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Evaluation of the effectiveness of ankle arthrodesis options

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Abstract

Introduction Treatment methods for late stages of ankle osteoarthritis are varied, but the issue of assessing the long-term results of various fixation methods has not yet been studied, and this issue is of great importance in clinical practice.

Purpose To compare the effectiveness of the fixation methods commonly used for ankle arthrodesis in patients with advanced ankle osteoarthritis.

Materials and methods Eighty-two patients with advanced ankle osteoarthritis were treated with ankle fusion between 2019 and 2023 at three major medical institutions. All patients underwent 12-month follow-ups. The patients were divided into four groups depending on the method of surgical fixation of bone fragments.

Results Most patients showed a significant improvement in the function and a decrease in pain intensity after the arthrodesis operation. The comparison of the effectiveness of various surgical fixation methods found that external apparatus screw fixation is characterized by lower blood loss and a relatively short duration of the operation. Plate and screw fixation resulted in higher AOFAS and VAS scores at 3 months postoperatively. However, by the 12th month after surgery, the differences in these two indicators were insignificant.

Discussion Despite the various complications that occur in ankle arthrodesis, it remains effective for most patients. Among them, the Ilizarov apparatus is more suitable for patients with compromised conditions in the surgical area. Each method of surgical fixation has its own advantages and shortcomings, but the difference in long-term effectiveness is small.

Conclusion Ankle arthrodesis is an effective treatment for advanced ankle osteoarthritis. The choice of surgical method is still subject to the principle of individual approach.

Keywords: ankle arthrodesis, apparatus of external fixation, screw, plate, intramedullary nail, osteoarthritis

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INTRODUCTION

Osteoarthritis (OA) affects 7 % of the world population that is more than 500 million people [1, 2]. In turn, ankle joint OA accounts for up to 1 % [3–5], and it can be classified into primary and secondary, depending on the etiology of the primary pathology. The causes of secondary osteoarthritis of the ankle joint (SOA) include trauma, rheumatoid arthritis, osteonecrosis of the talus, failed surgical interventions, anatomical deformity, and others [6, 7], and post-traumatic osteoarthritis is the most common cause of the development of pathology. It constitutes up to 78 % [8, 9].

The main treatments of late stage osteoarthritis are mainly arthroplasty or arthrodesis of the joint [5, 10–12].

Ankle arthroplasty has not become widespread yet [13], although its use in numbers has been growing over the years [13, 14]. In contrast, ankle arthrodesis has been considered the "gold standard" for the treatment of late OA stages since its development in 1879 to the present day [9, 11, 12, 15, 16].

Despite ankle arthrodesis is quite well established scientists and clinicians still face numerous problems in their practical work. Thus, the optimal fixation method for this type of surgery is controversial [3, 11, 16, 17, 18].

To date, more than 40 surgical methods for performing arthrodesis have been developed [11, 15, 16]. The most common of them are classified according to the type of surgical fixation, which includes external and internal (screws, pins, plates or intramedullary pins) means [8–11, 16, 17, 19].

The team of authors had the opportunity and need to compare the effectiveness of the four most common fixation methods using a multicenter open prospective cohort study.

Purpose To compare the effectiveness of the fixation methods commonly used for ankle arthrodesis in patients with advanced ankle osteoarthritis.

MATERIALS AND METHODS

The study was approved by the regional ethics committee, and informed consent was obtained from all participating patients.

The study included 82 patients (34 men and 48 women, mean age 55.57 ± 11.85 years) with late stages of osteoarthritis of the ankle joint, who underwent arthrodesis in three large medical institutions in Wuhan (China) and Kazan (Russia) from 2019 to 2023

The patients were divided into four groups according to the method of fone fragment fixation during the ankle joint arthrodesis procedure:

— External fixation (EF) group: 21 patients (9 men and 12 women, mean age 59.05 ± 5.93 years), arthrodesis of the joint joint was performed with the Ilizarov apparatus (IA);

— Screw fixation (SF) group: 23 patients (8 men and 15 women, mean age 54.22 ± 10.30 years), arthrodesis of the joint was performed with screws;

— Plate fixation (PF) group: 20 patients (9 men and 11 women, mean age 55.10 ± 15.76 years), arthrodesis of the ankle joint was performed with plates;

— Intramedullary fixation group (IMF): 18 patients (8 men and 10 women, mean age 53.78 ± 13.83 years), joint arthrodesis was performed using IM pins.

