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EFFECTIVENESS OF TITANIUM PLATES IN POST-FRACTURE RECOVERY OF THE TIBIA

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Abstract

This study examines the effectiveness of using titanium plates in the treatment of tibia fractures, analyzing clinical outcomes and identifying complications associated with this method. Titanium, recognized for its biocompatibility and corrosion resistance properties, offers a durable and safe solution in orthopedic surgery. The study included a systematic review of the medical literature and an analysis of data from patients treated with titanium plates for tibia fractures over the past five years. The results indicate an improved bone healing rate and a reduction in recovery time compared to other treatment methods. However, complications, including infections and foreign body reactions, have been identified that require additional medical attention. The conclusions stress the importance of careful monitoring of post-operative patients and rigorous case selection to minimize risks. Finally, the study suggests that titanium plates are an effective and safe option for the treatment of shin fractures, with the potential to improve clinical outcomes in orthopedic practice.

Keywords*:* titanium: tibia fractures: biocompatibility: clinical outcomes: post-operative complications.

Introduction

Shin fractures are a significant challenge in the medical field due to the crucial role that the tibia plays in supporting the body's weight and mobility. These injuries can have a profound impact on patients' quality of life, generating an imperative need for effective and sustainable treatment solutions [1-3].

In this context, titanium wafers are emerging as a promising option, due to their superior biomechanical and biocompatible properties. Therefore, this review aims to evaluate the effectiveness of titanium plates in the post-fracture recovery process of the tibia, providing a detailed insight into their applicability and clinical results [1-3].

The tibia, being the largest bone in the lower segment, is frequently at risk of fracture, either from direct causes, such as sports impact or road accidents, or indirect, through repetitive stress or osteoporosis. Shin fractures range from simple cracks to complicated fractures that require complex surgeries and lengthy recovery periods. The treatment of these fractures has evolved, from conservative methods, such as casts and immobilizations, to advanced surgical solutions, which include internal fixation with screws, rods, and metal plates [1-4].

Among the materials used, titanium stands out due to its unique characteristics. This metal is extremely resistant to corrosion, and has excellent density and fatigue resistance, while

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being lightweight and completely biocompatible, which reduces the risk of rejection and side effects. Moreover, the flexibility and mechanical strength of titanium allow for a stable fixation, which is essential for proper bone healing. These properties make titanium plates an attractive option for orthopedic surgeons, especially in complex cases or in patients with specific biomechanical requirements [2-4].

