

Original article

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Tibiototalcaneal arthrodesis for end-stage post-traumatic osteoarthritis of the ankle and subtalar joints: a comparative assessment of internal fixation implants

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Abstract

Introduction Post-traumatic osteoarthritis of the ankle and subtalar joints develops secondary to joint trauma, with clinical signs of pain and dysfunction of the lower limbs in working age patients. Tibiototalcaneal arthrodesis (TTCA) is the standard surgical treatment for end-stage disease. The optimal fixation method remains a matter of debate.

The **objective** was to compare clinical and functional outcomes of TTCA for end-stage post-traumatic osteoarthritis of the ankle and subtalar joints using three methods of internal fixation.

Material and methods A retrospective controlled parallel-group study enrolled 46 patients treated with TTCA and anatomically curved retrograde intramedullary nail (Group 1, $n = 15$); TTCA using a straight retrograde intramedullary nail (Group 2, $n = 15$); arthrodesis and interlocking nailing (Group 3, $n = 16$). Clinical status and functionality were evaluated using the American Orthopaedic Foot and Ankle Society (AOFAS) score and the Visual Analogue Scale (VAS). Statistical analysis was produced using Kruskal – Wallis test, Mann – Whitney U-test with Bonferroni correction, Pearson χ^2 test, Fisher's exact test ($p < 0.05$).

Results Groups were comparable for age and VAS pain intensity at baseline ($p = 0.162$ and $p = 0.268$, respectively). Baseline AOFAS differed significantly ($p = 0.049$) with the median measuring 20.0 (15.0–32.5) in Group 1, 32.0 (27.5–40.0) in Group 2, and 29.5 (26.0–37.2) in Group 3. The AOFAS functional scores were comparable at a follow-up examination measuring 73.0 (52.5–79.0), 71.0 (66.5–78.0), and 75.0 (50.8–80.0) in the groups, respectively ($p = 0.978$). Pain reduction was equivalent across groups ($p = 0.661$). Complications developed in seven cases (15.2 %) with no significant between groups differences ($p = 0.354$); active smoking was a significant predictor of complications (31.2 % vs 6.7 %; $p = 0.040$). Patient satisfaction was 100%, 93.3 %, and 75.0% in groups 1, 2 and 3, respectively ($p = 0.067$).

Discussion Comparable outcomes across three groups were consistent with the literature: the success of arthrodesis rather relies on adequate foot positioning and the quality of joint resection rather than on a fixation construct.

Conclusion The three internal fixation options for TTCA provided comparable clinical and functional results in the mid-term follow-up period. Individual patient characteristics and surgical experience would be essential for the choice of the construct.

Keywords: tibiototalcaneal arthrodesis, retrograde intramedullary interlocking nailing, internal plate fixation, post-traumatic osteoarthritis, ankle joint, subtalar joint, AOFAS score, visual analogue scale

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INTRODUCTION

Posttraumatic osteoarthritis (OA) of the ankle and subtalar joints is a common and debilitating musculoskeletal disorder. Patients who suffer from ankle arthritis often experience severe and debilitating pain, leading to impaired function and reduced quality of life [1, 2]. Posttraumatic ankle arthritis (AA) is considered as the most common cause of ankle arthritis which is relatively rare compared to arthritis of the hip and the knee [3]. Posttraumatic ankle arthritis occurs in a generally younger, active population and patients with end-stage ankle arthritis experience a high degree of functional impairment [2].

The main etiology, representing 75–80 % of all cases, is a traumatic event, and ankle osteoarthritis affects 1 % of the adult population [4, 5, 6, 7]. Post-traumatic OA develops secondary to joint trauma. Individuals with a history of impaired ligaments of the ankle joint develop ankle OA in 3.85 % and in 2.66 % without a previous injury (relative risk 1.46 %). The overall rate of posttraumatic OA after ankle fracture fixation is 27.7 % in patients under 50 over a five-year follow-up period. Ankle fracture-dislocations are associated with 43 % of early posttraumatic AA within two to three years. Predisposing factors include obesity, fracture dislocation, posterior tibial fracture, articular incongruity, female gender, and a high body mass index [7]. The time from injury to the end-stage disease averages 20 years, decreasing in cases of severe injuries or complicated healing.

The degree of functional impairment in end-stage ankle OA is quite significant: the American Orthopaedic Foot and Ankle Society (AOFAS) ankle score, representing a widely accepted clinical-functional evaluation of the patients, showed an overall mean of 38 scores [6]. The severity of pain and physical limitations correlates with the severity of clinical symptoms to a greater extent than with the radiographic manifestations. The prevalence of this pathology is significantly higher among individuals with a history of severe lower limb injuries [4, 5].