It should be especially noted that in the AEF group, there were 11 patients with rheumatoid arthritis, three with gouty arthritis and one with post-infectious osteoarthritis. These categories are often considered unsuitable for fixation types other than AEF due to compromised skin or bone in the surgical site [4, 11, 17].

The comparison of the basic data of the patient groups (gender, target limb, age, BMI, stage of osteoarthritis) found that the differences were insignificant (Table 1).

Table 1

Basic patients' information

Parameter		AEF group (n = 21)	SF group (n = 23)	PF group (n = 20)	IMF group (n = 18)	p
Age		59.05 ± 5.93	54.22 ± 10.30	55.10 ± 15.76	53.78 ± 13.83	0.47
BMI		26.73 ± 3.05	24.77 ± 3.61	25.68 ± 3.10	26.09 ± 4.76	0.35
Males	n	9	8	9	8	0.89
	%	43	35	45	44	
Females	n	12	15	11	10	
	%	57	65	55	56	
Involved limb, left	n	8	11	11	8	0.75
	%	38	48	55	44	
Involved limb, right	n	13	12	9	10	
	%	62	52	45	56	
OA stage IIIb	n	9	14	14	11	0.35
	%	43	61	70	61	
OA stage IV	n	12	9	6	7	
	%	57	39	30	39	

Surgical technologies

The choice of surgical approach and fixation method depends on the stage of ankle OA stage, deformity, as well as on the personal preferences of the surgeon.

In cases with the lesion in the tibiotalar joint, the medial malleolus was not involved in the pathological process or the lesion was mild, and the condition of the skin on the lateral malleolus and the overall alignment of the ankle joint were assessed as satisfactory, a lateral approach was used. A longitudinal incision of 10–15 cm was made along the projection of the lateral malleolus, its apex, 2 cm lower.

The anterior approach was used in cases if surgical treatment required approach to both the medial and lateral malleolus. It passed between the tibialis anterior tendon and the extensor of the great toe.

If the skin condition of the anterior joint surface was compromised, a paired approach was chosen: lateral approach + small medial incision. The first incision was between the extensor longus of the great toe and the tibialis anterior tendon, and the second was between the peroneus tendons or the extensor digitorum longus.

Osteotomy of the fibula was used in a lateral approach and in cases with difficult reduction of the talus is difficult; the fibula was cut 6–7 cm above the ankle joint to expose its lateral surface and prepare for bone grafting.

During the operation, periarticular scars, ossifications, and remnants of cartilage were removed from the articular surfaces. Corrective osteotomies were also performed on the articular surfaces of the distal tibia and the upper part of the talus. The surfaces were leveled and filled with bone chips. Next, the ankle joint was fixed with an appropriate means chosen: Ilizarov AEF, 2–3 cannulated 3.5-mm screws, an anterior or lateral fixation plate, or a retrograde HAN nail.

The most important element in achieving ankle arthrodesis in the compromised condition of the skin and bone tissue, or signs of infection was the use of the Ilizarov AEF. The ability of extrafocal effect on the fusion of bone fragments with AEF is a great uncontested advantage, but also significantly impacts the outcome of stabilizing surgery in the area of the joint, what we observed from results of the study.

In the postoperative period, patients were treated with a short plaster cast on the lower leg and foot to immobilize the joint.

All patients are advised to use crutches and avoid weight-bearing on the target limb for 5 weeks after the operation. Limited weight-bearing began at 6 weeks and gradually progressed to full one after 3 to 6 months. During this period, the cast was changed every 3 months.

Examination of patients

All patients underwent a pre- and postoperative specialized examination, the function of the affected limb and pain were assessed using the American Society of Foot and Ankle Surgeons Scoring System (AOFAS) and Visual Analogue Pain Score (VAS) [20]. X-ray studies were used to assess the degree of preoperative state of the ankle joint and postoperative bone fusion. Postoperative complications were also recorded.

Statistical methods of processing the findings

Study data were analyzed using SPSS 26.0. Measurement parameters were presented as ($X \pm S$), and a paired t-test was used for comparison between the groups. Calculation data were expressed as rates or percentage, and the χ^2 test was used. Analysis of variance was performed with repeated measures for continuous variables. The results were considered statistically significant at $p < 0.05$.

