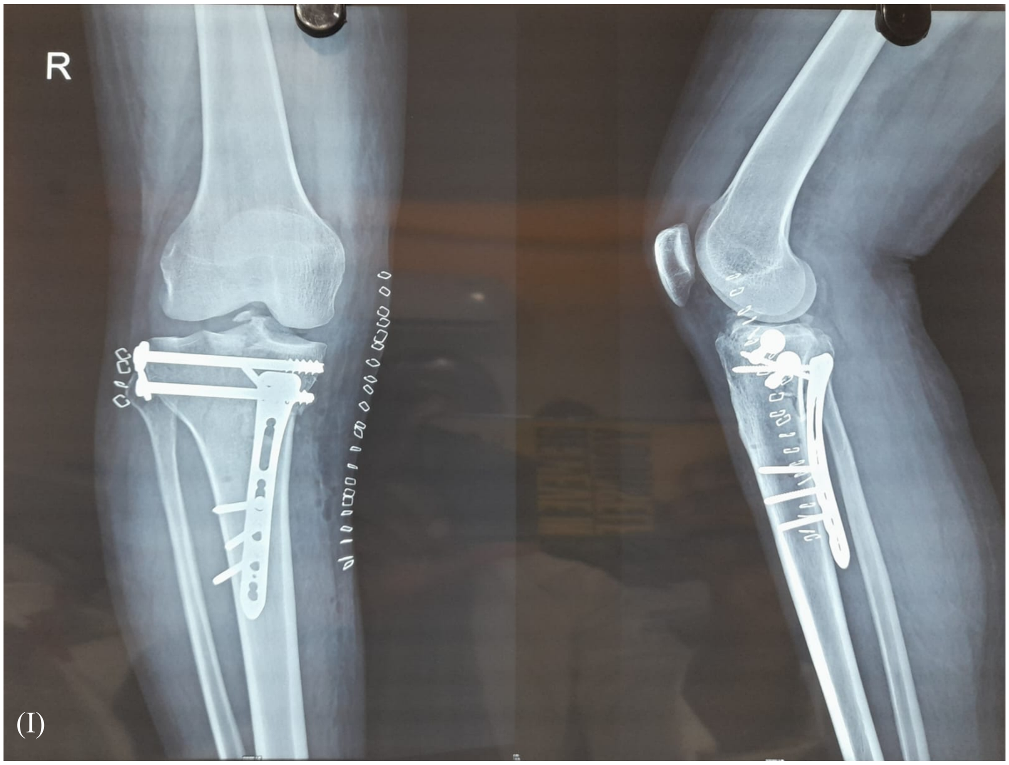

Figure 17 (I): Post-operative xray

CASE 2: A 36 year old male diagnosed with right proximal tibia fracture (schatzker type 5) and underwent ORIF with plating. This patient was planned with a CT scan with 3D MODEL.

