Literature Review

DOI 10.18019/1028-4427-2021-27-1-104-111

Plate fixation in the treatment of adults with distal femoral fractures: history, current state, and prospects of development (review of literature)

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Introduction Distal femoral fractures are a challenging medical and social problem as they may occur at any age. All the available osteosynthesis types can be used to treat such injuries. However, despite the disadvantages, fixation with plates has been the most common and developed. **Aim of study** was to analyze the world literature and summarize the information regarding the use of plate fixation in the treatment of distal femoral fractures, identifying unresolved issues and promising directions. **Materials and methods** The following sources were used for collecting the information: Pubmed and E-library databases, publications of Elsevier, Springer and other publishing companies, materials of the Russian National Library, AO Surgery Reference on line. **Results** A review of global literature demonstrated that a minimally invasive approach which allows for bone fragment blood flow and stable fixation with a locking compression plate (LCP) are the most important factors that can improve the quality of treatment with plating. **Discussion** Plate fixation is still the most preferred method in the treatment of distal femoral fractures. In most severe injuries, accompanied by the medial support loss (33-A3, 33-C2 and 33-C3 fracture types according to AO classification), the use of not only the lateral but also the medial plate to achieve stable osteosynthesis has been discussed. **Conclusion** Further advance of the technology for treating these injures may be associated with designing an "anatomical" medial plate and a method for its minimally invasive implantation. Development of a lateral plate which could provide the stability similar to bilateral osteosynthesis seems even more prospective. Undoubtedly, such a plate would be useful in limb reconstruction surgery as well, for changing the external fixation to internal one after deformity correction and limb lengthening.
Keywords: distal femoral fractures, unstable fractures, plate fixation, medial and lateral plate fixation, bilateral plate fixation

When you start talking about joint wounds, you involuntarily think about knee wounds
N.I. Pirogov

INTRODUCTION

Fractures of the distal femur occur in 12 cases per 100,000 [1, 2, 3]. Among all fractures of the femur, fractures of the distal part account for 6 to 7 % [1, 3, 4]. At a young age, fractures in this anatomical region happen due to high-energy trauma, and more than half of the injuries have been sustained in road traffic accidents [1]. This mechanism of injuries accounts for 17 to 40 % of cases [2, 4]. On the contrary, low energy trauma is the main cause in elderly population. The frequency of fractures of the distal femur in patients aged over 85 increases to 170 cases per 100,000. This is explained by a low bone quality due to osteoporosis [1]. Moreover, fractures in this area in the elderly are of high social significance as they may be peri-implant fractures after total knee arthroplasty (TKA). According to statistic data, up to 300,000 primary TKA operations have been performed annually in the United States and the incidence of periprosthetic fractures in the first five years post-surgery is about 0.3 to 2.5 % [5, 6]. Their rate may reach 38 % after revision arthroplasty [6, 7].

Conservative treatment has been currently used for nondisplaced fractures or at high risk of surgical treatment in comorbid patients [1]. Conservative treatment may result in the contracture of the knee joint, mal-union, nonunion as well as in deep vein thrombosis, decompensation of concomitant pathology [3, 8]. To achieve the best result, it has been recommended to apply the surgical treatment method which would enable to achieve anatomical reduction of the articular surface, restore the axis and length of the femur, ensure stable fixation of bone fragments and, consequently, early mobilization of the patient [3, 8].

Relevant methods of osteosynthesis in the treatment of fractures of the distal femur still remain plating [2, 3, 5, 7–15], intramedullary [3, 9, 15–18] and transosseous osteosynthesis [9, 18–22]. There are also references to a possible use of arthroplasty [3].

Cherevaty N.I., Solomin L.N. Plate fixation in the treatment of adults with distal femoral fractures: history, current state, and prospects of development (literature review). *Genij Ortopedii*, 2021, vol. 27, no 1, pp. 104-111. DOI 10.18019/1028-4427-2021-27-1-104-111

The literature search highlights a number of comparative studies demonstrating the results of treating patients with different types of metal structures [8, 9, 23–28]. Some investigate the differences between bone fixation with plates [8, 9, 28], others compare the results of plating and nailing [9, 25–27, 29]. Although the results of plating and nailing are approximately comparable, it should be noted that intraosseous fixators are not possible to use in all types of fractures [9, 25, 27]. As for the results of treatment of patients with different types of plates, there is a significant discrepancy in the data of their assessment. According to the data of different researchers, the union rate averages between 71 and 95 % [25, 37–39]. In complex fractures (33-A3, 33-C2, 33-C3 according to AO classification), a combination of several internal fixators can be used to ensure the rigidity of the structure and uniform distribution of the load between the bone and the implant: "plate-plate" or "plate-nail" [15, 16], “nail-compression wires” [30].