When conservative treatment of end stages post-traumatic arthritis of the ankle and subtalar joints is ineffective, surgical intervention is indicated. The pathology is associated with involvement of the hindfoot. Total ankle arthroplasty is not an adequate treatment method for concurrent subtalar and ankle arthritis, since it can ensure restoration of ankle mobility and does not eliminate pathological changes in the subtalar joint [8, 9, 10]. In such clinical situations, tibiotalar-calcaneal arthrodesis (TTCA) is the method of choice to facilitate simultaneous stabilization of both joints, reliable pain relief and restoration of limb support function [8, 9, 11, 12].

Isolated end stage AA (without involving the subtalar joint) can be treated with two surgical methods: ankle arthrodesis and total ankle arthroplasty. Arthrodesis is traditionally considered the "gold standard" due to its predictable pain relief, reliability, and acceptable long-term complications [10, 13]. Total ankle arthroplasty provides higher short-term functionality and quality of life; however, the advantage levels out by 4–10 years of follow-up, and the rate of revision interventions is significantly higher with arthroplasty [10, 14, 15]. The TARVA (Total Ankle Replacement Vs. Arthrodesis) study did not confirm the superiority of arthroplasty in the primary outcome at 52 weeks of follow-up [16]. However, when the degenerative process extends to the subtalar joint (as in the patients in this series), total ankle arthroplasty loses its effectiveness as an isolated intervention. Replacing the ankle alone does not eliminate the pain and functional deficits caused by subtalar damage.

Retrograde intramedullary nailing (RIMN) offers benefits among the internal fixation methods used in TTCA with the construct centrally positioned and multiplanar locking ensuring high rotational and axial stability and simultaneous ankle and subtalar fixation [9, 11]. Plating can

be used in isolated and combined procedures to allow for precise compression at the arthrodesis site [17, 18, 19]. The Ilizarov external fixation is normally used for significant bone defects or severe deformities [20, 21]. There is a paucity of data to compare different intramedullary nail and plate designs in TTCA.

The **objective** was to compare clinical and functional outcomes of TTCA for end-stage post-traumatic OA of the ankle and subtalar joints using three methods of internal fixation.

MATERIAL AND METHODS

A retrospective, controlled, parallel-group study was conducted. The minimum postoperative follow-up period was 12 months. Inclusion criteria included age over 18 years; end-stage ankle and subtalar joint arthritis (Kellgren–Lawrence grades III–IV [22]); ineffective conservative treatment for at least six months; proficiency in written Russian; informed voluntary consent. Exclusion criteria included significant defects of the talus; deformities of the ankle and foot of neurogenic genesis (cerebral palsy, polyneuropathy, consequences of acute cerebrovascular accident, etc.); high activity of rheumatoid arthritis; oncological or metastatic bone lesions; mental disorders; indications for external fixation (severe deformities, active infectious joint lesion); significant defects of the integumentary tissues or the need for staged skin reconstruction; midfoot and forefoot deformity requiring surgical treatment; patient's refusal of arthrodesis.

Active smoking status was considered as a potential risk factor for delayed consolidation and postoperative complications, since the negative impact of smoking on bone fusion during arthrodesis of the foot and ankle was reported [23, 24]. The study included 46 patients with confirmed posttraumatic arthrosis of the ankle and subtalar joints who underwent TTCA produced for 19 (41.3 %) male and 27 (58.7 %) female patients (Table 1).

Table 1

Characterization of patient groups

Description			Group 1 (anatomically curved pin), <i>n</i> = 15	Group 2 (straight retrograde pin), <i>n</i> = 15	Group 3 (plating), <i>n</i> = 16	<i>p</i>
Gender	male	abs.	8	2	9	0.027*
		%	53	13	56	
	female	abs.	7	13	7	
		%	47	87	44	
Age, years Me (Q1–Q3)			52 (47–61)	54 (38–56)	46 (36–51)	0.162
Previous surgical treatment		abs.	9	8	9	0.934
		%	60.0	53.3	56.2	
Smoking (active)		abs.	7	3	6	0.297
		%	46.7	20.0	37.5	
AOFAS to, score Me (Q1–Q3)			20.0 (15.0–32.5)	32.0 (27.5–40.0)	29.5 (26.0–37.2)	0.049*
VAS to, score Me (Q1–Q3)			7.0 (6.0–9.0)	7.0 (6.0–7.5)	8.0 (7.0–8.2)	0.268

Note: *, statistically significant differences ($p < 0.05$); Me, median; Q1, Q3, lower and upper quartiles.

