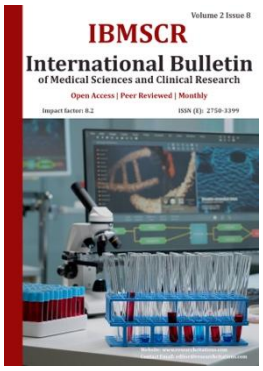

DISTAL FEMUR FRACTURES AND THEIR TREATMENT

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Abstract: The goal of this study was to provide an update on the management of these fractures. The basic points of treatment are summarized. The technical details and the indications of the different surgical treatments are then described. Finally, recent radiological, clinical and biomechanical results published in the literature are reported to compare the techniques.

Key words: distal femur, fracture, supracondylar and intercondylar fracture, internal fixation, biomechanics

Recent studies report the overall incidence of distal femur fractures as 8.7/100,000/year. This incidence is expected to rise with high energy motor vehicle collisions and elderly osteoporotic fractures in native and prosthetic knees keep increasing. These fractures are more common in males in the younger age spectrum while females predominate for elderly osteoporotic fractures. Surgical treatment is recommended for these fractures to maintain articular congruity, enable early joint motion and assisted ambulation. Over the last two decades, development of minimally invasive and quadriceps sparing surgical approaches, availability of angle stable implants have helped achieve predictable healing and early return to function in these patients. Currently, laterally positioned locked plate is the implant of choice across all fracture patterns. Retrograde with capital implantation of intramedullary nails with provision for multiplanar distal locking is preferred for extra-articular and partial articular fractures. Even with these advancements, nonunion after distal femur fracture fixation can be as high as 19%. Further recent research has helped us understand the biomechanical limitations and healing problems with lateral locked plate fixation and intramedullary nails. This has lead to development of more robust constructs such as nail-plate and double plate constructs aiming for improved construct strength and to minimize failures. Early results with these combination constructs have shown promise in high risk situations such as fractures with extensive metaphyseal fragmentation, osteoporosis and periprosthetic fractures. These constructs however, run the risk of being over stiff and can inhibit healing if not kept balanced. The ideal stiffness that is needed for fracture healing is not clearly known and current research in this domain has lead to the development of smart implants which are expected to evolve and may help improve clinical results in future. Distal femur fractures follow a bimodal distribution similar to several other lower extremity fractures. Fractures in younger patients are often a result of high energy motor vehicle collisions causing varying degrees of chondral and bony fragmentation, soft tissue injury and rarely major vascular disruptions. On the contrary, fractures in the elderly are characterized by low velocity injury mechanisms compounded by the presence of osteoporosis and degenerative changes in the knee joint. In addition, a spurt in the incidence of periprosthetic distal femur fractures around a knee prosthesis has become a major concern in view of the distinct challenges in achieving a stable fixation of these injuries

in the limited bone available around the prosthesis. Regardless of the injury pattern, these fractures at different ends of the spectrum often benefit from appropriate early surgical management either in the form of osteosynthesis or rarely endoprosthetic reconstruction in select elderly patients. The goal of surgical management is to restore early joint mobility and ensure durable long term functional recovery with minimal surgical morbidity. A meticulous articular reconstruction with restoration of length, rotation and axial alignment using fixation techniques and implants that allow early physiological loading can achieve satisfactory outcome in most patients. A small subset of elderly patients may also benefit from an early endoprosthetic reconstruction to minimise failures and reoperation rates after internal fixation in non reconstructible fracture patterns in native and prosthetic knees. In spite of the rapid evolution of improved surgical techniques and implants over the last two decades to address unmet needs and challenges in the treatment of these injuries, problems still remain highlighting the limitations of the current fixation techniques. The purpose of this research is to present the current understanding and practices in fracture classification, preoperative evaluation, surgical approaches, implant choices and their relevant biomechanics, reduction and internal fixation techniques in treating native and periprosthetic distal femur fractures based on our own experience and a comprehensive review of relevant publications over the last 15 years, with more focus on recent studies. The universal applicability of the lateral locked plate across fracture patterns makes it the most popular implant in treating distal femur fractures. However, recent papers have reported nonunion and delayed union in up to 20% of patients. These reports have identified several problems with healing at the metaphyseal region and implant failures after lateral locked plating for distal femur fractures. Most failures are delayed in nature occurring after an established nonunion leading to fatigue failure of the implant rather than fracture instability or faulty implant design or problems with manufacturing. This highlights the problems in achieving optimal construct stiffness with highly stiff constructs limiting axial micromotion, resulting in delayed healing and subsequent failure of the construct. Though the ideal construct stiffness in a lateral locked plate fixation is still unknown, based on current evidence, use of a long titanium plate with a sufficiently long working length, a total screw density of 0.4 - 0.5 in the diaphyseal segment including cortical screws at the proximal and distal end of the diaphyseal part of the construct may be the best solution to allow optimal micromotion within the tolerable strain limits to facilitate secondary healing at the metaphysis. In order to limit failures, it is also important to appreciate the limitations of a lateral locked plate to allow physiological loading during healing in fractures in extensive medial comminution, bone loss and also in patients with osteoporosis. Augmented fixation primarily aims to overcome the limitations with the use of single lateral locked plate by adding more points of fixation medially. Though different augmented fixation techniques have been described, nail - plate construct and dual plating are the most popular techniques with several publications in the last 5 years documenting improved healing rates and less complications compared to single lateral locked plate fixation. Other less commonly used techniques include, supplementation with a medial intra-osseous plate, intramedullary rods, medially inserted flexible nails and compression bolts. While lateral locked plating is limited by off-axis loading, intramedullary nails can be too flexible sometimes resulting in failures when used in isolation. Nail- plate construct (NP) provides the biomechanical advantages of both implants with improved axial and torsional stiffness. In a NP construct, the nail restores length/