Transosseous osteosynthesis has been used in the last 15–20 years as a part of damage control orthopaedics [1, 31–33]. Definitive treatment of distal femur fractures with external fixation has been described only in few studies [20, 21, 34, 35].

Despite the improvement of metal fixators and methods of their application, the treatment results of such fractures are far from ideal in the 21st century. Nonunion rate is 6 %, migration of metal structures is 3.3 %, infectious complications occur in 2.7 % of cases, and 11.5 % of patients have repeated operations [8, 9, 14]. In polytrauma patients, good and excellent treatment results of distal femur fractures have been achieved only in 48 to 74.5 % of cases [17, 36]. Even if anatomical reduction and fixation of articular fragments can be achieved in multi-fragmented intra-articular fractures in the elderly with osteoporosis, the result, as a rule, remains poor. In such cases, the treatment algorithm includes primary arthroplasty [3].

The aim of the study was to analyze the literature and summarize the information regarding the use of plating in the treatment of distal femur fractures, to trace the history of the use of various types of plates, to assess the current state of distal femur surgery.

MATERIAL AND METHODS

This review was prepared using the following search and information services: the PubMed database, the resources of the scientific electronic library E-library, published products (Elsevier, Springer, etc.), publications of the Russian National Library, and the Internet portal of the AO Surgery Reference. The materials were published from 1963 to 2019, inclusive.

RESULTS

It should be stated that fixation with plates has been still the most widely used osteosynthesis. And its development is expected to improve the results of treatment in patients with fractures of the distal femur [4, 27, 28]. The first attempts to use plating in the treatment of fractures of the distal femur date back to the mid-60s of the last century. The condylar blade plate was the first on-bone fixator used in osteosynthesis of fractures of the distal femur (Fig. 1), and M.E. Muller became a pioneer in orthopedic surgery of the femur [37]. The introduction of this metal plate into practice was a significant technological breakthrough. However, it was recognized that the methodology of its application results in certain difficulties. Thus, the loss of reduction was possible when the blade was driven into the bone, or even may split the latter. Equally problematic was the formation of a canal for the blade parallel to the guide wire. The error in its formation could lead to varus or valgus of the femur. Finally, the canal for the insertion of the blade may be incorrectly formed in the sagittal plane, which interferes with the positioning of the plate. The inaccuracy in the formation of the canal for blade insertion forces the surgeon to reshape the canal, which leads to a decrease in the bone substance in the femoral condyles and the loss of future fixation stability. The first results of the use of the blade plate were discouraging. The results of conservative treatment were significantly superior to those of surgical treatment (90 % versus 54 %, respectively) [38, 39].

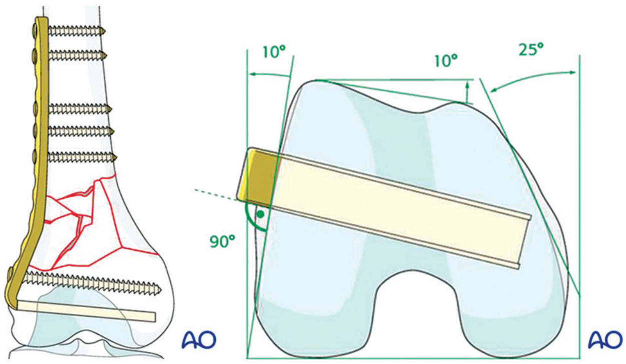

Fig. 1 Condylar blade plate (AO Surgery Reference, 2020)

The first report on the condylar buttress plate (CBP) dates back to 1977 [40]. Its design features the replacement of the blade with screws in the distal part of the plate (Fig. 2). The advantage is that it becomes possible first to correctly position the plate along the bone, and only then to insert the screws into the distal fragment. The entire installation technology is implemented more delicately and prevents loss of reduction. Although union was achieved in over 90 % of cases, good and excellent results (according to the Shatzker and Lambert systems) were achieved in 50 to 84 % of patients [8, 41]. Moreover, the subjective satisfaction of patients with the treatment results was 50 % [41]. The most common complication after osteosynthesis of the distal femur is varus collapse, which occurs in 16.7 to 42.0 % of cases after using a condylar buttress plate [8, 41, 42]. To date, we have not been able to find recommendations of AO Trauma on the use of this metal plate.