RESULTS

The results of four different fixation methods at different time-point after surgery are presented in Figures 1 to 4.

Clinical case 1 A 60-year-old patient was admitted to the department with stage IV rheumatoid arthritis of the left ankle joint. Arthrodesis of the left ankle joint was performed with the Ilizarov AEF. Radiographs before surgery, during fixation and 3 months after surgery are presented in Figure 1.

Clinical case 2 A 58-year-old patient with stage IV post-traumatic OA of the left ankle joint underwent arthrodesis with screw fixation. Radiographs before surgery, during treatment and after 3 months post-surgery are shown in Figure 2.

Clinical case 3 A 45-year-old patient was admitted to the department with stage IIIb post-traumatic OA of the right ankle. Ankle arthrodesis with plate fixation was performed. Radiographs before surgery, 6 months and 12 months after surgery are presented in Figure 3.

Clinical case 4 A 58-year-old patient was admitted with stage IV post-traumatic right ankle OA. Arthrodesis of the ankle joint was performed with IMF nail. Radiographs before surgery, three days and 3 months after surgery are presented in Figure 4.

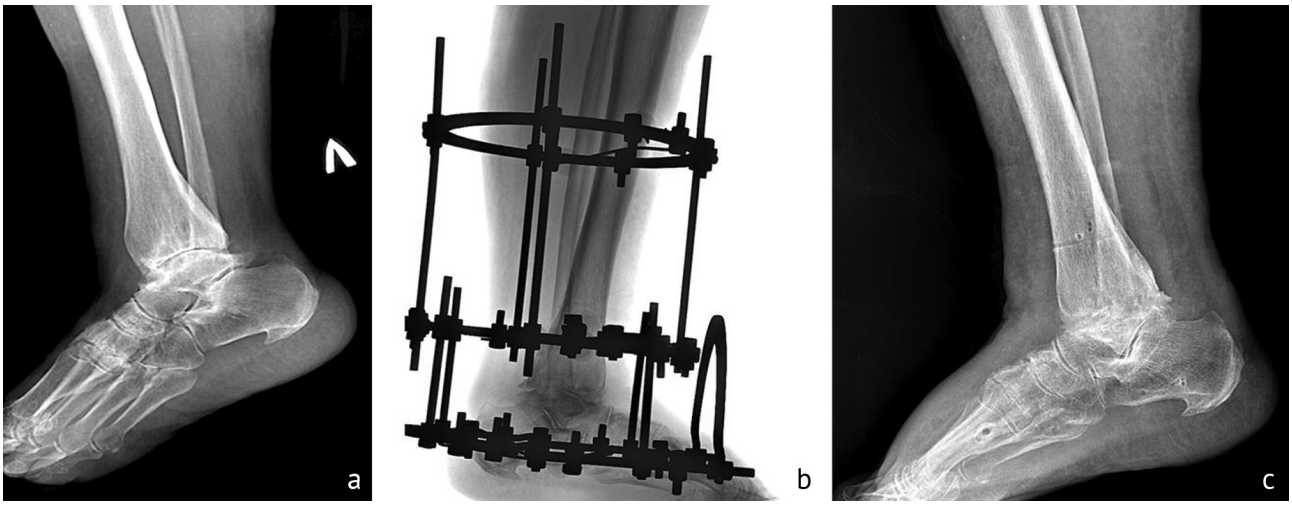

Fig. 1 Radiographs of the left ankle of a 60-year-old patient (lateral views): dynamics of the arthrodesis process with Ilizarov external fixation before surgery (*a*), 1st day after surgery (*b*), 3rd month after surgery (*c*)