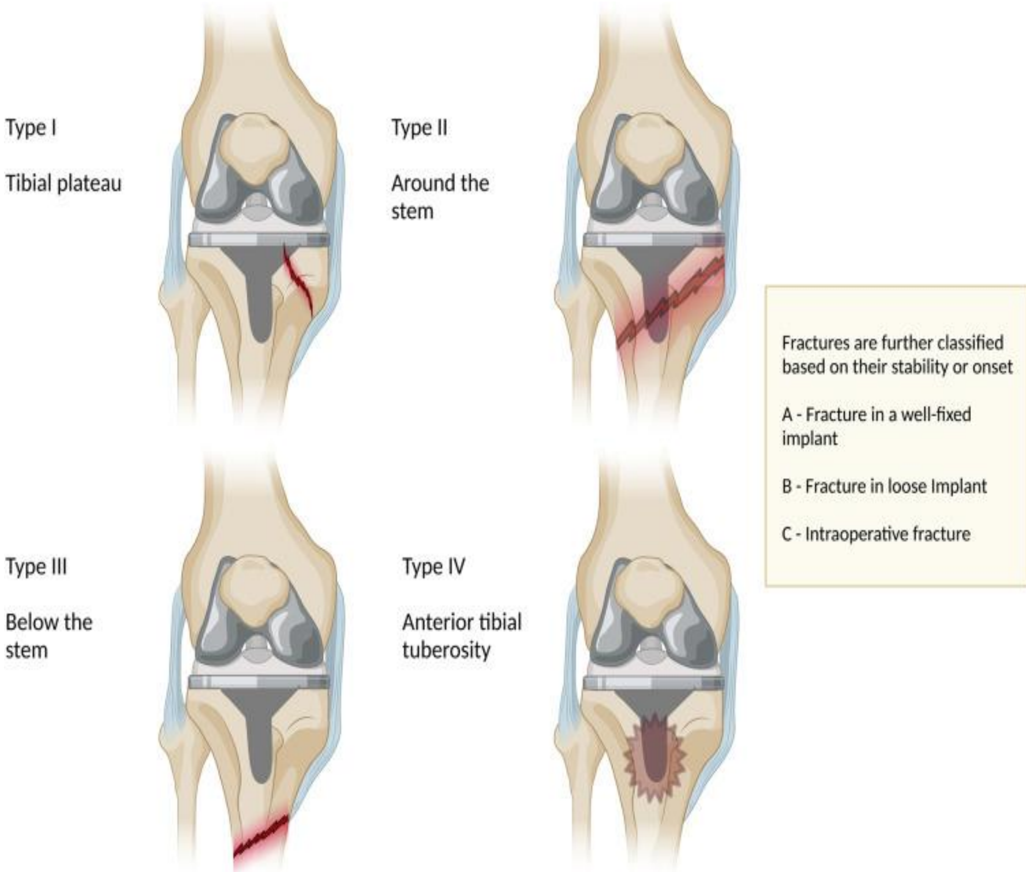

Fig 1. Felix N. classification for tibial fractures. An additional suffix is added based on component stability. A - the implant is well-fixed, B - the implant is slightly loose, and C - intraoperative fractures [4].

In this review, we will explore the literature in detail, to determine the efficacy of titanium plates in different clinical scenarios of tibial fractures. We will look at comparative studies that evaluate titanium wafers against other materials such as stainless steel or cobalt-chromium-based alloys, providing a broad perspective on the advantages and limitations of each option. Through this analysis, our goal is to provide a solid knowledge base for physicians and patients in choosing the most appropriate treatment method, thus contributing to improving clinical outcomes and accelerating the recovery process for patients [4-6].

Anatomy and biomechanics of the tibia

The tibia, commonly called the shin bone, is an essential component of the skeleton of the lower limb, being located between the knee and the ankle. It is the larger of the two calf bones, its partner being the fibula, thinner and located laterally to the tibia. Functionally, the tibia plays a primary role in supporting body weight and in the biomechanics of walking, making it susceptible to various types of fractures [4-6].

The tibia is a long bone, with a robust central diaphysis and two epiphyses, one proximal and one distal, which form the joints at the knee and ankle, respectively. The proximal part articulates with the femur and fibula, forming the knee joint complex, while the distal part forms a major component of the ankle joint. The bone is surrounded by multiple layers of soft tissue, including muscles that contribute to foot and calf movements [5-7].

Superficially, the tibia features a ridge known as the tibial crest, which is the attachment point for the tendons of several important muscles. This ridge is also one of the most exposed parts of the bone, making it vulnerable to direct blows and injuries [5-7].

