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Review article

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Surgical approach to the treatment of patients with sequelae of intra-articular fractures of the distal tibia (literature review)

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Abstract

Background Management of patients with sequelae of intra-articular fractures of the distal tibia continues to be a substantial clinical challenge in orthopaedic trauma due to the high incidence, poor outcomes and high disability rate. The **objective** was to review Russian and international experience in repair of intra-articular ankle fractures and explore contemporary trends in treatment strategies. **Material and methods** The literature search was produced using medical electronic databases of eLibrary, PubMed, Medline, SpringerLink between 2000 and 2020 and keywords: cruzarthrosis, arthrodesis, total ankle arthroplasty, arthroscopy, distal tibia, ankle joint, joint replacement, intra-articular fractures of distal tibial. **Results** The article presents an insight into the problem of malunited and nonunited ankle fractures, ankle contractures and deformities, post-traumatic ankle arthritis. Major surgical techniques used to address sequelae of ankle fractures include correcting osteotomy, arthroscopy, distraction arthroplasty, arthrodesis, total ankle arthroplasty with the advantages and disadvantages with each of the practices. **Discussion** The surgical option would depend on the time of injury, condition of soft and bone tissue, malalignment and severity of ankle arthritis. Joint saving procedures of correcting osteotomy, arthroscopy or distraction arthroplasty can be applied at early stages of the disease, and arthrodesis or total ankle arthroplasty are secured for terminal stages of ankle arthritis. Benefits of total ankle arthroplasty include preservation and improvement of ankle mobility, a short inpatient period. Ankle fusion is associated with less complication rate and low costs. **Conclusion** There is an obvious need for a uniform treatment algorithm with specific indications and contraindications to each surgical option.

Keywords: ankle joint, ankle arthrosis, arthrodesis, total arthroplasty, joint replacement, arthroscopy, distal tibia, correcting osteotomy, nonunited fracture, sequelae of injury

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INTRODUCTION

Management of patients with sequelae of intra-articular fractures of the distal tibia continues to be a substantial clinical challenge in orthopaedic trauma due to the high incidence (medial and lateral malleolar fractures, broken anterior and posterior aspects of the tibia) that ranges 71 to 187 cases per 100,000 population [1–3]. Ankle fractures account for 9–20 % of all musculoskeletal injuries; tibia is the most frequent location for musculoskeletal injuries that constitute 60 % [4]. About 70 % of patients with ankle fractures are persons of working age from 25 to 60 years, and consequences of intra-articular fractures of the distal tibia remain one of the main causes of long-term disability in 8.8 – 46 % of cases [5–8].

The complexity of surgical treatment of the consequences of intra-articular injuries of the distal tibia is associated with concomitant alteration of the articular surfaces that make up the ankle joint, and chronic instability of the joint, developing as a result of injury to the capsular ligamentous apparatus. The ankle anatomy determines a greater load per square centimeter of the articular surface than in other joints of the lower limb. Ostearthritis of the ankle joint is observed to develop in 10–60 % of cases due to injury to the articular cartilage and incongruence of the articular surfaces that may result from incomplete reduction and instability of the joint. The talus dislocated laterally by 1 mm leads to incongruence in the ankle joint in 42 % and a significantly increased load on the joint [9–13]. Contracture and osteoarthritis of the ankle joint is associated with disengaged function of the joint due to unreasonably prolonged immobilization during conservative treatment or after osteosynthesis. The above factors cause a significant rate of adverse events affecting the final outcomes of intra-articular fractures of the distal tibia, despite the use of modern methods of surgical and conservative treatment (persistent pain and post-traumatic edema, malunited ankle fractures or nonunions, ankle contractures and deformities, post-traumatic ankle arthritis). The reported complication rate ranges between 7 and 68 % with conservative treatment; 47 % after surgical treatments that is apparently recorded for different severity of injury [7, 14–20].