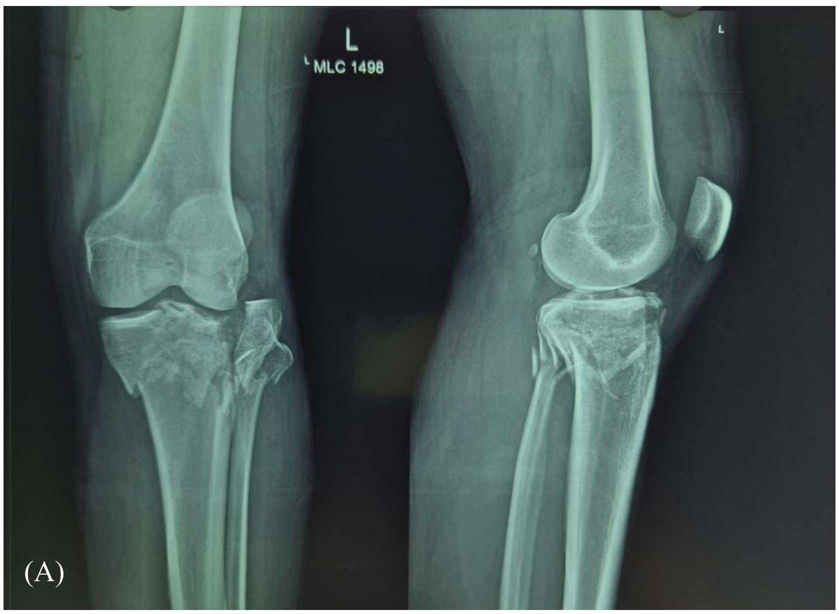

Figure 18 (A) : Pre-operative x-ray

Figure 18 (B) : CT Coronal View & Figure 18(C): CT Sagittal View

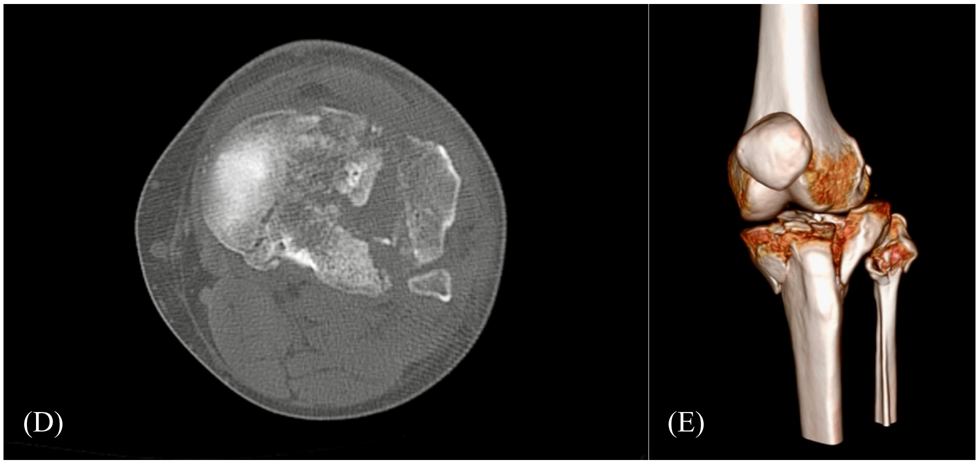

Figure 18 (D) : CT Axial View & Figure 17 (E): CT 3DView

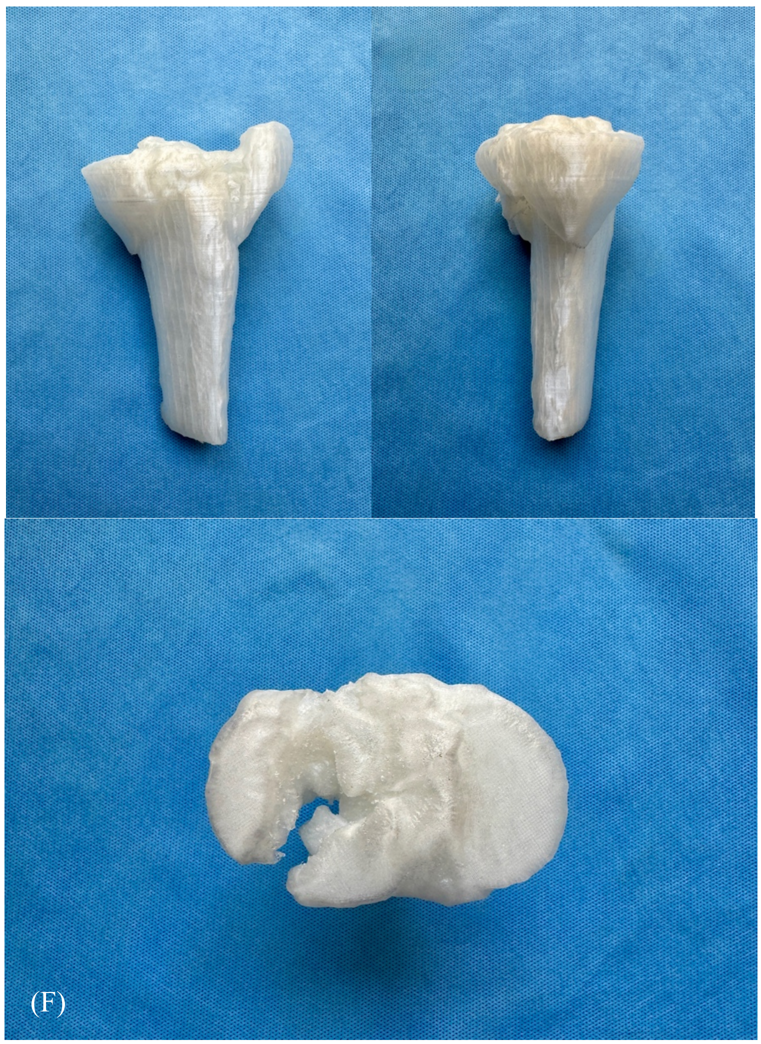

Figure 18 (F) : Pre op 3D bone mode

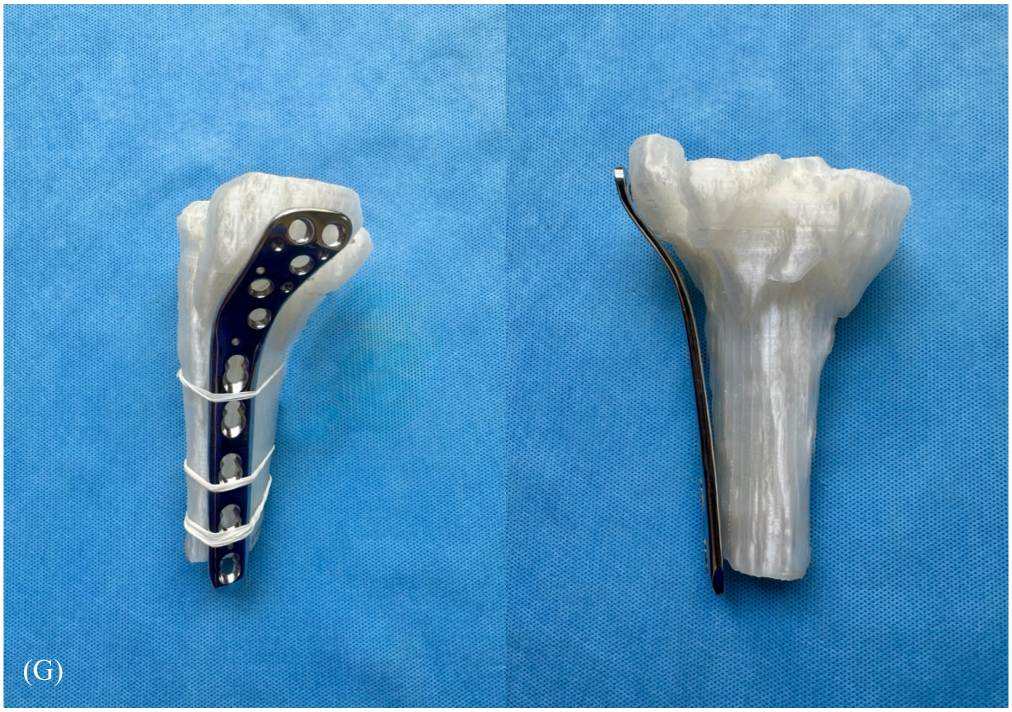

Figure 18 (G) : bone model post planning

Figure 18 (H): Implants planned preop

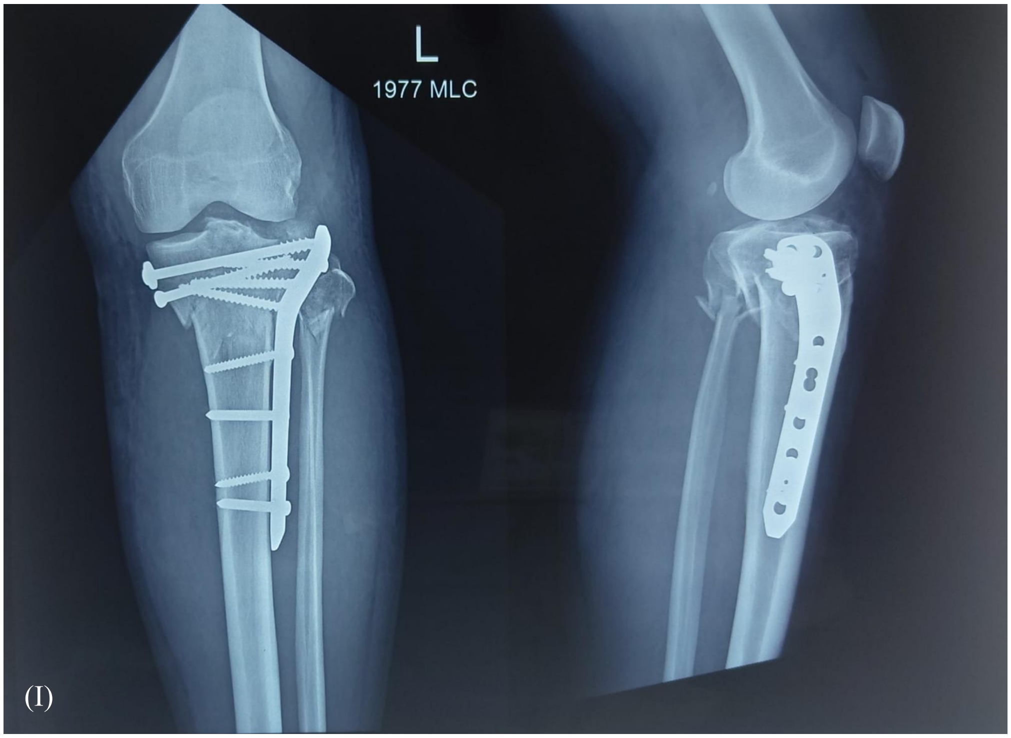

Figure 18 (I): Post-operative xray

RESULTS

40 cases of proximal tibia fractures of schatzker type 5 aand 6 were taken, Out of which 20 were with a 3D print and 20 without 3D print in BLDE (DEEMED TO BE UNIVERSITY) Shri B. M. Patil Medical College, Hospital & Research Centre, Vijayapura (April 2023 to march 2025).

Table 1: Comparison of age among groups

Age (in years)	3D print	Control
20-40	12 (60%)	8 (40%)
41-60	7 (35%)	10 (50%)
61-80	1 (5%)	2 (10%)
Total	**20 (100%)**	**20 (100%)**

Table 1 shows the age distribution comparison between 3D print and Control groups, with the 3D print group having more younger patients (60% in 20-40 years range) compared to the Control group (40%), while the Control group had more middle-aged patients (50% in 41-60 years range) compared to the 3Dprint group (35%).