Patients were divided into three groups depending on the type of fixation used:

- Group 1 ($n = 15$): TTCA using an anatomically curved retrograde intramedullary nail;
- Group 2 ($n = 15$): TTCA using a straight retrograde intramedullary nail;
- Group 3 ($n = 16$): arthrodesis using fixation with a bone plate.

Patients were allocated to groups in a non-randomized manner: the type of fixation device was determined by clinical indications and the preferences of the operating surgeon. Gender distribution was uneven: females significantly predominated in Group 2 (2:13). The initial level of functional activity in the groups differed significantly ($H = 6.036$; $p = 0.049$). There were no differences in the preoperative pain measured with VAS ($H = 2.636$; $p = 0.268$) (Table 1).

Surgical technique

In Groups 1 and 2, TTCA was performed using a locking intramedullary retrograde nail. The procedure was produced under general or spinal anesthesia with the patient lying on the healthy lateral or semi-lateral position. The nail insertion point was determined on the plantar surface of the foot using image intensifier. With the calcaneus exposed, the subtalar and ankle joints were sequentially penetrated. Before nail insertion, a thorough resection of the articular cartilage down to the subchondral bone was performed using an osteotome through a lateral (transfibular) approach, preserving congruent surfaces. The foot was fixed in neutral dorsiflexion (0°), 5° of calcaneal valgus, and external rotation corresponding to the contralateral limb. Multiplanar locking was performed in accordance with the nail design. The anatomical and straight rods differed in the geometry of the distal end of the pin, locking, and the mechanism of interfragmentary compression.

In Group 3, the bone was plated through an open surgical approach. Anatomical locking plate was placed and fixed with locking and compression screws after resection of the articular surfaces through a lateral (transfibular) approach, realignment of the limb providing congruent bony contact surfaces. The postoperative care protocol was identical in the three groups and included ankle immobilization for six weeks, limited weight-bearing for eight weeks and physical therapy from the first day after the procedure.

Clinical assessments

Clinical and functional evaluation of the surgical outcomes was performed using two instruments. The AOFAS ankle and hindfoot scale [25, 26] allowed for the assessment of pain (40 scores), functional activity (50 scores), and segment alignment (10 scores); the maximum score was 100 points, with a higher value indicating a better outcome. Pain intensity was assessed using VAS with 0 suggesting no pain and 10 indicating maximum tolerable pain. The assessment was performed preoperatively and at 12 months [27].

Statistical analysis

Statistical analysis was performed using IBM SPSS Statistics software (version 26.0; IBM Corp., Armonk, NY, USA). The normal distribution was tested using the Shapiro – Wilk test; due to deviations from the normal distribution, quantitative data were presented as Me (Q1–Q3). The Kruskal – Wallis test was employed to compare three independent groups. Pairwise comparisons were made with the Mann – Whitney U test and Bonferroni correction for statistically significant differences detected. Qualitative variables were compared using the Pearson χ^2 test; the Fisher's exact test was used for expected frequencies in cells less than five. The significance level was $p < 0.05$.

The study received a favourable opinion from the Ethics Committee of the National Medical Vreden Research Center for Trauma and Orthopedics" of the Ministry of Health of the Russian Federation (Abstract of Minutes No. 1 Protocol No. 1 dated February 5, 2024). The patients gave informed consent for publication of the findings without identification.

RESULTS

Functional outcomes were comparable in the three groups at a follow-up (Table 2). The median AOFAS scored 73.0 (52.5–79.0) post-op in Group 1, 71.0 (66.5–78.0) in Group 2, and 75.0 (50.8–80.0) in Group 3; there were no differences between the groups ($H = 0.045$; $p = 0.978$). Patients in Group 1, who initially had the lowest AOFAS scores, showed postoperative results that were completely comparable with Groups 2 and 3. The median absolute increase in AOFAS scored 47.0 (34.0–51.0) in Group 1, 36.0 (34.0–45.0) in Group 2, and 36.0 (14.2–47.5) in Group 3 ($H = 3.621$; $p = 0.164$). The intensity of pain showed no differences between the groups ($H = 0.829$; $p = 0.661$) post-op.