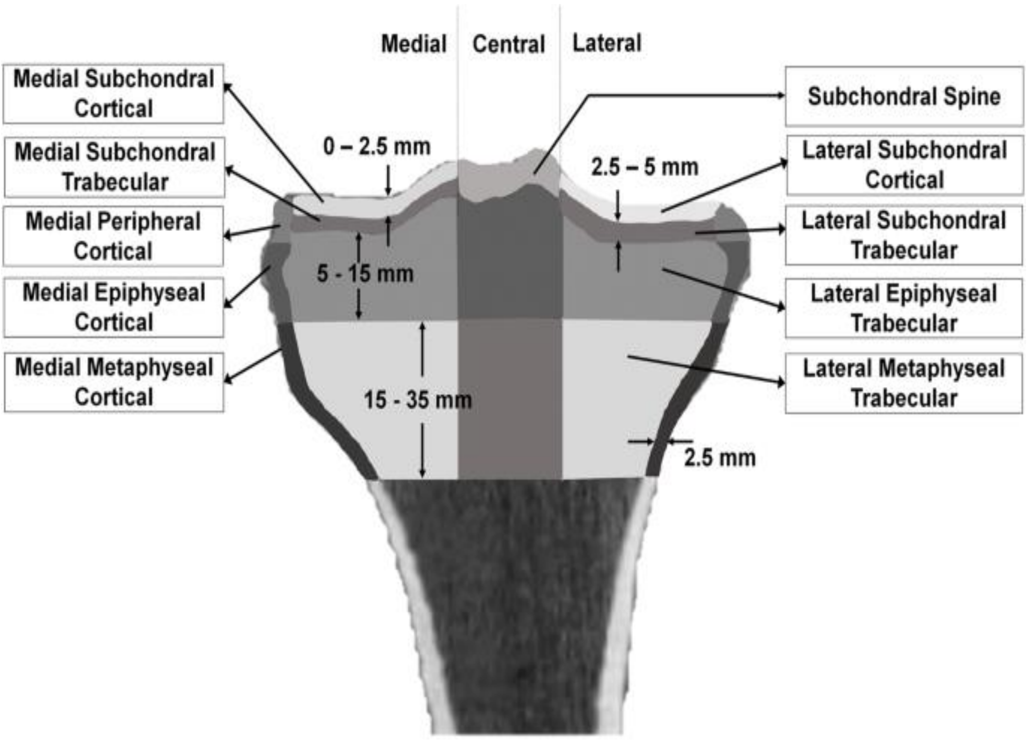

Fig 2. The regions used for analyzing the proximal tibia metrics. The images show the different regions used in the analysis of FE results of the proximal tibia. The lateral regions are positioned on the right side, while the medial regions are on the left side of the image [7].

Biomechanically, the tibia transfers the forces generated by the movements of the body and its weight from the knee to the ankle. The distribution of this weight and forces is essential for effective movement and for minimizing stress on other body structures, such as joints and other bones. During walking, the tibia absorbs and dissipates significant forces, which exposes it to an increased risk of fractures, especially in contexts of direct impact or repetitive stress [7-10].

The stability of the tibia and the ability to withstand mechanical loads depend not only on its structural integrity but also on the quality and functionality of the associated muscle and ligament systems. Any weakness in these structures can alter the distribution of force and increase susceptibility to fractures or other injuries [7-11].

A detailed understanding of the anatomy and biomechanics of the tibia is crucial for proper diagnosis and planning effective fracture treatments. This includes choosing the type of immobilization, surgical techniques, and implant materials, such as titanium plates, that must adequately align and support the geometry and natural function of the tibia [8-12].

Modern technologies, including advanced imaging and biomechanical simulations, play a key role in optimizing treatments for shin fractures, allowing interventions to be customized according to the specifics of the injury and the individual characteristics of each patient. Thus, by applying the knowledge of anatomy and biomechanics, the prognosis of patients with tibia fractures can be significantly improved, reducing recovery time and maximizing post-treatment functionality [9-12].

Titanium plates in the treatment of tibia fractures

Titanium is a material of choice in orthopedic surgery, preferred for its biomechanical properties and superior biocompatibility. As a lightweight and highly resistant metal, titanium provides significant mechanical strength needed in the repair of heavily loaded bone structures such as the tibia. Furthermore, its corrosion resistance and non-magnetic characteristics make it ideal for long-term use and compatible with magnetic resonance imaging (MRI), avoiding interference or the need to remove the implant for diagnosis [12-15].

Tibia fractures can range from simple cracks to complex fractures involving multiple splits or crushing of the bone. In these cases, titanium plates prove to be essential for restoring the structural integrity of the tibia. By using titanium plates and screws, surgeons can fix bone fragments in an optimal position for healing, minimizing movement at the fracture site and facilitating natural bone recovery. [15-17].