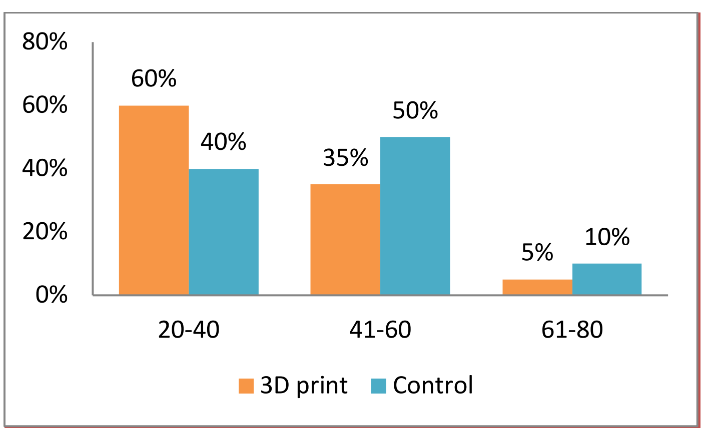

Figure 19: Comparison of age among groups

Table 2: Comparison of gender among groups

Gender	3D print	Control
Female	1 (5%)	4 (20%)
Male	19 (95%)	16 (80%)
Total	**20 (100%)**	**20 (100%)**

Table 2 demonstrates a strong male predominance in both groups, with 95% males in the 3D print group and 80% males in the Control group, and though the Control group had a slightly higher percentage of females (20% versus 5%).

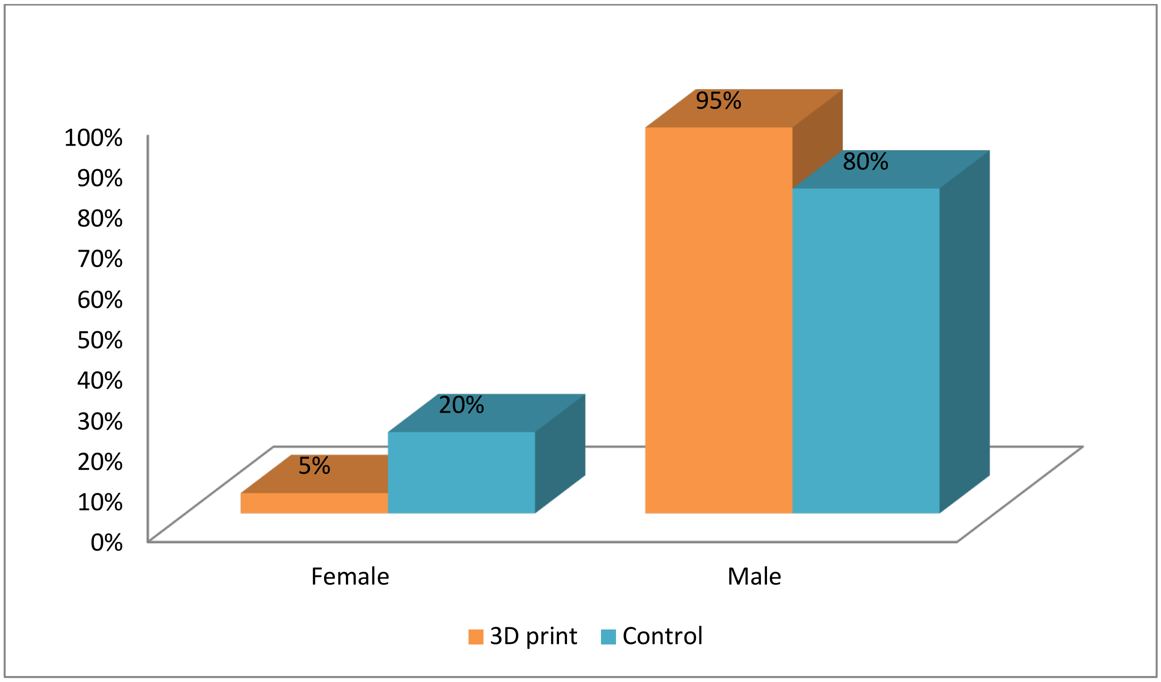

Figure 20: Comparison of gender among groups

Table 3: Comparison of fracture pattern according to schatzker classification among groups

Schatzker type	3D print	Control
Type 5	9 (45%)	9 (45%)
Type 6	11 (55%)	11 (55%)
Total	**20 (100%)**	**20 (100%)**

Table 3 reveals identical distribution of Schatzker fracture types between groups, with 45% Type 5 fractures and 55% Type 6 fractures in both the 3D print and Control groups.

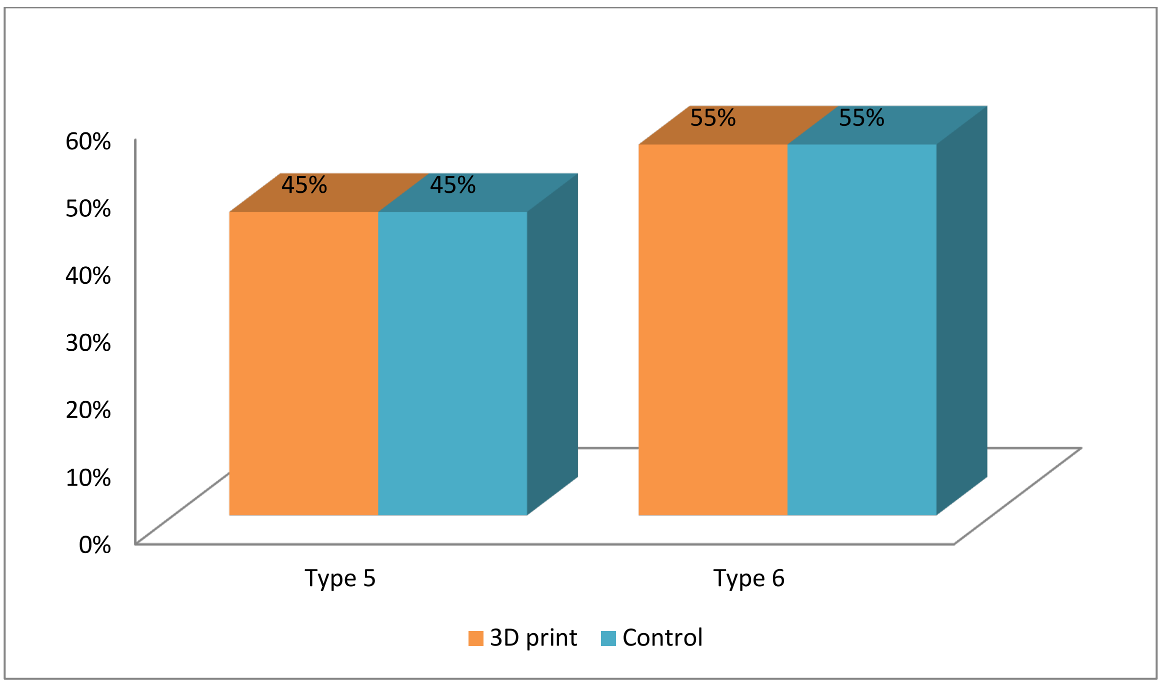

Figure 21: Comparison of fracture pattern according to schatzker classification among groups

Table 4: Side distribution among groups

Side affected	3D print	Control
Left	8 (40%)	11 (55%)
Right	12 (60%)	9 (45%)
Total	**20 (100%)**	**20 (100%)**

Table 4 indicates that the 3D print group had more right-sided fractures (60% versus 45%), while the Control group had more left-sided fractures (55% versus 40%).