Table 2

Clinical and functional results of surgical treatment

Description		Group 1 (anatomically curved pin), $n = 15$	Group 2 (straight retrograde pin), $n = 15$	Group 3 (plating), $n = 16$	p
AOFAS post-op (score), Me (Q1–Q3)		73.0 (52.5–79.0)	71.0 (66.5–78.0)	75.0 (50.8–80.0)	0.978
Increase in AOFAS (score), Me (Q1–Q3)		47.0 (34.0–51.0)	36.0 (34.0–45.0)	36.0 (14.2–47.5)	0.164
VAS post-op (score), Me (Q1–Q3)		2.0 (1.0–3.0)	2.0 (2.0–3.0)	2.5 (1.0–4.2)	0.661
Healing	abs.	15	14	14	0.371
	%	100.0	93.3	87.5	
Adverse events	abs.	2	1	4	–
	%	13.3	6.7	25.0	
Satisfaction with outcomes	abs.	15	14	12	0.067
	%	100.0	93.3	75.0	

Note: Me, median; Q1, Q3, lower and upper quartiles; no intergroup comparison performed

The dynamics in AOFAS in the comparison groups is presented in Figure 1, the dynamics in VAS presented in Figure 2.

A comparison in the functional improvement (increase in AOFAS) is presented in Figure 3.

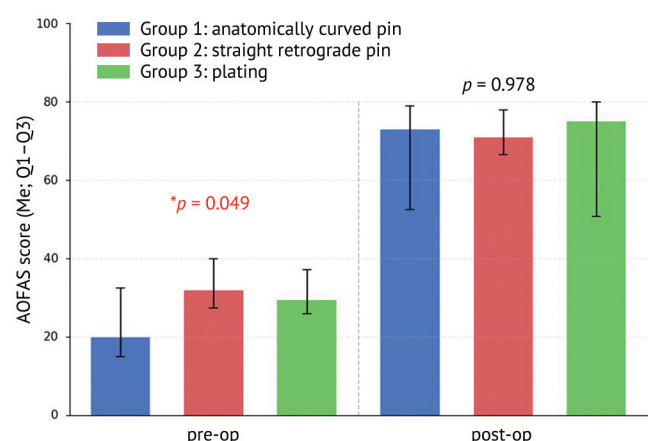


Fig. 1 AOFAS scores pre- and post-op in the comparison groups (bars, Me; error bars, Q1–Q3): $^*(p = 0.049)$ statistically significant differences in preoperative scores between the groups; ($p = 0.978$) postoperative scores are comparable

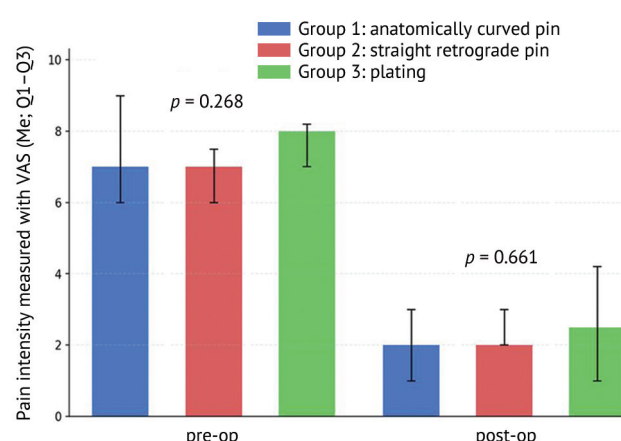


Fig. 2 Visual analogue scale (VAS) scores pre- and post-op in the comparison groups (bars, Me; error bars, Q1–Q3). Differences between the groups are statistically insignificant at all observation periods

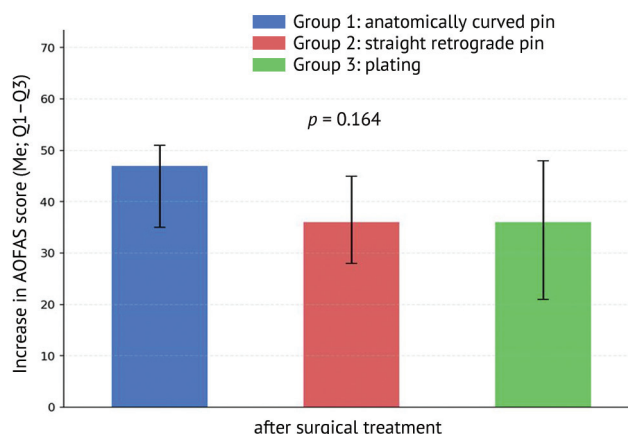


Fig. 3 Absolute increase in AOFAS score after surgical treatment in the comparison groups (bars, median; error bars, Q1–Q3). Differences between groups are statistically insignificant ($p = 0.164$)