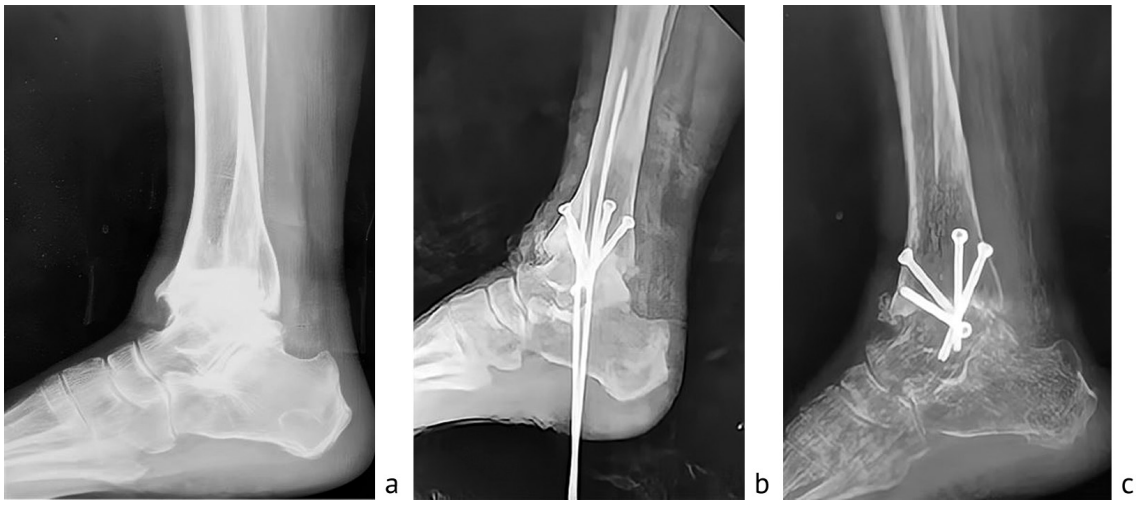

Fig. 2 Radiographs of the left ankle joint of a 58-year-old patient (lateral views); dynamics of the arthrodesis process with intraosseous cannulated screws fixation: before surgery (*a*), 1st day after surgery (*b*), 3rd month after surgery (*c*)

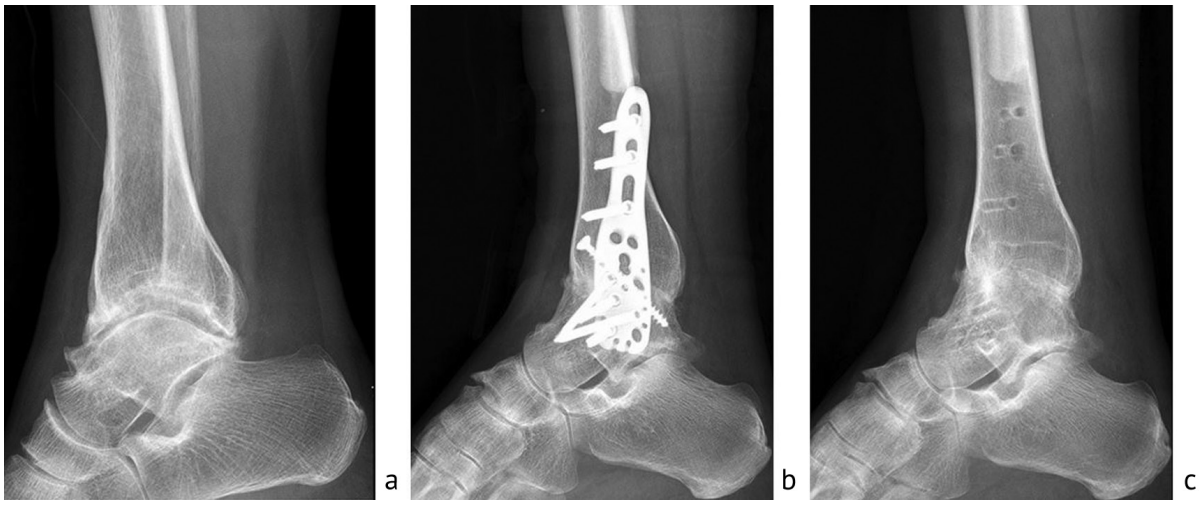

Fig. 3 Lateral radiographs of the right ankle joint in a 45-year-old patient: dynamics of the arthrodesis process with bone plate fixation and screws: before surgery (*a*);6th month after surgery (*b*); 12th month after surgery (*c*)