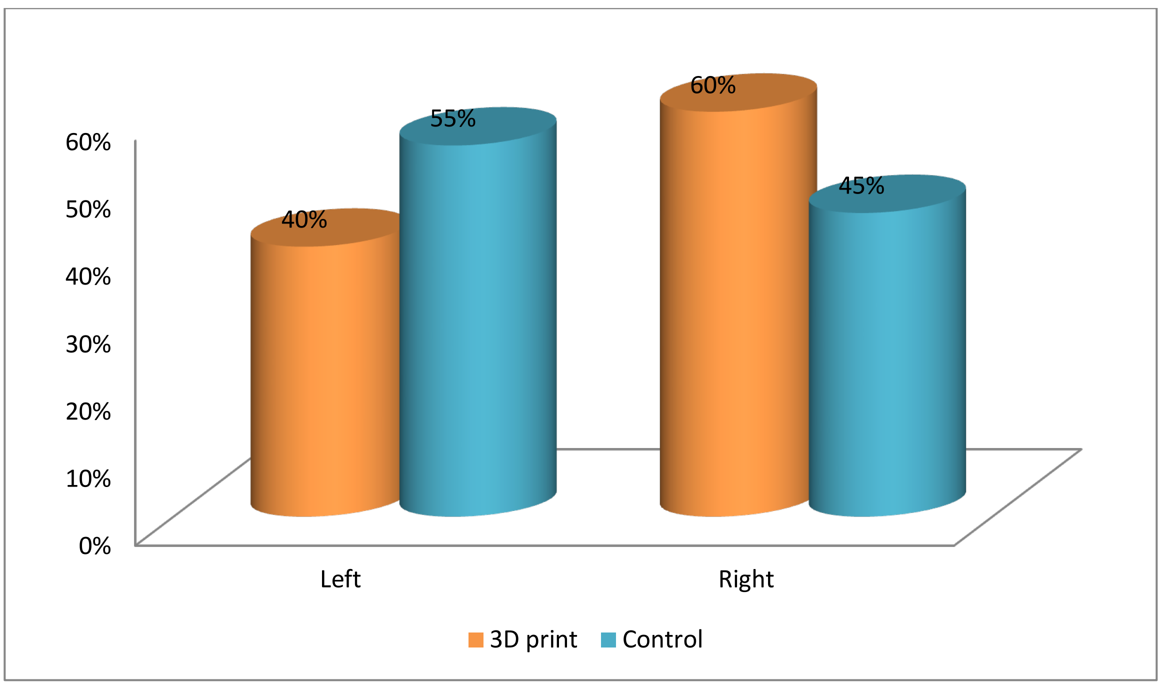

Figure 22: Side distribution among groups

Table 5: Comparison of mode of injury among groups

Mode of injury	3D print	Control
Fall from height	6 (30%)	6 (30%)
RTA	14 (70%)	14 (70%)
Total	**20 (100%)**	**20 (100%)**

Table 5 shows identical mode of injury distribution between groups, with road traffic accidents being the predominant cause (70%) in both groups and falls from height accounting for 30% in both groups (p=1.0).

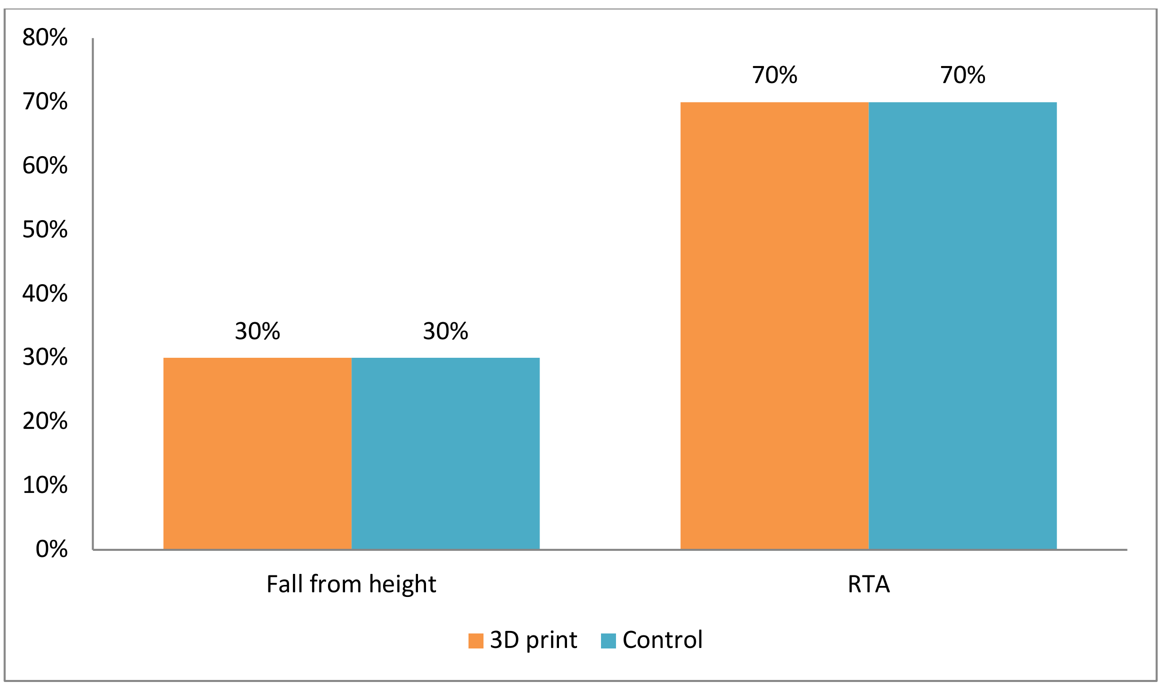

Figure 23: Comparison of mode of injury among groups

Table 6: Comparison of different parameters among groups

Parameters (mean±SD)	3D print	Control	p-value
Surgery time (minutes)	110.2±19.3	142.5±34.04	**0.001**
Blood loss (ml)	275±109.4	370±155.1	**0.03**
Fluoroscopy exposure (msv)	0.22±0.15	0.34±0.06	**0.002**

Table 6 demonstrates significant differences in surgical parameters, with the 3D print group having significantly shorter surgery time (110.2±19.3 minutes versus 142.5±34.04 minutes; p=0.001) and significantly less blood loss (275±109.4 ml versus 370±155.1 ml; p=0.03). The 3D print group had a significantly shorter fluoroscopy exposure compared to the controls (0.22±0.15 vs 0.34±0.06;p=0.002).