MATERIAL AND METHODS

The original literature search was conducted on key resources including electronic medical databases of eLibrary, PubMed, Medline and SpringerLink using keywords: ankle joint, ankle arthrosis, arthrodesis, total joint arthroplasty, joint replacemrent, arthroscopy of the ankle joint, distal tibia, ankle joint, ankle arthrosis, total arthroplasty, joint replacement, intra-articular ankle fractures. Preference was given to the articles and dissertation materials published over the past 15 years. Full-text versions of articles, dissertations and abstracts of dissertations were analyzed. Scientific papers found in the literature lists of reviewed contributions were analyzed to obtain additional information about the results of surgical treatment and rehabilitation of patients with the consequences of intra-articular injuries to the distal tibia.

RESULTS

Despite the variety of surgical techniques and metal constructs offered (both commercially available and author's devices), the rate of poor outcomes is still high, and their treatment is not an easy task for many surgeons. Post-traumatic ankle arthritis is the first common condition among the consequences of ankle fractures (up to 60 %). Surgical interventions used in the treatment of the condition can be divided into joint-preserving (correction osteotomies of the distal fibula and tibia with subsequent osteosynthesis, arthroscopic interventions, distraction arthroplasty) and non-preserving joint procedures (fusion and total ankle arthroplasty) [17, 21–24].

Correction osteotomy is most common among joint-preserving surgeries and indicated for malunited fractures, nonunions of the distal tibia or fibula with impaired congruence in the ankle joint, mechanical axis of the lower limb with resultant inadequate distribution and increased loading on the ankle joint, degradation of the articular cartilage and ankle arthritis. Correction osteotomy is used to restore the biomechanical axis of the limb, anatomical relationships in the ankle joint and provide unloading for the articular cartilage. Different types of osteotomies (wedge-shaped, oblique, angular, along the fracture line, etc.) and fixation modalities and bone graft options for defect repair are widely discussed in the literature. The use of correction osteotomies is reported to be effective in 75–92.5 % of cases [25–28].

In 2013, I.O. Pankov et al. analyzed outcomes of 38 patients with malunited pronation-eversion fractures of the distal tibia. All patients underwent corrective osteotomy along the fracture line, bone reduction to restore the limb axis and anatomical relationships in the joint followed by external fixation for 8 weeks. Treatment outcomes were rated as excellent in 4 cases (10.5 %), as good in 22 cases (57.9 %), as fair in 12 cases (31.6 %) and no poor results were reported [29]. In 2011, the main databases were searched by R.J.A. Van Wensen et al. from 1960 to 2007 to identify studies reporting with osteotomy produced for malunited ankle. They analyzed 15 studies involving 177 patients. One hundred and thirty-seven patients (77.4 %) had a good or excellent result after osteotomy. The authors concluded that osteotomy was needed to prevent post-traumatic osteoarthritis and pointed to the low effectiveness of the treatment in case of baseline early osteoarthritis, and the need to analyze larger groups of patients with a high level of evidence [19].

Endoscopic surgery introduced into clinical practice allowed for arthroscopy of the ankle joint to be used in the treatment of patients with post-traumatic ankle arthritis and facilitated identification of articular cartilage defects. Intra-articular fractures of the distal tibia are mostly accompanied by involvement of the tibial cartilage in the majority of cases and the articular surface of the talus at the time of injury and secondarily with the impingement syndrome. Ankle arthritis is likely to develop due to cartilage injury even with the biomechanical axis of the limb and congruence in the ankle joint completely restored in the treatment of the consequences of injuries. Arthroscopy is used to treat delayed ankle injuries as a standalone technique and in combination with other surgical procedures [30–32].

Minimally invasive arthroscopy assisted treatment can be used to address causes of chronic pain, adhesions and impingement syndrome, bone-cartilaginous exostoses, osteophytes, chondromic bodies, impaired cartilage, remove bumps, abrasions, smooth down the articular surfaces with a shaver after preliminary stretching of the ankle joint manually or with distraction devices. The regenerative process can be arthroscopically initiated in the cartilage tissue through subchondral bone drilling to repair deep cartilage defects, and specially created cellular implants and collagen matrices induced by autologous chondrocytes can be employed to fill in the defects. The strategy of treating cartilage defects would depend on the defect size. Debridement and drilling of the underlying subchondral bone can be efficient for a articular cartilage defect sized less than 15 mm. With a larger size involvement a cartilage defect can be additionally covered with a bone-cartilage graft or matrix induced by autologous chondrocytes [33–39].