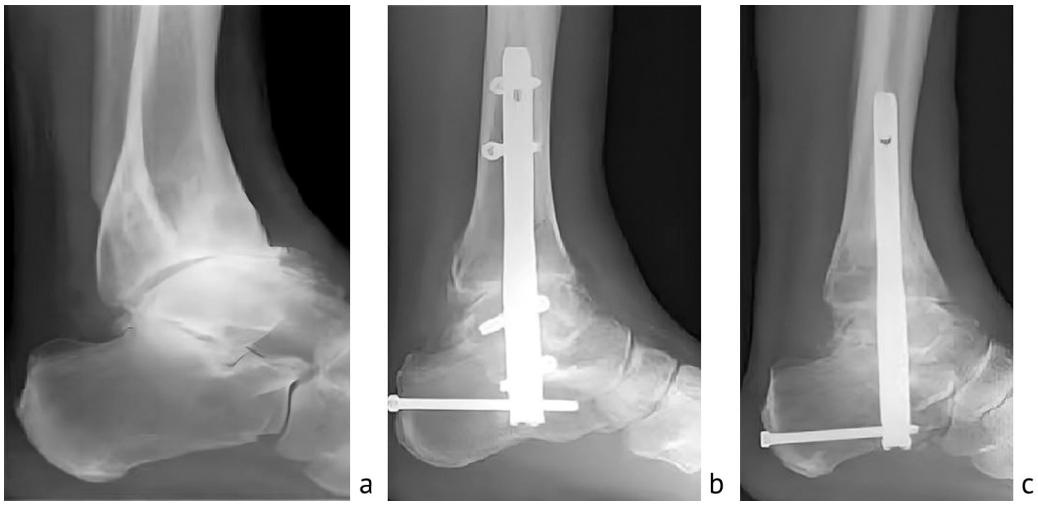

Fig. 4 Lateral radiographs of the right ankle joint in a 58-year-old patient; dynamics of the arthrodesis process with internal fixation and a retrograde locking screw: before surgery (*a*); 3rd day after surgery (*b*); 3rd month after surgery (*c*)

As a result, it was found that there was no significant difference in the volume of intraoperative blood loss between the AEF and IMF groups. Similarly, there was no significant difference in this parameter between the SF and PF groups. However, intraoperative blood loss with the first two fixation methods was significantly less than with the last two (Table 2; Fig. 5).

Table 2

Assessment of differences in the volume of intraoperative blood loss in the groups of patients with different fixation arthrodesis for arthrodesis

Method of surgical fixation	Blood loss (ml)	
EF group (*n* = 21)	118.81 ± 10.36	
SF group (*n* = 23)		125.65 ± 5.90
PF group (*n* = 20)		130.50 ± 10.38
IMF group (*n* = 18)	115.56 ± 8.73	
p	0.25	0.09

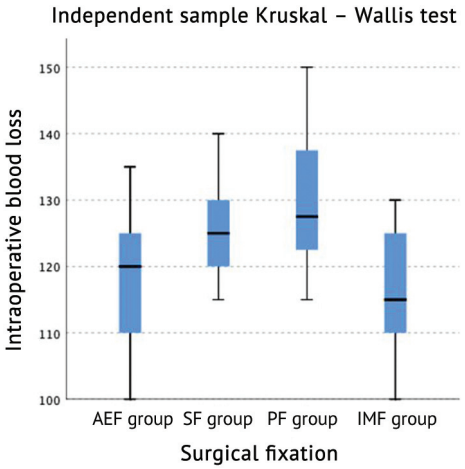

Fig. 5 Differences in the volume of intraoperative blood loss in groups of patients with different fixation options for arthrodesis

A comparative analysis of the operation duration revealed no differences between the AEF and IMF groups. Likewise, there was no significant difference in the operative time between the SF and PF groups. However, the duration of the operation was significantly less with the first two types of fixation than with the last two (Table 3; Fig. 6).

Table 3

Assessment of differences in the duration of surgery in groups of patients with different fixation options for arthrodesis

Method of surgical fixation	Duration of intervention (min)	
EF group (*n* = 21)	145.24 ± 9.15	
SF group (*n* = 23)		153.26 ± 11.04
PF group (*n* = 20)		154.25 ± 13.89
IMF group (*n* = 18)	142.50 ± 9.59	
p	0.43	0.78

Note: the significance of differences between groups was assessed using the Student – Newman – Keuls test