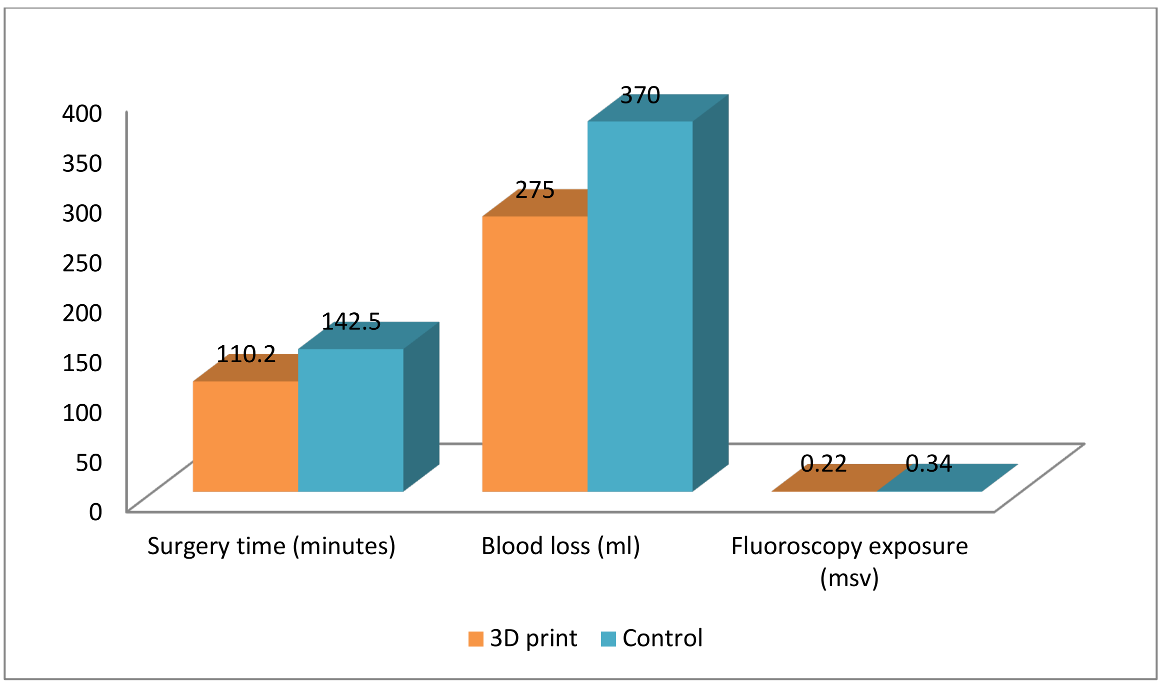

Figure 24: Comparison of different parameters among groups

Table 7: Comparison of implant trial among groups

Implant trial	3D print	Control	p-value
0	14 (70%)	**2 (10%)**	**<0.001**
1	5 (25%)	15 (75%)	
2	1 (5%)	3 (15%)	
Total	**20 (100%)**	**20 (100%)**	

Table 7 reveals that the 3D print group required fewer implant trials, with 70% needing zero trial compared to 10% needing zero and 75% needing 1 trial in control group and this difference reached statistical significance (p<0.001).

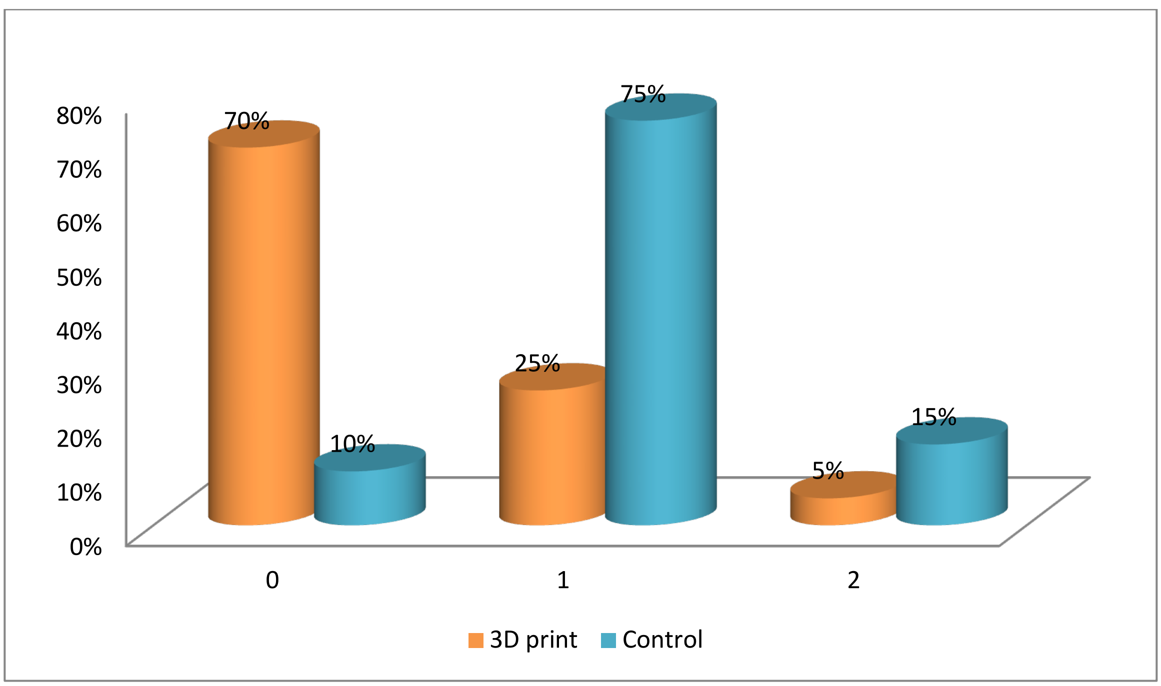

Figure 25: Comparison of implant trial among groups

DISCUSSION

Proximal tibial fractures, particularly Schatzker type V and VI, present significant challenges in orthopaedic trauma management due to their complex intra-articular nature, accompanying soft tissue injuries, and the critical importance of restoring articular congruity to minimize post-traumatic arthritis. These high-energy injuries typically occur in bimodal age distributions: younger patients following high-velocity trauma and elderly patients with osteoporotic bone following relatively low-energy mechanisms. Despite advancements in surgical techniques and implant technology, the management of these complex fractures remains challenging, with reported complication rates ranging from 10% to 40%, including malunion, non-union, infection, and post-traumatic arthritis. The introduction of three-dimensional (3D) printing technology has revolutionized preoperative planning for complex fractures by allowing surgeons to better understand fracture morphology, simulate reduction manoeuvres, and pre-contour implants before entering the operating room. This study compares the outcomes of proximal tibial Schatzker type V and VI fractures treated with or without the aid of 3D-printed models for preoperative planning and assesses whether this technology confers significant advantages in terms of surgical efficiency, accuracy, and patient outcomes.