Complications were recorded for all 46 patients. A non-healing wound was observed in Group 1 ($n = 2$; 13.3 %). A broken implant and non-union at the arthrodesis site was seen in Group 2 ($n = 1$; 6.7 %). Adverse events observed in four patients (25.0 %) of Group 3 included: arthrodesis failure (including one case with broken construct) ($n = 2$); infectious and inflammatory complications (osteomyelitis and wound infection) ($n = 2$). Bone consolidation was radiographically evaluated in the 46 patients. Arthrodesis was achieved in 43 patients (93.5 %) including 15 (100.0 %) in Group 1, 14 of 15 (93.3 %) in Group 2, and 14 of 16 (87.5 %) in Group 3. Three cases of failure (6.5 %) were observed in Group 2 as pin fracture and nonunion ($n = 1$), in Group 3 as arthrodesis nonunion ($n = 2$). No statistically significant differences in the rate of radiographic union were found between the groups ($\chi^2 = 1.985$; $df = 2$; $p = 0.371$). The result was indicative due to low expected frequencies in some cells.

Pooled analysis of the three groups showed a statistically significant association between active smoking and postoperative complications. Complications were recorded in five of 16 smoking patients (31.2 %) versus two of 30 non-smokers (6.7 %); Fisher's exact test, $p = 0.040$. Satisfaction with the treatment results was reported by 15 (100 %) patients in Group 1, 14 (93.3 %) patients in Group 2, and 12 (75.0 %) patients in Group 3 ($\chi^2 = 5.400$; $df = 2$; $p = 0.067$). The differences between the groups did not reach the level of statistical significance. However, more patients who were not satisfied with the outcome were observed in Group 3 (four of 16, 25.0 %). The four cases of dissatisfaction were associated with postoperative complications. The median satisfaction rate scored 4.0 (4.0–4.5) in Groups 1 and 2 and 4.0 (4.0–5.0) in Group 3 (Kruskal – Wallis test: $H = 0.086$; $p = 0.958$) using a scale of 1 to 5. No differences in subjective assessment of the results were found between the groups.

DISCUSSION

No significant differences in postoperative clinical and functional parameters were found between the three groups ($p = 0.978$ according to AOFAS; $p = 0.661$ according to VAS). This is consistent with the concept reported in the literature: the outcome of arthrodesis is rather determined by accuracy of foot positioning and the quality of resected articular surfaces than by the design of the fixation system [8, 17, 28, 39]. The postoperative AOFAS scores (median 71.0–75.0) correspond to the range reported in foreign studies on TTCA with a retrograde intramedullary nail. A systematic review reported by Franceschi et al. [29] included 22 studies (more than 700 patients) with the consolidation rate of 80–96 % and a significant improvement in pain and functionality.

The increase in AOFAS scored 30–50 in prospective cohort studies with at least five years of follow-up [30, 31], which coincides with the median increase of 36.0–47.0 scores recorded in this series of observations.

The AOFAS in healthy individuals normally scores 90–100 [32]. According to the literature, postoperative AOFAS in arthrodesis for posttraumatic arthritis ranges between 61 and 83 scores (in most series, 70–83 scores with an observation period of 2 to 15 years) [32–34], while preoperative values in end-stage arthritis do not exceed 25–33 scores [33]. The medians of 71.0–75.0 scores in this series fall within this range. However, arthrodesis does not ensure complete restoration of functional activity. Biomechanical analysis suggests that patients continue to have disturbances in gait patterns and experience decreased weight-bearing capacity of the operated limb compared to the norm [34, 35].

In this series, complications were found in seven of 46 patients (15.2 %) including two cases (13.3 %) in Group 1, one case (6.7 %) in Group 2, and four cases (25.0 %) in Group 3; no statistically significant differences were found between the groups ($p = 0.354$). The radiographic union rate was 93.5 % (43 of 46 patients) with no significant differences between the groups ($p = 0.371$), which is in line with 80–96 % reported in systematic reviews of TTCA [29]. The cumulative postoperative complication rate of 15.2 % is also in line with the lower limit of the range reported in the literature for TTCA: wound complications occur in 20–24 %, nonunion observed in 8–19 %, and revision surgery is required in 8–32 % of cases [29]. The most heterogeneous complication profile was recorded in Group 3 (plating), which is consistent with observations of van den Heuvel et al. [36], who recorded a higher incidence of deep infection with plating (28.6 % versus 0 % in the pin groups; $p = 0.017$), and the inter-group difference did not reach the significance threshold in this series. Risk factors for non-union in TTCA include diabetes mellitus, active smoking, and Charcot neuroarthropathy [37]. Active smoking was a significant predictor of postoperative complications in this series regardless of the fixation method used. Adverse events developed in 31.2 % of smoking patients versus 6.7 % of non-smokers (Fisher's exact test, $p = 0.040$), which is supported by the known negative effect of nicotine on bone consolidation and soft tissue healing.