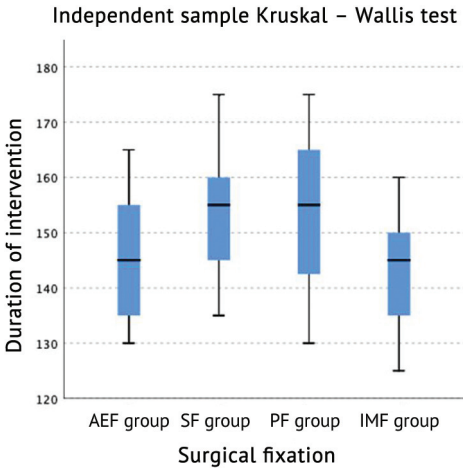

Fig. 6 Differences in the duration of the operation in groups of patients with different fixation options for arthrodesis

A comparative analysis of the dynamics of the functional state of the affected limb in groups of patients after arthrodesis revealed that 3 months after surgery, a significant difference between AOFAS scores was observed. At the same time, the maximum score was recorded in the PF group (68.95 ± 3.44 points), the minimum in Ilizarov apparatus EF group (62.67 ± 1.32 points) (Table 4).

Table 4

Comparison of the average AOFAS score in groups of patients after arthrodesis surgery

Method of surgical fixation	Average AOFAS score post-surgery			
	3 months	6 months		12 months
EF group (*n* = 21)	62.67 ± 1.32	73.48 ± 5.48		77.62 ± 6.74
SF group (*n* = 23)	66.57 ± 2.43		76.35 ± 3.42	79.91 ± 5.08
PF group (*n* = 20)	68.95 ± 3.44		77.30 ± 3.51	80.60 ± 3.73
IMF group (*n* = 18)	64.72 ± 1.32	72.94 ± 3.08		80.50 ± 3.26
p	1.00	0.67	0.45	0.23

Note: the significance of differences between groups was assessed using the Student – Newman – Keuls test

After 6 months, there was no significant difference between the mean AOFAS score in the AFF and IMF groups ($p = 0.67$). Similarly, AOFAS scores were not significantly different between the SF and PF groups ($p = 0.45$). However, the average AOFAS score in the SF and PF groups was significantly higher than in the AEF and IMF groups ($p < 0.05$) (Table 4).

Analysis of the average AOFAS score at the follow-ups did not reveal differences between the groups (Table 4). The dynamics of this parameter in all groups was unidirectional, an increase in the average score and improvement in the function of the affected limb (Fig. 7).

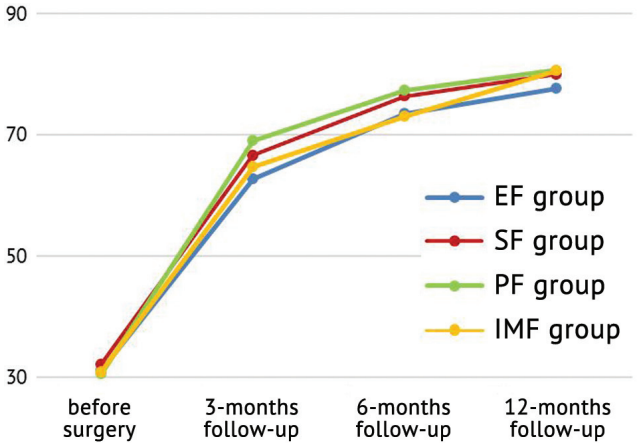

Fig. 7 Comparison of the dynamics of the average AOFAS score in groups of patients with different fixation options after arthrodesis procedure

Comparison of pain intensity in the affected joint 3 months after the intervention revealed no significant differences between the average VAS scores in the SF, PF and IMF groups. However, the AEF group had a significantly higher mean score than the other three fixation methods (Table 5).

Similar results were obtained upon re-evaluating the intensity of pain 6 months after (Table 5).

However, a comparative analysis of the final assessment of pain according to VAS one year after surgery revealed no differences between the groups (Table 5; Fig. 8).