In 2015, A.I. Gorodnichenko and co-authors explored the role of arthroscopy in the diagnosis and treatment of ankle injuries in 44 patients who were divided into 2 groups: the main (n = 27) and control (n = 17). Signs of ankle arthritis were seen in 27 patients of the main group after surgical interventions for intraarticular fractures. 17 controls with ankle injuries had a history of chronic ankle pain. Arthroscopic procedure in the main group was performed in 2 stages: diagnostic and therapeutic. No arthroscopy was produced for patients of the second group that was treated with nonsteroidal anti-inflammatory drugs, physiotherapy and intra-articular use of glucocorticosteroid hormones. Patients of the main group could experience pain free everyday activity in 100 % of cases with complete restoration of the ankle function noted in 74 % (20) at a long term. Controls could return to pain free everyday activity in 17.6 % (3) of patients without complete restoration of joint function. The authors concluded that arthroscopy was very informative for post-traumatic ankle injuries and effecient for the entire spectrum of intra-articular conditions improving the quality of life of the patients [40]. Other researchers report a high percentage of good results (up to 96 %) in arthroscopic treatment of the ankle arthritis in patients with initial stages of the condition (grades I and II) to completely regain anatomical relationships and well realigned axis of the lower limb [41–42].

Distraction arthroplasty (arthrodiastasis) is one of the joint-preserving techniques improving reparative activity to restore the articular cartilage. This can be achieved by prolonged (from 6 weeks to 3–4 months) unloading of the cartilage of the ankle joint through distraction with the external fixation device. The Ilizarov frame is most useful for gradual distraction if compared to monolateral external fixation devices facilitating normal biomechanical relationships in the joint. The effectiveness of the method ranges from 55 to 91 %, and its use can help postpone or avoid arthrodesis of the joint in osteoarthritis grades 1–2 [43–45]. The combined use of distraction arthroplasty with the Ilizarov frame and treatment and diagnosis arthroscopy is reported [46].

Ankle fusion has been recognized as the "gold standard" procedure that does not preserve the ankle joint in intra-articular injuries to the distal tibia. In addition to a late stage of ankle arthritis fusion can be indicated for malunited fractures and nonunions resulting from intra-articular injuries, pronounced combined contracture in the ankle joint, impaired support to the foot due to neglected injury to the ligamentous apparatus. The procedure is aimed at creating bone ankylosis in a functionally adequate position to provide support to the foot, relieve chronic pain and improve the quality of life for the patients. There are many methods used to achieve arthrodesis, but none of them can be completely satisfactory.

Arthrodeses are divided into compression and non-compression procedures. Bone ankylosis can be achieved with compression arthrodesis through transosseous fixation using frames developed by Ilizarov, Volkov-Oganesyan, Grishin to maintain the amount of compression needed [47–49]. In 2012, Yu.A. Plakseychuk et al. analyzed outcomes of arthrodesis using the Ilizarov frame and bone graft in a large cohort of patients (n = 286) who suffered arthritis of the ankle and subtalar joints grades III–IV. Arthrodesis was performed for 36 patients using the author's method (main group). Fusion was achieved in all patients of the main group and in 97.2 % of controls, and compression arthrodesis with an external fixation device is reported to be effective in the treatment of osteoarthritis relieving pain and restoring support to the limb [47]. Ankle arthrodesis can be achieved in a closed way using the Ilizarov frame in the presence of osteoarthritis and infectious changes in the joint [50]. Bone plating, intramedullary nailing, screws, author's constructs can be employed for non-compression arthrodesis after processing the articular surfaces and bone realignment [51–53].