Titanium pads are designed to conform to the anatomy of the tibia, allowing for a custom fit to each particular case. The varied configurations of the plates allow the approach of a wide range of fracture types, from longitudinal to transverse or oblique [15-18].

The implantation of a titanium plate begins with a thorough evaluation of the fracture through advanced imaging. In the operating room, the surgeon makes an incision to expose the fractured area and carefully cleans the space of loose bone fragments or damaged tissue. The plate is then shaped and adapted to the surface of the tibia, being fixed with titanium screws that penetrate and stabilize the bone fragments [16-18].

This internal fixation technique allows the patient to start the rehabilitation process earlier, reducing the risk of postoperative complications such as muscle atrophy or joint stiffness. Titanium pads are also designed to evenly distribute mechanical forces while walking, protecting the healing site and promoting faster and more efficient recovery [16-19].

Multiple clinical studies have highlighted the effectiveness of titanium plates in accelerating the healing process and reducing the duration of hospitalization. The biocompatibility of titanium minimizes the risks of inflammatory reaction and implant rejection, making these pads a safe and durable option for patients [17-19].

Therefore, titanium plates represent an advanced solution in the treatment of shin fractures, offering an optimal combination of mechanical strength, biocompatibility, and flexibility in application, which makes them essential in the modern surgical arsenal. They ensure not only effective healing but also excellent functional recovery, restoring patients' mobility and quality of life [17-20].