axial alignment and acts as a medial strut substituting for the deficient or weak medial cortex, while the plate helps to achieve more points of fixation distally and also improves torsional stiffness by adding more proximal points of fixation closer to the fracture. The NP construct can also be linked to the lateral plate both distally and proximally to improve fixation strength. Liporace, et al advocates linking the lateral plate and the intramedullary nail to improve result. They also recommended to use nails long enough to reach the lesser trochanter and the plate ending more proximally to achieve fixation into the femoral neck in line with the concept of stabilising the entire bone and avoiding any proximal stress risers especially in elderly patients. A specifically designed linked NP construct where the nail is linked to a locking attachment washer distally is also available and initial biomechanical and clinical studies have shown promising results. This construct improves stability of fixation compared to nail alone and minimises the surgical morbidity of using a long lateral plate. Similarly double plating (DP) of the distal femur is an alternate technique that can be used to improve fixation strength in complex A or C type fractures. Adding a medial plate improves fixation strength in fractures with medial comminution. It is a promising technique which offers several advantages over single-plate fixation, including improved stability, reduced risk of complications, and an earlier return to function. Adding a medial plate to lateral-locked plating improves fracture stability. Dual-plate fixation enables early weight-bearing and improved patient satisfaction. There is evidence to support the effectiveness of dual plating in attaining union, preserving alignment, and controlling complications, making it a viable approach for treating distal femur fractures. In a retrospective cohort study, dual plating for distal femoral fractures demonstrated a 96% union rate, satisfactory limb alignment, and common complications. Biomechanical studies by Goodnough et al. show that dual plating provides greater stiffness, reduced displacement, and lower failure rates in distal femur fractures. Concerns with adding a medial plate include difficulties in negating the vascular structures, lack of a widespread availability of an anatomical designed plate option and possibility of devascularisation, which may lead to increased infection and nonunion. Cadaveric studies have shown 50 - 50% of the distal femur is safe to perform a mini invasive medial plating without major concerns about the vascular structures and risk of devascularisation. For fractures needing a more proximal fixation, a bent helical plate or a NP construct can be used. While anatomical medial plates are available in some countries, different plating options such as proximal humerus and tibial plates, reconstruction and dynamic compression plates can all be used. Biomechanical studies have shown improved axial and torsional strength with DP or NP constructs compared to use of lateral locked plates or retrograde locking nails alone. Studies have also shown improved mean loads to failure and construct survival rates with both DP and NP constructs. While the double plating technique has shown positive outcomes in several studies, it's crucial to acknowledge its limitations and potential complications. Careful consideration of each patient's unique characteristics and fracture pattern is necessary to determine the most suitable approach. Further research and advancements in fixation technology are needed to address the challenges associated with the double plating technique and enhance patient outcomes in junctional femur fracture treatment. The indications for DP or NP have to be carefully chosen since the widespread outcomes with these techniques is still not entirely known. There are concerns with creating a very rigid construct with DP or NP, especially when they are linked. Currently, fractures with major medial comminution, severe osteoporosis, very distal fracture exits especially on the lateral

side which limits the effectiveness of the lateral plate, periprosthetic fractures and nonunions are some of the relevant indications to use augmented constructs. While the indications for DP and NP are similar, NP has the advantage of being minimally invasive and more biological compared to DP. It may also be more suitable for periprosthetic fractures to allow early weight bearing. DP on the other hand, is preferred for very distal fractures, ones with severe articular comminution and in periprosthetic fractures which cannot be nailed. Periprosthetic distal femur fractures represent a rapidly growing problem that presents distinct surgical challenges needing a different approach in terms of implants and surgical strategy compared to nonprosthetic distal femur fractures. These fractures are complicated by the presence of femoral implants of different designs, poor quality and limited bone available to achieve a secure fixation in the distal segment. Osteoporotic distal femur, compromised fixation points due to presence of metallic pegs and housing for the cam-post designs and patients with a higher mean age who cannot comply with restricted weight bearing protocols post surgery makes it extremely difficult to achieve stable fixation with currently available implants. Fractures proximal to the prosthesis can be stabilised with a nail in open box femoral designs. The need for supplemental fixation in these more proximal fractures may not be needed if they can be stabilised with an intramedullary implant unless there is extensive metaphyseal fragmentation which is rare in these low velocity fractures. If such fractures cannot be nailed because of prosthetic design constraints, then a single lateral plate if patients can comply with restricted weight bearing or else DP can be used. DP or NP is also preferred in patients with severe osteoporosis. For more distal fractures, augmented constructs are the most preferred option because of limited bone available distally for fixation. While a NP is more biological, DP can also be used in cases where nailing is not possible. Even when nailing is possible, the technique can be difficult in periprosthetic fractures. Most often the available box in the femoral component is located more posterior to allow current nail designs to maintain reduction without creating an extension deformity at the fracture. The medio-lateral position of the prosthesis can also have a bearing on the alignment due to altered nail entry. Recently introduced more modern nail designs take this into account have a more pronounced radius of curvature to permit a more posterior entry point without creating malreduction at the fracture. The driving end of the nail is also designed smaller to permit safe passage through most modern knee prosthetic designs. The quality of the surgical technique is the primary factor, and the only guarantee of obtaining good radiological and clinical results in distal femoral fractures. All types of fractures can be treated with locking plates and a classic or mini-invasive surgical approach is possible. Recent biomechanical studies have shown that results are better with locking plates. The surgical technique must be rigorous and the biomechanical qualities of these implants must be understood to prevent the development of major complications.

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