Intramedullary nailing is considered as a single entity in most published series without differentiation based on the specific design [29, 30, 31]. An attempt was made in the series to compare two different types of retrograde nails with each other and with external fixation. The number of locking planes, the geometry of the distal end, and the mechanism of interfragmentary compression are theoretically capable of influencing primary stability. However, it was established in this series that, if the surgical technique is adequately produced, the design differences do not affect the clinical outcome. The outcome would rather rely on a surgical technique (precise resection and correct positioning) than on the choice of implant [8, 9, 39].

The initial difference in preoperative AOFAS scores ($p = 0.049$) is to be commented. Patients in Group 1 had the most severe functional status before surgery (20.0 (15.0–32.5) scores), which probably reflects the peculiarities of patient routing. Nevertheless, it was this group that showed the greatest absolute increase in AOFAS (47.0 (34.0–51.0) scores) and reached the results that were completely comparable with Groups 2 and 3 (Figs. 1, 3). The presented observations confirm the effectiveness of TTCA with anatomically curved retrograde intramedullary nail in patients with pronounced functional deficit, which is consistent with the data of the systematic review reported by Jehan et al. [1].

There were 86.7 % females in Group 2, which could have affected the results, since this factor was not included in the multivariate analysis. Fletcher et al. [38] reported that females with end-stage ankle osteoarthritis have higher initial levels of pain and functional impairment than males, while postoperative gains in functionality are comparable between the genders. The absence of significant postoperative differences between the groups in this series allows us to consider the influence of gender imbalance as insignificant; however, the small sample size does not rule out residual systematic bias. It would be advisable to consider gender in the multivariate analysis in future studies. A comparable decrease in postoperative VAS ($p = 0.661$, Fig. 2) indicates an equivalent analgesic effect of the three methods. A systematic review reported by Jehan et al. [1] included 613 patients treated with TTCA using a locking intramedullary nail and improved pain and functionality post-op regardless of the type of intramedullary fixation, which is consistent with the results of the present series. In practice, the choice of fixation method in TTCA is determined by the extent of joint damage, the quality of bone tissue, the condition of soft tissues and surgical experience [9].

Patients of this series with concurrent ankle and subtalar involvement could not be treated with TAA, as an isolated intervention because replacement of a joint could not eliminate the pathology of the contralateral joint. TTCA for such clinical scenario remains the only adequate method, and the comparison was carried out by the type of fixation construct used [8, 9, 10]. Limitations of this series include a small sample size (15–16 patients in each group) reducing the statistical power of pairwise comparisons. The retrospective design did not allow us to rule out selection bias, which is indirectly indicated by the baseline heterogeneity of the groups according to AOFAS. Gender imbalance in Group 2 (86.7 % females) was not considered in the multivariate analysis.

CONCLUSION

The retrospective study demonstrated the comparability of clinical and functional outcomes of TTCA using three types of internal fixation: the median AOFAS scored 73.0–75.0 at 12 months with no differences between the groups ($p = 0.978$), reduction in pain intensity measured with VAS being equivalent in all groups ($p = 0.661$). The rate of radiographic fusion reached 93.5 % in the total sample with 100 % of patients treated with anatomically curved nail, 93.3 % of cases treated with the straight retrograde nail, 87.5 % of cases treated with plating; $p = 0.371$. Patients with the most severe functional deficit at baseline (Group 1, preoperative median AOFAS scored 20.0) showed the greatest absolute increase in the parameter suggesting the advantages of an anatomically curved nail in severely impaired function.

Conflict of interests The authors declared no potential conflicts of interest with respect to the authorship and/or publication of this article.

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Ethical Approval The study was conducted in accordance with basic ethical principles and guidelines. The study protocol was approved by the Ethics Committee of the R.R. Vreden National Medical Research Center of Traumatology and Orthopedics of the Russian Ministry of Health (Abstract of minutes No. 1 Protocol No. 1 dated February 5, 2024). The patients gave informed consent for publication of the findings without identification.

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