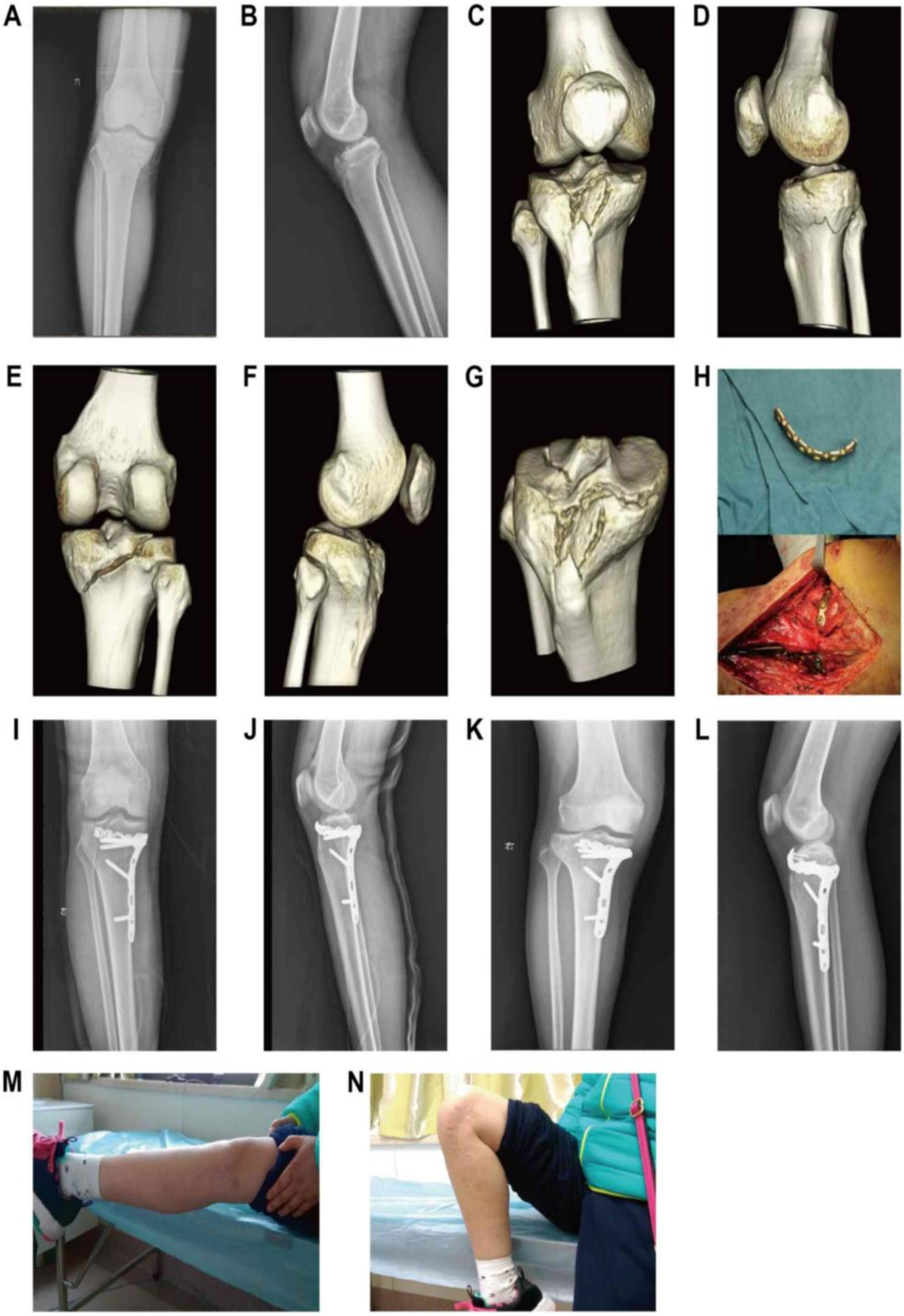

Fig 3 - A case study of a 33-year-old woman with varus hyperextension at the tibial plateau, Schatzker type V fractures resulting from a fall. Pre-operative radiographic images in A) frontal and B) lateral views. Pre-operative three-dimensional CT scan showing fractures across three columns. C) Front view. D) Left side lateral view. E) Rear view. F) Right side lateral view. G) Transverse view. H) Image of a 3.5 mm rebuilt titanium plate, placed horizontally, displaying its location during the surgical procedure. Radiographs immediately after surgery in I) frontal and J) lateral

positions. Radiographs one year post-surgery in K) frontal and L) lateral views, show that the fractures have healed with no loss of reduction. M and N) General functional position of the patient one year post-operation [15].

Clinical outcomes and complications

The use of titanium plates in the treatment of tibia fractures has demonstrated positive clinical outcomes, marking a significant improvement in healing rates and post-treatment functionality. Studies show that patients with titanium plates experience a reduction in the time it takes for bone strengthening, allowing for early mobilization and a faster return to daily activities. Also, due to the superior mechanical stability and optimal integration of titanium implants, patients benefit from an improvement in bone alignment and a decrease in the risk of malunion (healing of bones in an incorrect position) or nonunion (absence of bone healing) [18-20].

Although titanium pads are generally well-tolerated and safe, there are potential complications associated with their use. Complications can range from minor to severe, including any surgical procedure that carries a risk of infection. In the case of titanium implants, infections can be superficial at the incision or deeper around the implant. Treatment may require antibiotics or, in severe cases, removal of the implant. Although rare, some people may develop reactions to the implant metal, manifested by pain, inflammation, and joint dysfunction. In cases of persistent infection, implant slippage, or plate fracture under mechanical stress, new surgery may be required to adjust or replace the implant. Titanium pads can sometimes irritate surrounding soft tissues, such as muscles or tendons, leading to pain or discomfort [18-20].

To minimize the risk of complications, proper patient selection and the use of precise surgical techniques are essential. Careful post-operative monitoring and effective communication with patients about potential signs and symptoms of complications can help identify and manage any issues promptly. In addition, recent developments in implant design and manufacturing technology continue to improve the safety and efficacy of titanium pads [18-21].

Therefore, although titanium plates offer many advantages in the treatment of tibial fractures, it is vital for physicians to be aware of possible complications and to handle each case with particular care to ensure the best clinical outcomes for patients [19-21].