Table 5

Comparison of the average VAS score in groups of patients after arthrodesis surgery

Method of surgical fixation	Average VAS score post-surgery				
	3 months		6 months		12 months
EF group ($n = 21$)	4.24 ± 0.83		3.43 ± 0.93		2.81 ± 1.08
SF group ($n = 23$)		3.57 ± 0.66		2.78 ± 0.85	2.61 ± 0.78
PF group ($n = 20$)		3.50 ± 0.76		2.65 ± 0.59	2.25 ± 0.55
IMF group ($n = 18$)		3.67 ± 0.91		2.78 ± 0.88	2.61 ± 0.85
p	1.00	0.78	1.00	0.87	0.15

Note: significance of differences between the groups was assessed using the Student – Newman – Keuls test

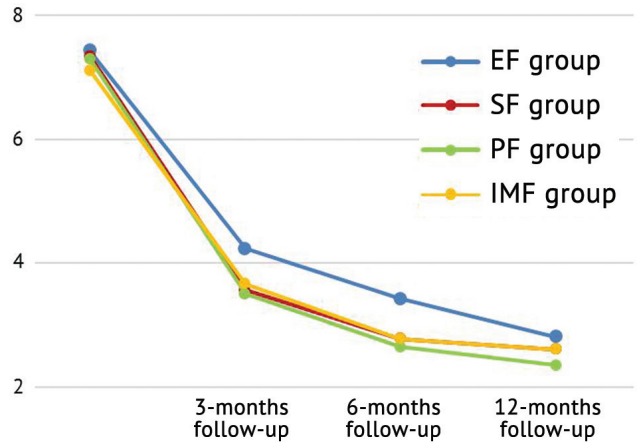

Fig. 8 Comparison of the dynamics of the average VAS score in groups with regard to fixation options

The postoperative period was uneventful in most cases. The diagram shows that the maximum of complications in the postoperative period was recorded in the IMF group, and the minimum in PF group (Fig. 9). However, these differences were not statistically significant ($p > 0.05$).

Fusion was achieved in most patients postoperatively, regardless of the method of fixation (Fig. 10).

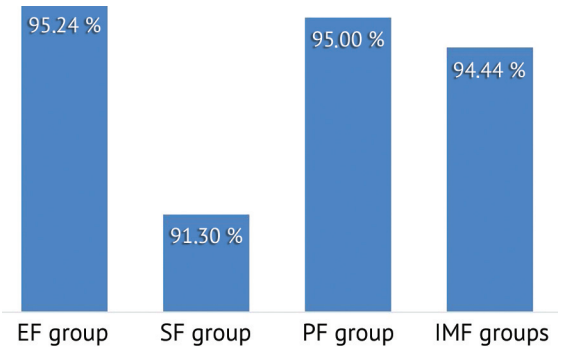

Fig. 9 Comparison of the incidence of complications with regard to the method of fixation

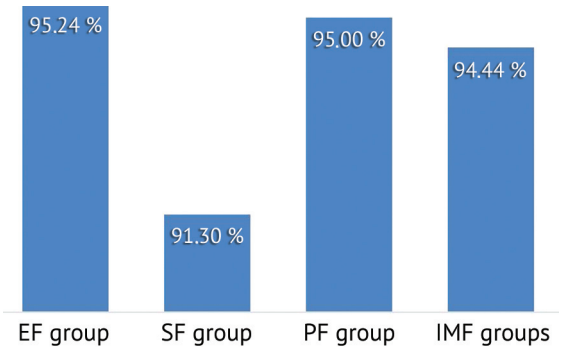

Fig. 10 Comparison of fusion rates in regard to the method of fixation

As follows from the diagram above, postoperative fusion was the highest in the AFF group, and the lowest rate was in cases of fixation with screws. However, the differences between the groups did not reach the level of statistical significance.

DISCUSSION

Ankle joint arthrodesis is a reliable method for treating advanced stages of ankle OA, which effectively reduces pain intensity and improves the function of the affected limb [4]. The success of arthrodesis the joint lies in the observance of several key principles, including adequate bone contact, interosseous compression and stability at the bone contact site [8, 13]. The success rate is 85–100 % [9, 15].

A study by Morasiewicz et al. [17] revealed that the intensity of pain assessed using the VAS scale in arthrodesis of the ankle joint with Ilizarov apparatus fixation is lower than with screw fixation. However, Teramoto et al. [21] reported that intraoperative bleeding and operative time were lower with screw-fixed arthrodesis of the anklet joint than with the Ilizarov fixation.

Nonunion is the most common among postoperative complications. Historical data report that the incidence of nonunion reached 40 % [22], but in the current literature the reported incidence of nonunion approaches 10 % [15, 23].

SF is traditionally considered a more preferable technique due to its easy performance and high fusion rate [24]. More recent studies have shown SF fusion rates ranging from 91 to 100 % [8]. However, there is no guarantee of its reliability in patients with osteoporosis [25].