In 2015, D.V. Pavlov et al. reviewed outcomes of 53 patients treated with ankle fusion using different methods: cannulated screws (n = 22), retrograde intramedullary rods HAN (n = 24), transarticular fixation with three wires (n = 4), Ilizarov external fixation (n = 6). The operations performed included resection of articular surfaces and the use of osteotomies. The best results were achieved with screws (bone ankylosis was achieved in 68 % of cases) and an external fixation device (67 %); worse outcomes were seen with the use of wires (25 %). Although fusion was achieved in 62 % of patients with use of IM nails, the complications rate (fibrous ankylosis, infection and amputation) was higher and amounted to 38 % and could be caused by insufficient primary compression and impaired circulation of the talus due to large rod placed in the bone [54]. Some authors prefer bone plates as a fixation device due to greater reliability in the formation of bone ankylosis, ease of use and inexpensiveness [55].

IM nailing can be the best option for ankle fusion with degenerative subtalar joint. In 2016, K.S. Mikhailov et al. reviewed outcomes of 63 patients treated with double-articular arthrodesis using retrograde blocking nail. Fusion was achieved in 94 % of patients with significant ($p < 0.01$) improvement of all clinical and functional parameters measured with the visual analog scale, AOFAS (the American Orthopaedic Foot and Ankle Society)

score, and biomechanics of the feet at the gait [56]. Post-traumatic ankle arthritis grades III–IV can be treated with arthroscopic technique. In 2017, L.K. Brizhan et al. reported results of treatment of ankle arthritis grades III–IV using minimally invasive arthroscopic fusion of the ankle joint. Arthroscopic arthrodesis is considered as an alternative to classical arthrodesis due to the high risk of infectious complications. Post-traumatic ankle arthritis grades III–IV (group I, n = 102) was treated with arthrodesis of the ankle joint using a retrograde intramedullary rod HAN (46 of them were produced with classical open technique). Patients of group II (n = 56) underwent arthroscopic debridement of the articular cartilage of the tibia and the talus with a shaver after distraction with hardware until bleeding appeared, and synovial excrescence, intra-articular bodies, etc. were removed and malleolus intersected if needed. Then fixation was performed with an IM nail as in group I. Postoperative complication rate was shown to reduce by 26 %, the length of hospital stay by 40 % and the period of disability by 20 % with fusion achieved in 100 % of cases [57]. Successful use of arthroscopic arthrodesis is reported in ankle arthritis grades III-IV with length of fusion of 8.5 weeks [58, 59].

There is no consensus among surgeons regarding treatment of the articular surfaces of the ankle joint with arthrodesis and bone grafts. Some surgeons choose to completely remove the cartilage before the bleeding, others consider rigid fixation of the joint having an important role. There is no consensus on the methods of fixation. A number of authors consider the use of several cannulated screws being practical, others recognize bone plating and screws as the most effective fixation. Ther are also options with intramedullary nailing, and the Ilizarov external fixation [60]. The relative ease of performing surgical intervention is an apparent advantage of the arthrodesis technique. However, there is a tendency in gradual decline of arthrodeses procedures that can be associated with a high complications rate that is reported to occur in 60 % of cases. In addition to that, arthrodesis is known to have a negative impact on the biomechanics of the foot leading to the development of osteoarthritis of other joints and pain and resulting in greater role of total ankle arthroplasty and arthroscopy of the ankle joint in the treatment of ankle arthritis [61, 62].

Total ankle arthroplasty of the joint is a high-tech and time-consuming surgical intervention, but there are still many controversies in the use of the method. There are strict indications for arthroplasty considering the age and body mass index of the patient, severity of pain, the need for at least 70 % of the ROM in the joint and absence of deformity of the hindfoot. No more than 20 % of patients with ankle injuries meet these criteria. The optimal age of candidates for total ankle replacement has changed over time, being appropriate for younger and elderly patients [63, 64]. Unconstrained implants allow for reduced and more uniform distribution of the load on the bone at the implant fixation sites to improve stability and the survival period. Total ankle replacement is also divided into cement and cement–free fixation, two-component and three-component implants. Implant designs, navigation and tools for their implantation are being improved with use of CT modeling and 3D printing of implants and resector blocks. Cementless implantation consisting of three components is thought to provide the best results with the five–year survival rate of 72.7–98 %, and ten-year survival rate of 80 % [56, 66].