Conclusions

Titanium plates are effective in stabilizing shin fractures, providing robust support, and facilitating rapid healing, allowing patients to begin the rehabilitation process sooner. Titanium is distinguished by its excellent biocompatibility, minimizing the risk of side effects, including implant rejection and local inflammation, compared to other metal materials used in orthopedic surgery.

Due to its corrosion and fatigue resistance properties, titanium provides a durable solution for orthopedic implants, ensuring long-term functionality without requiring repeated surgery to replace or adjust the implant. Although the use of titanium plates may be associated with certain complications, such as infections or soft tissue irritation, these risks remain relatively low and can be effectively managed through appropriate surgical techniques and close monitoring.

Titanium plates are available in various shapes and sizes, allowing surgeons to precisely tailor them to the specifics of the fracture and the anatomy of each patient, which improves bone alignment and optimizes the healing process.

It is crucial to carefully monitor patients after surgery for titanium plate implantation to detect and intervene promptly in case of any complications, thus ensuring the best long-term results.

Further research and development in the design and technology of titanium plates is essential to further improve the effectiveness and safety of these implants, adapting them to the dynamically changing needs of patients and the healthcare environment.

References

1. Kim JK, Kim JO, Koh YD. *Management of Distal Ulnar Fracture Combined with Distal Radius Fracture.* **J Hand Surg Asian Pac Vol.** 2016, 21, 2, 155-60. doi: 10.1142/S2424835516400075.
2. Lee SK, Kim KJ, Choy WS. *Modified retrograde percutaneous intramedullary multiple Kirschner wire fixation for treatment of unstable displaced metacarpal neck and shaft fractures.* **Eur J Orthop Surg Traumatol**. 2013, 23, 5, 535-43. doi: 10.1007/s00590-012-1036-6.
3. Naito K, Sugiyama Y, Obata H, Mogami A, Obayashi O and Kaneko K. *Screw fixation and autogenous bone graft for an irreducible distal ulna fracture associated with distal radius fracture*. **J Hand Surg Asian Pac**. 2017, 22, 2, 236-239. doi: 10.1142/S0218810417720145
4. Assala Abu-Mukh, Giacomo Placella, Francesco Anzano, Salvatore Mosca, Vincenzo Salini, Mattia Alessio-Mazzola. *Tibia periprosthetic fracture management – A 30-year systematic review*. **Health Sciences Review**. 2023, 100133, https://doi.org/10.1016/j.hsr.2023.100133
5. Stock K, Benedikt S, Kastenberger T, Kaiser P, Arora R, Zelger P, Pallua JD, Schmidle G. *Outcomes of distal ulna locking plate in management of unstable distal ulna fractures: a prospective case series*. **Arch Orthop Trauma Surg**. 2023, 143, 6, 3137-3144. doi: 10.1007/s00402-022-04549-4.
6. Firoozabadi R, Schneidkraut J, Beingessner D, Dunbar R and Barei D. *Hyperextension varus bicondylar tibial plateau fracture pattern: Diagnosis and treatment strategie*s. **J Orthop Trauma**. 2016, 30, 5, e152-7. doi: 10.1097/BOT.0000000000000510.
7. Arjmand, H., Nazemi, M., Kontulainen, S.A. *et al*. *Mechanical Metrics of the Proximal Tibia are Precise and Differentiate Osteoarthritic and Normal Knees: A Finite Element Study*. **Sci Rep**. 2018, 8, 11478 . https://doi.org/10.1038/s41598-018-29880-y
8. Cohen AP, King D, and Gibbon AJ. *Impingement fracture of the anteromedial tibial margin: A radiographic sign of combined posterolateral complex and posterior cruciate ligament disruption*. **Skeletal Radiol**. 2001, 30, 2, 114-6. doi: 10.1007/s002560000309
9. Bennett DL, George MJ, El-Khoury GY, Stanley MD and Sundaram M. *Anterior rim tibial plateau fractures and posterolateral corner knee injury.* **Emerg Radiol.** 2003, 10, 2, 76-83. doi: 10.1007/s10140-003-0298-z.
10. Arora R, Lutz M, Hennerbichler A, Krappinger D, Espen D, Gabl M. *Complications following internal fixation of unstable distal radius fracture with a palmar locking-plate*. **J Orthop Trauma**. 2007, 21, 5, 316-22. doi: 10.1097/BOT.0b013e318059b993.