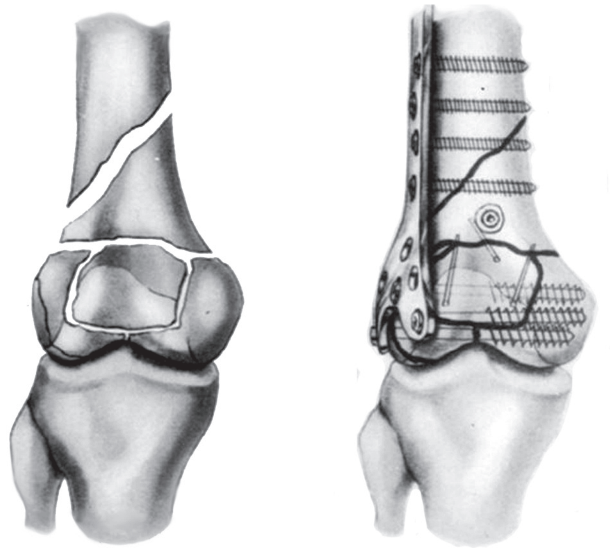

Fig. 2 Condyle buttress plate (H.Tscherne, 1977)

The dynamic condylar screw (DCS) was first reported by Shatzker et al. (1989). The similarity to the blade plate lies only in the fixed angle of 95° between the intraosseous and extraosseous parts of the fixator. But the blade is replaced by a 12.5 mm cannulated screw for cancellous bone, which is inserted along the guide (wire) (Fig. 3). Repeated attempts are possible to guide the wire to achieve the correct position. Another advantage of this metal implant is the ability, due to the thread of the compression screw for spongy bone, to adequately fix osteoporotic bone fragments [43]. Excellent and good results were reported in 71 to 96 % of patients, with the incidence of nonunion and infection being 5.0–5.7 and 2.3 %, respectively [8, 44, 45]. Despite the tangible benefits of DCS, the problem was not completely solved. First, the fixator could only be used for the osteosynthesis of the extra-articular component of the fracture. Second, as with the blade plate, the use of DCS for extremely low fractures would be not possible, because the screw itself should be installed 2 cm above the articular surface. Minimally invasive installation of the plate was difficult [46].

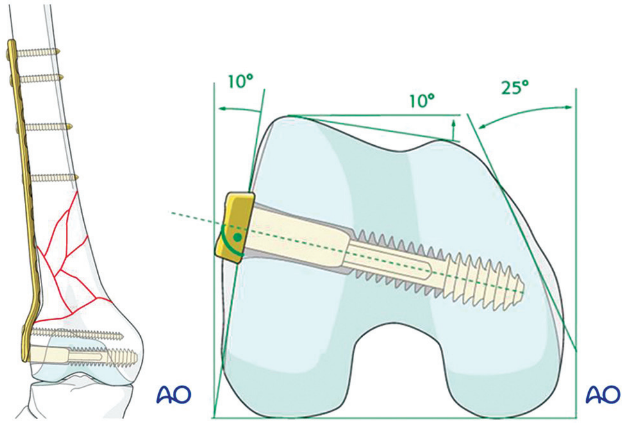

Fig. 3 Dynamic condylar screw (AO Surgery Reference, 2020)

A new metal design of the plate appeared at the turn of the century that completely differed in its features from its predecessors, the so called locking compression plate (LCP) [47, 48]. The plate is a single whole construct with the screws and features a uniform distribution of the load on the entire construct. It enabled to widen the indications for patients with bad bone quality [23]. Screws with angular stability provide a more rigid fixation of both distal and proximal fragments. One more merit is the fact that the plate is not pressed to the bone that enables to preserve periosteal blood flow [2]. An important difference from its predecessors is several fixation points in the distal fragment that enhance osteosynthesis stability (Fig. 4a).

Petsatodis et al. (2010) reported on treatment of 116 patients using DCS, LCP and CBP and concluded on better results with the use of dynamic femur screw, 96 % of good and excellent results. For LCP and CBP, good and excellent results were 84 % and 71 %, respectively. The number of complications, such as nonunion, mal-union, knee contracture was higher with LCP and CBP application.

The latest designs of plates on the markets are variable angle locking compression plates (VA-LCP) that enable the multiaxial insertion of 4.5-mm screws (Fig. 4b). The complication rate with the use of the plate is from 9.3 to 22 % that is comparable with the complication rates of the plate with angle stability. The merit of the technology is possible fixation of unusual fragments. It avoids screw penetration into the joint if the placement of the plate is not ideal or its contact with the fixator that was previously implanted [5, 29].