Demographic Analysis

Our study included a total of 40 patients with Schatzker type V and VI proximal tibial fractures, equally divided between the 3D print group and the conventional (control) group. Demographic analysis revealed some differences between the two groups, particularly in age distribution. The 3D print group had a higher proportion of younger patients, with 60% in the 20-40 years age range compared to 40% in the control group. The control group had more middle-aged patients (50% in the 41-60 years range versus 35% in the 3D print group). This age distribution aligns with the findings of Malik Set al. who reported a similar bimodal age distribution in tibial plateau fractures, with peaks in the third and sixth decades of life.[105]

Gender distribution in our study showed a strong male predominance in both groups (95% in the 3D print group and 80% in the control group). This male preponderance is consistent with the literature, as demonstrated by Pun et al., who reported 73% male patients in their series of complex tibial plateau fractures.[106] The higher male percentage in our study compared to the literature might reflect regional variations in activities, occupations, and transportation methods, as suggested by Schatzker et al. in their original classification study.[107]

Regarding fracture classification, our study had an identical distribution of Schatzker types between the two groups, with 45% type V and 55% type VI fractures in each group. This balanced distribution eliminates potential bias that could arise from having different fracture patterns between groups. Duan S et al., in their comparative study of 3D-printed models for tibial plateau fractures, similarly ensured an equal distribution of fracture types to maintain comparability between treatment groups.[108]

Mode of Injury and Side Affected

The mechanism of injury in our cohort was predominantly road traffic accidents (70% in both groups), followed by falls from height (30% in both groups). The high proportion of high-energy trauma mechanisms underscores the severity and complexity of Schatzker type V and VI fractures. Regarding the side affected, the 3D print group had more right-sided fractures (60% versus 45% in the control group), while the control group had more left-sided fractures (55% versus 40% in the 3D print group). Although this difference was noted, it does not appear to have statistical significance or clinical relevance to the outcomes measured in our study. Sirvent Galvez E et al. similarly found no correlation between the side affected and surgical outcomes in their analysis of factors influencing the results of tibial plateau fracture treatment.[109]

Surgical Parameters

Our study demonstrated significant advantages in surgical parameters for the 3D print group compared to the control group. The mean surgical time was significantly shorter in the 3D print group (110.2±19.3 minutes versus 142.5±34.04 minutes in the control group; p=0.001). This 32.3-minute (22.7%) reduction in surgical time represents a substantial improvement in operational efficiency. Similar findings were reported by Zheng et al., who found a 21% reduction in surgical time when using 3D-printed models for preoperative planning in complex tibial plateau fractures.[110]

The reduced surgical time can be attributed to several factors facilitated by 3D printing technology. First, the ability to study the fracture pattern in detail preoperatively allows surgeons to develop a more precise surgical plan. Second, the opportunity to simulate reduction manoeuvres on the 3D model helps anticipate and overcome challenges that might be encountered during the actual surgery. Third, pre-contouring of implants using the 3D model ensures a better fit without the need for multiple adjustments intraoperatively. These advantages were also highlighted by Lou et al., who found that 3D printing technology significantly improved the precision of preoperative planning and reduced the learning curve for treating complex fractures.[111]

Intraoperative blood loss was also significantly lower in the 3D print group (275±109.4 ml versus 370±155.1 ml in the control group; $p=0.03$). This 95 ml (25.7%) reduction in blood loss is clinically significant and aligns with the findings of Bai et al., who reported a 24% reduction in blood loss when using 3D-printed models for acetabular fracture surgery.[113]Reduced blood loss can be attributed to shorter surgical time, more precise soft tissue dissection, and fewer surgical manoeuvres needed for fracture reduction, all facilitated by better preoperative planning using 3D models.

Radiation Exposure

Fluoroscopy exposure was significantly reduced in the 3D print group compared to the control group (0.22±0.15 mSv versus 0.34±0.06 mSv; $p=0.002$). This 35% reduction in radiation exposure represents an important advantage from both patient safety and occupational health perspectives. Radiation exposure during orthopaedic procedures has been a growing concern, with studies showing cumulative effects on both patients and surgical teams. Ivanov S et al. reported similar findings, with a 31% reduction in radiation exposure when using 3D-printed models for pelvic and acetabular fractures.[114] The reduced need for intraoperative fluoroscopy can be attributed to better visualization and understanding of the fracture pattern preoperatively, allowing for more confident and precise surgical manoeuvres with less reliance on radiographic confirmation.

Hu et al. conducted a randomized controlled trial comparing conventional versus 3D printing-assisted surgery for tibial plateau fractures and found that 3D printing significantly reduced fluoroscopy times from an average of 55.5 seconds to 38.7 seconds, representing a 30% reduction similar to our findings.[115] They attributed this reduction to the improved spatial understanding of the fracture configuration and pre-planned reduction strategy, which minimized the need for intraoperative imaging verification.

Implant Trials

One of the most striking differences between the two groups in our study was the number of implant trials required during surgery. In the 3D print group, 70% of cases required zero implant trials, meaning the first selected implant was appropriate without any need for adjustment or replacement. In contrast, only 10% of cases in the control group required zero trials, with 75% requiring one trial and 15% requiring two trials ($p<0.001$). This significant difference can be directly attributed to the ability to pre-contour implants using the 3D-printed model before surgery.

Liu et al. reported similar advantages in their study of 3D-printed models for preoperative planning in calcaneal fractures, with a 65% reduction in implant trials when using patient-specific 3D models.[115] The ability to select and contour implants preoperatively not only saves time during surgery but also reduces the stress on the surgical team and minimizes soft tissue handling, potentially reducing postoperative complications.

Giannetti et al. conducted a systematic review of 3D printing applications in orthopaedic trauma and found that across multiple studies, the use of 3D models consistently reduced implant trial attempts by 50-70% compared to conventional techniques.[116] They concluded that this advantage translates to cost savings through reduced operating room time and fewer discarded implants, though these economic benefits must be balanced against the cost of producing the 3D models.

Comparison with Literature on Preoperative Planning Methods

The evolution of preoperative planning for complex fractures has progressed from simple radiographs to computed tomography (CT) scans, and now to 3D-printed models. Each advancement has improved the surgeon's understanding of fracture patterns and facilitated more precise surgical planning. Traditional methods using radiographs and CT scans provide valuable information but lack the tactile feedback and true three-dimensional appreciation that physical 3D models offer.

Xie et al. conducted a comparative study between conventional preoperative planning using CT scans versus 3D-printed models for complex tibial plateau fractures.[117] They found that surgeons using 3D models were able to more accurately predict the surgical approach, implant requirements, and potential challenges compared to those using only CT images. This improved planning translated to better surgical efficiency and reduced complications, similar to our findings.

The impact of 3D printing technology extends beyond the intraoperative advantages observed in our study. This educational benefit suggests that 3D printing technology may have a role in accelerating the learning curve for complex fracture management and improving surgical skills among trainees.

Precision and Accuracy of Reduction

Although our study did not directly measure the accuracy of fracture reduction, the literature suggests that 3D printing technology contributes to improved reduction quality and alignment. Huang et al. used digital evaluation methods to assess the precision of reduction in complex intra-articular fractures and found that cases planned with 3D-printed models achieved more anatomic reductions than conventional methods.[118] They attributed this improvement to better visualization of fracture lines, particularly in areas difficult to appreciate on standard imaging, such as posterior column involvement in tibial plateau fractures.

The improved accuracy of reduction has important implications for long-term outcomes, as articular congruity is a critical factor in preventing post-traumatic arthritis. This suggests that the precision advantage conferred by 3D printing technology may translate to improved long-term clinical outcomes.

Cost-Effectiveness Considerations

While our study focused on clinical and surgical parameters, the cost-effectiveness of 3D printing technology in fracture management is an important consideration for healthcare systems. The direct costs of producing 3D-printed models must be weighed against the potential savings from reduced operating time, decreased blood loss necessitating fewer transfusions, reduced radiation exposure, and fewer implant trials.