Evaluation of the outcomes of total ankle arthroplasty is based on the results of physical and radiological examination of patients, biomechanical static-dynamic parameters of the lower extremities using different grading systems [67-69]. In 2012, D.V. Pavlov et al. evaluated the static-dynamic function of the lower extremities in 18 patients after total ankle arthroplasty. Six-month follow-up showed the lower limb being adapted to loads with an increase in the maximum push-off force, the rhythm coefficient and the redistribution of support on the operated limb. At 12 months, biomechanical parameters continued to improve with the alignment between the healthy and operated limb reaching the norm after 24 months [67]. In 2018, K.S. Mikhailov et al. reviewed outcomes of total ankle arthroplasty in 71 patients, and concluded that total arthroplasty of the ankle joint provides good or satisfactory results in the majority of patients: 100 % on a visual-analog scale and 96 % on AOFAS scale at 2 years; 100 % on both scales at 3 years; 92.3 % at 5 years and 85.7 % at 7 years [68].

Despite the advantages of normal biomechanics restored in the segment and a limited ROM (about 25°) maintained in the ankle joint at a short term, total arthroplasty has shortcomings that are seen at a long term. Instability of implant components, tibial, in particular, stress ankle fracture that can occur in almost 20 % and infection are most common complications. Ossifications, ankle exostoses interfering with the gait and local osteoporosis are less common [68, 70]. Reoperation rate reaches 24 % [71]. An "ideal" implant for arthroplasty can be designed with maximum consideration of anatomical, biomechanical and functional aspects of the ankle joint, the variety of functions, huge static and dynamic loads the joint sustains.

DISCUSSION

Surgical rehabilitation of patients with intra-articular fractures of the distal tibia is aimed at relieving pain, restoring the limb's ability to support and preserving the ankle function, if possible. The choice of the surgical modality would depend on the time of injury, condition of soft and bone tissues, the presence of a joint deformity and severity of ankle arthritis. A joint-preserving surgery can be a good option at the initial stage of treatment of intra-articular fractures. Corrective osteotomy can be used to correct post-traumatic deformity or nonunion to restore the relationship in the joint, biomechanical axis of the limb and achieve a good treatment result [72, 73]. The treatment may fail with injury to the articular cartilage and can lead to the development of post-traumatic arthritis. Arthroscopic interventions can help to avoid adverse events [40, 41]. Distraction arthroplasty is reported to be a more effective method of treatment preventing the development of arthritis with the possibility of cartilage regeneration through the mechanical impact to be avoided for a certain time [46]. Post-traumatic ankle arthritis grades III–IV can be addressed with fusion and total ankle arthroplasty. In addition to pain relief, total ankle arthroplasty can maintain and improve mobility in the ankle joint to facilitate a physiological gait using rough surfaces, stairs, slopes and a shorter period of hospitalization [74, 75]. Ankle fusion can be considered a better option with fewer complications, less costs, less blood transfusion as compared to arthroplasty procedure, and be used for failures of total ankle arthroplasty [76, 77]. No significant differences is seen between the methods at a short term. An individual approach can be recommended considering different surgical options for a specific clinical scenario [78].

Despite the technological advances in orthopaedic surgery management of patients with sequelae of intra-articular fractures of the distal tibia continues to be a substantial clinical challenge in orthopaedic trauma due to the high incidence, poor outcomes and high disability rate. Orthopaedic and trauma surgeons do not have an unambiguous solution to the question of the optimal method of treating the consequences of ankle injuries with indications and contraindications to be clarified and specified. There is a paucity of literature on such important aspects as the choice of treatment strategy with consideration of bone mineral density of the distal tibia and the talus due to a long-standing pathological process, lack of support on the limb and impaired reparative osteogenesis, biomechanical aspects to correct deformities of the lower limb.

CONCLUSION

Treatment of patients with sequelae of intra-articular fractures of the distal tibia continues to be a substantial clinical challenge in orthopaedic trauma due to the high incidence, poor outcomes and high disability rate. There is an obvious need for a uniform treatment algorithm with specific indications and contraindications to each surgical option.

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