11. Giordano J, Schatzker M and Kfuri M. *The 'Hoop' plate for posterior bicondylar shear tibial plateau fractures: Description of a new surgical technique*. **J Knee Surg**. 2017, 30, 6, 509-513. doi: 10.1055/s-0036-1593366.
12. Chiba T, Sugita T, Onuma M, Kawamata T and Umehara J. *Injuries to the posterolateral aspect of the knee accompanied by compression fracture of the anterior part of the medial tibial plateau*. **Arthroscopy**. 2001, 17, 6, 642-7. doi: 10.1053/jars.2001.22362.
13. Yoo JH, Kim EH, Yim SJ and Lee BI. *A case of compression fracture of medial tibial plateau and medial femoral condyle combined with posterior cruciate ligament and posterolateral corner injury*. **Knee**. 2009, 16, 1, 83-6. doi: 10.1016/j.knee.2008.08.002.
14. Wu CM, Chen YA, Liao HT, Chen CH, Pan CH and Chen CT. *Surgical treatment of isolated zygomatic fracture: Outcome comparison between titanium plate and bioabsorbable plate.* **Asian J Surg**. 2018, 41, 4, 370-376. doi: 10.1016/j.asjsur.2017.03.003
15. Huang Y, Jiao J, Cheng W, Xiao F, Zuo W and Wang J. *Joint line plate fixation for tibial plateau fractures caused by hyperextension varus.* **Exp Ther Med**. 2021, 21, 6. 621. doi: 10.3892/etm.2021.10053
16. Darrow BG, Weigel JP, Greenacre CB, Xie X, Liaw PK and Biskup JJ. *Ex vivo biomechanical comparison of titanium locking plate, stainless steel nonlocking plate, and Tie-in external fixator applied by a dorsal approach on ostectomized humeri of pigeons (Columba livia).* **J Avian Med Surg.** 2019, 33, 1, 29-37. doi: 10.1647/2017-305.
17. Schliemann B, Seifert R, Theisen C, Gehweiler D, Wähnert D, Schulze M, Raschke MJ and Weimann A. *PEEK versus titanium locking plates for proximal humerus fracture fixation: A comparative biomechanical study in two- and three-part fractures*. ***Arch* Orthop Trauma Surg**. 2017, 137, 1, 63-71. doi: 10.1007/s00402-016-2620-8.
18. Hong F, Wang N and Chen GJ. *Posterior medial approach inverted L-shaped incision combined with reconstruction plate for posterior condylar fracture of tibial plateau*. **Zhongguo Gu Shang**. 2016, 29, 11, 1027-1032. doi: 10.3969/j.issn.1003-0034.2016.11.011.
19. Luo CF, Sun H, Zhang B and Zeng BF. *Three-column fixation for complex tibial plateau fractures*. **J Orthop Trauma**. 2010, 24,11, 683-92. doi: 10.1097/BOT.0b013e3181d436f3
20. Insall JN, Ranawat CS, Aglietti P and Shine J. *A comparison of four models of total knee-replacement prostheses*. **J Bone Joint Surg Am**. 1976, 58, 6, 754-65.
21. Dreyfuss D, Allon R, Izacson N, and Hutt D. *A Comparison of locking plates and intramedullary pinning for fixation of metacarpal shaft fractures*. **Hand (NY).** 2019, 14, 1, 27-33. doi: 10.1177/1558944718798854.

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