They estimated that for complex intra-articular fractures such as Schatzker V and VI tibial plateau fractures, the break-even point was reached with a reduction of surgical time by approximately 25 minutes, which is less than the 32.3-minute reduction observed in our study.

Clinical Implications and Future Directions

The findings of our study have several important clinical implications. First, they suggest that incorporating 3D-printed models into the preoperative planning for complex tibial plateau fractures leads to more efficient surgery with reduced operating time, blood loss, radiation exposure, and fewer implant trials. These advantages directly benefit both patients and surgical teams.

Second, our results highlight the potential role of 3D printing technology in standardizing the approach to complex fractures. By providing a tangible model of the patient's specific fracture pattern, 3D printing helps bridge experience gaps between surgeons and may contribute to more consistent outcomes across different healthcare providers.

Looking to the future, several avenues for advancement exist in this field. Patient-specific instrumentation (PSI) derived from 3D models represents the next evolution in precision orthopaedics. Wang et al. described the use of 3D-printed cutting guides for tibial plateau fractures that further improved the precision of osteotomy and reduction.^125^ These custom instruments, designed based on the patient's specific anatomy and fracture pattern, have the potential to further enhance surgical precision and efficiency.

Another promising direction is the integration of 3D printing with augmented reality (AR) and virtual reality (VR) technologies.

CONCLUSION

The present study substantiates the significant advantages of using 3D printing models in the surgical management of complex proximal tibial intra-articular fractures, specifically Schatzker types V and VI. Our findings demonstrate that 3D printing technology offers measurable benefits that directly impact the quality and efficiency of surgical care. The observed reduction in surgical time (22.7% less in the 3D print group) represents not only greater operational efficiency but also potentially reduced infection risk and anaesthetic complications associated with prolonged surgeries. Similarly, the significant decrease in intraoperative blood loss (25.7% reduction) suggests less surgical trauma and potentially fewer transfusion-related complications.

The marked reduction in fluoroscopy exposure (35% less radiation) observed in the 3D print group has important implications for both patient safety and occupational health of the surgical team, particularly in high-volume trauma centres where cumulative radiation exposure is a concern. Perhaps most notably, the dramatic decrease in implant trials required, with 70% of 3D print cases needing zero trials compared to only 10% in the control group, demonstrates how pre-contouring implants on anatomically accurate models translates to more efficient and precise hardware selection and placement.

These advantages collectively suggest that 3D printing technology provides surgeons with enhanced spatial understanding of complex fracture patterns, allowing for more thorough preoperative planning and surgical simulation. The ability to physically manipulate a model of the patient's specific fracture pattern appears to bridge the gap between two-dimensional or even digital three-dimensional imaging and the actual intraoperative findings, leading to more confident and efficient surgical execution.

While the initial cost and time investment required for 3D printing must be considered, our findings suggest that these factors may be offset by the gains in surgical efficiency, reduced resource utilization, and potentially improved outcomes. The technology appears particularly valuable for complex intra-articular fractures like Schatzker types V and VI, where precise restoration of articular congruity is critical for optimizing functional outcomes and minimizing post-traumatic arthritis.

In conclusion, this study provides compelling evidence that 3D printing technology represents a valuable adjunct in the management of complex proximal tibial fractures. As this technology becomes more accessible and streamlined, its integration into routine preoperative planning for complex fractures may become the standard of care, potentially improving both the process and outcomes of surgical management for these challenging injuries.

LIMITATIONS

Despite the positive findings, our study has several limitations that should be acknowledged. The relatively small sample size of 40 patients (20 in each group) limits the statistical power of our analyses. A larger multicenter study would provide more robust evidence regarding the advantages of 3D printing technology in fracture management.

Additionally, we did not assess long-term functional outcomes or rates of post-traumatic arthritis, which are critical measures of successful tibial plateau fracture treatment. Future studies with longer follow-up periods are needed to determine whether the short-term surgical advantages translate to improved long-term patient outcomes.

The 3D printing technology itself also has limitations. The time required to produce accurate models (typically 24-48 hours) may delay surgery in emergency situations. The quality of the 3D model is heavily dependent on the quality of the CT scan from which it is derived, and artifacts or poor scan quality can lead to inaccurate models. Furthermore, soft tissue structures are not well represented in current 3D printing technology, limiting the comprehensive understanding of the injury.

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ANNEXURE I

INFORMED CONSENT FORM FOR PARTICIPATION IN DISSERTATION / RESEARCH

I, the undersigned, _______________, S/O D/O W/O ________________, aged ____years, ordinarily resident of ____________, do hereby state/declare that Dr RAHUL SHENOY A of Shri. B. M. Patil Medical College Hospital & Research Centre has examined me thoroughly on ______________ at ______________ (place), and it has been explained to me in my own language that I am suffering from ________________ disease (condition), and this disease/condition mimics the following diseases. Further, Dr RAHUL SHENOY A informed me that he is conducting a dissertation/research titled " STUDY OF PROXIMAL TIBIA INTRA ARTICULAR FRACTURES SCHATZKER TYPE 5 AND 6 TREATED WITH OR WITHOUT 3D PRINTING MODEL - A COMPARATIVE STUDY " under the guidance of Dr. SANTOSH S NANDI requesting my participation in the study. Apart from routine treatment procedures, the pre-operative, operative, postoperative and follow-up observations will be utilized for the study as reference data.

The doctor has also informed me that during this procedure, adverse results might occur. Most of them are treatable but not anticipated; hence, there is a chance of aggravating my condition. In rare circumstances, it may prove fatal despite the expected diagnosis and best treatment made available. Further doctor has informed me that my participation in this study will help in the evaluation of the results of the study, which is a useful reference to the treatment of other similar cases in the near future and also, I may be benefited from getting relieved from suffering or a cure of the disease I am suffering.

The doctor has also informed me that information given by me, observations made/ photographs/ video graphs taken upon me by the investigator will be kept secret and not assessed by anyone other than my legal hirer or me except for academic purposes.

The doctor did inform me that though my participation is purely voluntary, based on the information given by me, I can ask for any clarification during the course of treatment/study related to diagnosis, the procedure of treatment, the result of treatment, or prognosis. I've been informed that I can withdraw from my participation in this study at any time if I want, or the investigator can terminate me from the study at any time from the study but not the procedure of treatment and follow-up unless I request to discharged.

After understanding the nature of the dissertation or research, the diagnosis made, mode of treatment, I the undersigned Shri/Smt ________________________________, under my full conscious state of mind, agree to participate in the said research/dissertation.

Signature of the patient:

Signature of doctor:

Witness: 1.

2.