On the other hand, some authors note that PF has high stability and rigidity [26]. In one of the latest studies, the rate of arthrodesis fusion with PF application was observed to be up to 97.6 % [19, 27]. However, another study did not find a significant difference in the results between the use of screws and plates in arthrodesis of the joint [28].

In contrast, IM fixation has a low technical threshold and can be quickly mastered by surgeons, and its union rate is 71–95 % [6].

In this study, the overall fusion rate was 93.90 % (77 cases). Although there was a difference in fusion rates between the groups, it was not statistically significant.

Besides nonunion, other complications of ankle arthrodesis include aseptic loosening, malposition, infectious complications, and nerve damage [12, 15].

The study by Slivkova et al. showed that 28 % of patients start experiencing complications within three weeks after surgery [29]. Several authors have argued that treatment with intramedullary locking nails is more effective than screws and plates, with the advantage of high fusion rates and low complication rates. However, the technique requires reaming and may increase the likelihood of infection, pulmonary embolism, and systemic inflammation [6].

In our study, the overall complication rate was 12.20 % (10 cases).

Postoperative infections of the postoperative wound area or the exit sites of the pins predominated — 4 (4.88 %) cases. Two of these cases occurred in the AVF group. Changing the antiseptic, piercing the exit points of the needles with an antibiotic, and ultraviolet irradiation made it possible to stop complications without consequences for the final result of treatment in one patient. However, in another patient, arthrodesis did not occur as a result.

In the case of fixation with a blocked retrograde IM after deep infection, loosening of the implant occurred with the subsequent development of postoperative nonunion. One of the patients, after fixation with cannulated screws, underwent multiple debridement operations with antibiotic therapy. Attempts at revisions did not lead to relief of the infectious process, and arthrodesis did not take place.

The main cause of the two nonunion cases was fracture of the implants in the groups SF (one case) and PF (one case). Two relatively rare cases (2.4 %) of postoperative refracture that occurred after IM fixation were judged as associated with stress concentration.

We considered venous thromboembolism to be the most serious complication, since it could be fatal for the patient [30]. In this study, two cases (2.4 %) of this complication were observed in AEF and SF groups.

It should be noted that patients in the AEF group had more compromised conditions compared with other groups, and among them were patients with etiologies causing bone damage or infection. However, postoperative results, both in terms of the rate of union and the rate of complications, did not differ significantly from other groups. This confirms the position that EF has significant advantages in overcoming the above difficulties.

Thus, the majority of patients initially reported unsatisfactory ankle function and chronic pain of moderate and high intensity. After the arthrodesis operation, the majority of patients reported a significant improvement in function and a decrease in pain intensity, which indicates the effectiveness of this approach to the treatment of ankle OA.

The comparison of the effectiveness of the four surgical fixation methods found that they have both advantages and disadvantages. External fixation and nailing are characterized by lower volumes of blood loss and a relatively short duration of the operation. If plates and screws are used, functional recovery occurs faster and pain intensity is reduced more effectively. Overall, there was little difference in postoperative outcomes at long-term follow-up, and the effectiveness of the techniques used was similar. Based on this, we believe that the most appropriate surgical treatment plan should be developed considering the patient's condition, including his age, life history, patient compliance, and other factors and should be based on the principle of individual approach in combination with clinical examination and imaging [4, 10].

CONCLUSION

The effectiveness of ankle joint arthrodesis in the treatment of advanced OA is quite high and can significantly improve the function of the affected limb and reduce the intensity of pain in the joint.

Each fixation method has its own advantages and shortcomings, but there is no significant difference in long-term outcomes. The choice of the optimal surgical method to achieve the effective result should be based on the principle of an individual approach.

Conflict of interest *The authors declare that there are no obvious or potential conflicts of interest related to the publication of this article.*

Financing *The study was not sponsored.*

Ethical review *The study was reviewed and approved by the local ethics committee of the Federal State Budgetary Educational Institution of Higher Education Kazan State Medical University of the Ministry of Health of Russia (protocol No. 1 of 02.03.2021) and the Local Ethics Committee of the Central Hospital of Wuhan (protocol No. 2835 of 15.01.2019).*

Informed consent *All patients signed an informed consent.*

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