The most frequent and specific complication of the VA-LCP is its possible migration and secondary displacement of bone fragments in the early post-operative period which happens in 9.1–22.0 % of cases [49, 50]. Other complications are delayed consolidation, nonunion or mal-union, infection in the surgical area that are encountered in 16.8 to 35.0 % [49, 51, 52]. Thus, it can be stated that the treatment results with VA-LCP are comparable with those after LCP osteosynthesis.

Fig. 4 ***a*** Locking compression plate LCP (AO Surgery Reference, 2020); ***b*** Variable angle locking compression plate VA-LCP (K. Stoffel, 2019)

Thus, the results of distal femur fracture treatment have improved with the course of time but were inferior that in fractures of the other parts of the femur. It was revealed that the highest rate of complications was observed in AO fracture types 33-A3, 33-C2, 33-C3 [6, 13, 28]. Those are comminuted fractures with destruction of the bone metaphysis and consequently an absent contact between the fragments along the medial surface [4, 6, 13, 28].

It was required to study and analyze in detail the biomechanical base of the osteosynthesis in order to reveal the reasons of poor results.

It is known that medial stability is an inseparable part of the biomechanical component for providing stable osteosynthesis in the eccentrically loaded areas [4, 6, 12]. There is an opinion that if the gap between the fragments is more than 5 mm medially, the nonunion rate is significantly higher [4, 12]. If there is no such a medial support, there rises an issue to enhance osteosynthesis stability.

The first information on the use of bilaterally positioned fixators in distal femur fractures was reported in the work of Sanders et al. (1991). They considered the comminuted nature of the fracture of the inner cortical layer, a short distal bone fragment, and a decrease in metaphyseal bone mass as indications for the use of two plates. The author substantiated the need to use two fixators by excessive loads on an isolated lateral plate, which could lead to its break [6].

Later, there appeared the studies that described the column theory of long bone epiphysis composition [53–56]. Numerous studies prove the efficacy of osteosynthesis that includes the medial support in the management of distal femur fractures [57–61]. In those works, the objective was achieved by adding a buttress plate on the medial bone surface. Ziran et al. (2002), on the contrary, opine that osteosynthesis should be implemented from one anterolateral approach and place the fixators on the anterior and lateral sides for reducing the invasiveness. The author supposes that it decreases the forces acting on the bone both in the frontal and sagittal planes [31].

In 2017, I.G. Belenki and coauthors divided the distal femur on the lateral and medial columns. Lateral lower third of the diaphysis, the lateral condyle and lateral epicondyle were referred to the lateral column while the medial column included the medial lower third of the diaphysis, medial epicondyle and condyle. They modelled the fracture type 33-C2 (AO/OTA) on a plastic bone that lacks the contact between the proximal and distal fragments and performed a biomechanical study. The first series of the experiment investigated the magnitude of displacement under cyclic load in the conditions of an isolated use of the lateral plate while in the second series there was double-side plating. It was proven that two plates achieve stable fixation of bone fragments. In the first and second series, the maximum displacement was 0.3–1.9 mm and 0.35–0.95 mm, respectively, with the load ranging from 20 to120 kgf. Thus, it was proposed to use an adequate number of fixators depending on the number of columns involved in the fracture, [4].

Exact indications for application of bilateral osteosynthesis have not been defined yet. The majority of authors believe that along with the absent medial support, the indications for bilateral osteosynthesis of distal femur fractures might be low fractures of both condyles, medial Hoffa's fracture, all periprosthetic fractures after TKA, nonunion after osteosynthesis with one plate or screw, poor bone quality and multi-fragmented intra-articular fractures (AO 33-C3) [5, 7, 36, 43]. The main advantage of osteosynthesis with two plates is the ability to reduce the leverage of the force acting on the distal femur and, consequently, to increase the rigidity of the osteosynthesis [13].

It should be noted that the medial plate for distal femur which is anatomically pre-curved has not been designed yet. Therefore, plates designed for other anatomical areas have been used. The most commonly used plates are PHILOS type, which is a 3.5-mm plate for osteosynthesis of the proximal tibial part, a 3.5-mm reconstruction plate, a 4.5-mm buttress T-plate and some others [5, 11, 31]. It is important that the plates are of different length for prevention of load concentrated on the bone to avoid the risk of peri-implant fractures. Moreover, the medial plate should be shorter than the lateral one and have from 8 to 10 holes [13]. We could not find any clinical study that would compare the treatment results of using one versus two plates.