Date:

Place:

ANNEXURE – II

SCHEME OF CASE TAKING:

CASE NO. :

FOLLOW-UP NO. :

NAME :

AGE/SEX :

IP NO :

DATE OF ADMISSION :

DATE OF SURGERY :

DATE OF DISCHARGE :

OCCUPATION :

RESIDENCE :

Presenting complaints with duration :

History of presenting complaints :

Family History :

Personal History :

Past History :

Vitals

PR: R.R.:

B.P.: TEMP:

Systemic Examination:

Respiratory system -

Cardiovascular system -

Per abdomen -

Central nervous system -

<u>Local examination:</u>

Right/ Left Leg

Gait:

<u>Inspection</u>:

a) Attitude

b) Abnormal swelling

c) Shortening

d) Skin condition

e) Compound injury, if any

<u>Palpation:</u>

a) Swelling

b) Local tenderness

c) Bony irregularity

d) Abnormal movement

e) Crepitus/ grating of fragments

f) Absence of transmitted movements

g) Wound

<u>Movements</u>:	Active	Passive
Flexion		
Extension		

<u>Intra Operative details:</u>

Azadi Ka Amrit Mahotsav

BLDE
(DEEMED TO BE UNIVERSITY)
Declared as Deemed to be University u/s 3 of UGC Act, 1956
Accredited with 'A' Grade by NAAC (Cycle-2)
The Constituent College
SHRI B. M. PATIL MEDICAL COLLEGE, HOSPITAL & RESEARCH CENTRE, VIJAYAPURA

BLDE (DU)/IEC/ 975/2022-23 10/4/2023

INSTITUTIONAL ETHICAL CLEARANCE CERTIFICATE

The Ethical Committee of this University met on **Saturday, 18th March, 2023 at 11.30 a.m. in the CAL Laboratory, Dept. of Pharmacology,** scrutinizes the Synopsis/ Research Projects of Post Graduate Student / Under Graduate Student /Faculty members of this University /Ph.D. Student College from ethical clearance point of view. After scrutiny, the following original/ corrected and revised version synopsis of the thesis/ research projects has been accorded ethical clearance.

TITLE: "STUDY OF PROXIMAL TIBIA INTRA ARTICULAR FRACTURES SCHATZKER TYPE 5 AND 6 TREATED WITH OR WITHOUT 3D PRINTING MODEL" – A COMPARATIVE STUDY

NAME OF THE STUDENT/PRINCIPAL INVESTIGATOR: DR.RAHUL SHENOY A.

NAME OF THE GUIDE: DR. S.S. NANDI , PROFESSOR AND HOD,
DEPT. OF ORTHOPAEDICS

Dr. Santoshkumar Jeevangi
Chairperson
IEC, BLDE (DU),
VIJAYAPURA
Chairman,
Institutional Ethical Committee,
BLDE (Deemed to be University)
Vijayapura

Dr.Akram A. Naikwadi
Member Secretary
IEC, BLDE (DU),
VIJAYAPURA
MEMBER SECRETARY
Institutional Ethics Committee
BLDE (Deemed to be University)
Vijayapura-586103. Karnataka

Following documents were placed before Ethical Committee for Scrutinization.

- Copy of Synopsis/Research Projects
- Copy of inform consent form
- Any other relevant document

MASTERCHART

sl.no	Name	e (in yea	gender	Patient id	group	schatzker type	side affected	mode of injury	surgrey time (MINS)	Blood loss (ML)	Fluroscopy exposure (m	Implant Trial
1	BASAVARAJ	45	M	141719	3D Print	Type 5	Right	RTA	90	150	0.1836	1
2	MAHAVEER	36	M	245916	3D Print	Type 5	Left	Fall from height	115	200	0.1188	1
3	SHANMUKH	41	M	92968	3D Print	Type 5	Right	Fall from height	125	350	0.837	1
4	VIJAYKUMAR	50	M	286369	3D Print	Type 5	Right	RTA	100	250	0.2133	2
5	VISHWANATH	24	M	88832	3D Print	Type 5	Right	RTA	105	150	0.1728	1
6	CHANDBASHA	32	M	48490	3D Print	Type 6	Right	RTA	90	450	0.2268	1
7	SUDEEP	21	M	227754	3D Print	Type 6	Right	RTA	115	350	0.2727	1
8	RAMACHANDRA	36	M	116164	3D Print	Type 6	Right	Fall from height	125	250	0.1485	2
9	TOPU	45	M	145281	3D Print	Type 6	Left	RTA	130	300	0.2484	1
10	HANAMANTH	24	M	201299	3D Print	Type 5	Left	RTA	110	350	0.1998	1
11	VISHWANATH	35	M	30100	3D Print	Type 6	Right	RTA	100	250	0.1512	2
12	SHETAPPA	65	M	51292	3D Print	Type 6	Left	RTA	85	200	0.1728	1
13	SHIVAPPA	56	M	889	3D Print	Type 6	Right	Fall from height	120	450	0.2187	1
14	SAKLESH	23	M	1E+06	3D Print	Type 6	Left	Fall from height	115	200	0.1296	1
15	SHANTABAI	50	F	81453	3D Print	Type 6	Left	Fall from height	90	500	0.2754	1
16	GOUDAPPA	45	M	180885	3D Print	Type 5	Right	RTA	135	300	0.2376	1
17	DEVENDRA	28	M	40012	3D Print	Type 6	Left	RTA	110	100	0.1242	1
18	DAYANAND	28	M	90012	3D Print	Type 6	Right	RTA	70	150	0.1539	2
19	RAMANNA	30	M	5672	3D Print	Type 5	Right	RTA	125	300	0.1971	2
20	KIRANKUMAR	22	M	9569	3D Print	Type 5	Left	RTA	150	250	0.1537	1
21	SANTOSH	22	M	26841	Control	Type 5	Right	RTA	135	300	0.1863	1
22	AMBANNA	24	M	294791	Control	Type 6	Right	RTA	140	250	0.1701	2
23	REVANNASIDDA	54	M	229535	Control	Type 6	Right	Fall from height	125	250	0.1971	1
24	KUNAL	46	M	201592	Control	Type 6	Right	RTA	130	450	0.2997	2
25	BASAPPA	52	M	156713	Control	Type 6	Left	RTA	100	200	0.2376	2
26	SIDDAMMA	45	F	39512	Control	Type 6	Left	RTA	150	350	0.2403	2
27	SHRADHA	45	F	24651	Control	Type 5	Right	Fall from height	95	500	0.3618	1
28	VINOD	30	M	326738	Control	Type 6	Left	Fall from height	150	350	0.1755	2
29	ROOPSINGH	70	M	247492	Control	Type 6	Right	RTA	100	550	0.2619	1
30	MARAPPA	56	M	71796	Control	Type 5	Left	RTA	200	450	0.2295	2
31	BHIMASHANKAR	24	M	58622	Control	Type 5	Left	RTA	180	350	0.2781	2
32	HONAGUDEPPA	43	M	169985	Control	Type 6	Left	RTA	165	250	0.2106	2
33	UMESH	30	M	148095	Control	Type 6	Right	Fall from height	145	300	0.2241	1
34	SATYAPPA	58	M	20664	Control	Type 5	Left	RTA	120	200	0.1728	1
35	AKASH	58	M	146781	Control	Type 5	Left	RTA	90	350	0.2538	1
36	SULOCHANA	78	F	345765	Control	Type 5	Left	Fall from height	190	450	0.2997	1
37	RAVI	36	M	16007	Control	Type 5	Left	RTA	210	750	0.3996	2
38	ANAND	27	M	9955	Control	Type 6	Left	Fall from height	150	650	0.2835	2
39	TIPPARAY	38	M	2700	Control	Type 5	Right	RTA	130	150	0.2106	1
40	GANGAMMA	58	F	86202	Control	Type 6	Right	RTA	145	300	0.1512	1

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