We should name also the shortcomings of bilateral osteosynthesis. They are increase in the time of surgical intervention, more soft-tissue trauma with possible disorders of the periosteal blood flow. There is a term *dead bone sandwich* that describes aseptic bone necrosis resulting from application of two plates [3, 62]. Another shortcoming of double-column osteosynthesis is an extremely rigid fixation that may lead to delayed consolidation of the fracture or nonunion. It is recommended to choose the proper length and shape of the plate for fixation balance in order to prevent the above complication. Attention should be paid not to damage the neurovascular bundle in the course of medial plate placement.

DISCUSSION

Fractures of the distal femur remain a challenging social problem. First of all, it is associated with a sufficiently high rate of poor treatment results. Two social groups prevail in the structure of the injured, persons of working age who have this type of fracture as a component of polytrauma and elderly people who suffer pathological fractures due to osteoporosis or periprosthetic fractures after TKA. Comminuted fractures of the distal femoral epimetaphysis are specifically difficult to repair and the techniques of their management are under rigorous discussion.

The surgeon can use any type of osteosynthesis for distal femur fracture treatment, plating, nailing or transosseous osteosynthesis. Although few but the available studies prove that their results are comparable. However, the majority of surgeons prefer plating. It is associated with a number of advantages. The main one is that plating is possible for any kind of fracture, what is especially important in the case of intra-articular multi-fragmented fractures of the distal femur. Plating for management of fractures of such location was first applied in the 1960s. Since then, a great variety of plates has been developed. This variety might be explained by the fact that no fixator could be named perfect.

The theory of multi-column osteosynthesis appeared at the end of the 20th century and was based on distribution of loading on specific parts of the skeleton. The so called medial support in the fractures of epimetaphysis of bones was supposed to have a special significance. Since that moment, two plates have been used for osteosynthesis of the distal femur fractures, along the medial and lateral bone sides. It was a significant event in the treatment of distal femoral fractures that were accompanied by medial instability. However, one can still state that the number of poor outcomes remains high. It might be explained by the fact that a great number of surgeons still use osteosynthesis with only a lateral plate. Those who prefer two plates may excessively use skeletizing of bone fragments. It results in a *dead bone sandwich* and is the main cause of fracture nonunion. As far as the plates for medial femoral condyles that are "anatomically" curved have not been available yet, the issue of what plate is optimal remains open.

CONCLUSION

In conclusion, we would like to note that any plate, despite the surgeon's preference, has its merits and shortcomings. The same refers to the choice of either bilateral or unilateral osteosynthesis as there no comparative studies in favour of either of them. The boundary beyond which there is a danger of poor results due to fixation instability or nonunion due to extremely rigid fixation have not been settled yet. Therefore, the study of the medial support for fractures of 33-A3, 33-C2, 33-C3 is of special importance and seems to be a prospective direction. It should be noted that the official AO recommendations do not focus on the issue of the medial support integrity. Thus, a number of researchers coincide in the opinion about the need to use two plates for the fractures under this discussion. To date, a pre-modelled reconstruction plate has been most common in use. The low invasiveness of the techniques is of special significance for the authors. Ideally, it should be performed through skin incisions in order to prevent bone fragment de-vascularization resulting in dead bone sandwich. A special and industrially manufactured medial plate for facilitating the osteosynthesis procedure is a demanding issue for designers.

In our opinion, the development of a lateral plate which isolated use could retain all stability properties of bilateral osteosynthesis is also a prospective issue. It would simplify the intervention, reduce its time, and avoid the risk of damage to the neurovascular bundle. Undoubtedly, the construct should feature low invasive technique of its implantation. In future, such a metal implant might be developed for other locations that are unevenly loaded. It would also be required for reconstruction orthopaedics and serve as a fixator used after deformity correction and a limb lengthening procedure.

CONCLUSIONS

1. Osteosynthesis with plates remains the preferred treatment for distal femur fractures.

2. Treatment of distal femur fractures accompanied by medial loss of support (AO types 33-A3, 33-C2, 33-C3) has the greatest number of complications.

3. The solution to this problem may be associated with the improvement of bilateral "double-column" osteosynthesis (development and fabrication of a medial plate and the technique of its minimally invasive implantation), along with the development of a novel lateral plate that would provide the stability similar to two-plate osteosynthesis.

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Received: 18.05.2020

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