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Comparing the efficacy of ankle arthrodesis performed through anterior or lateral approaches in end-stage ankle arthritis treatment

Hongbin Cao¹, Nan Li¹, Guixin Wang¹, Jun Liang¹, Haijing Huang¹ and Jinquan He^{1*}

Abstract

Purpose To investigate the clinical efficacy of arthrodesis performed through anterior and lateral approaches for ankle arthritis treatment.

Methods A retrospective analysis of the clinical data of 86 patients with ankle arthritis treated with ankle arthrodesis between January 2019 and December 2022 was conducted. According to the inclusion and exclusion criteria, 65 patients were ultimately included. The ankle osteoarthritis score (AOS), the American Orthopaedic Foot and Ankle Society (AOFAS) ankle and hindfoot scoring system, and alignment changes (medial distal tibial angle (MDTA), anterior distal tibial angle (ADTA), and Talus tilt angle (TTA)) were used to evaluate ankle function before surgery and at the last follow-up.

Results Throughout the follow-up period, there were no significant differences between the two groups in terms of age, sex, operation time, average union time, union rate, total complication rate, or incidence of various types of complications. The AOSs were as follows: anterior approach group, preoperative 57.61 ± 3.64 ; last follow-up, 19.34 ± 2.19 ; lateral approach group, preoperative 56.62 ± 3.49 ; and last follow-up, 19.76 ± 2.39 . The AOFAS scores were as follows: anterior approach group, preoperative 38.64 ± 2.52 ; last follow-up, 79.75 ± 4.85 ; lateral approach group, preoperative 37.33 ± 2.18 ; and last follow-up, 80.00 ± 3.70 . Both patient groups exhibited good therapeutic effects before and after treatment, and there were no significant differences in the AOSs or AOFAS scores between groups at the last follow-up. Both patient groups exhibited significant changes in MDTA, TTA, and ADTA before and after treatment, and there were no significant differences between groups at the last follow-up. The preoperative TTA (5.02 ± 2.67) of the anterior approach group was smaller than that of the lateral approach group (14.28 ± 5.08), and the difference in TTA correction after different surgical approaches was significant, with the lateral approach treatment being more effective for TTA correction.

Conclusion Both the anterior approach and the lateral approach for the treatment of ankle arthritis can achieve good therapeutic effects, with no significant differences in complications between the two methods, and the lateral approach has good therapeutic efficacy for varus ankle arthritis greater than 10 degrees.

Keywords End-stage ankle arthritis, Anterior approach, Lateral approach, Ankle arthroplasty

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Introduction

Ankle osteoarthritis is a chronic degenerative disease characterized by cartilage degeneration, subchondral bone sclerosis, osteophyte formation, and joint deformity. Approximately 1% of the population worldwide suffers from ankle osteoarthritis [1, 2]. It can cause severe pain and disability, and its impact on quality of life is similar to that of end-stage hip and knee arthritis [3, 4]. Ankle osteoarthritis is caused primarily by traumatic factors, including recurrent ankle instability, ankle fractures, and talus fractures [2]. Other contributing factors include rheumatoid arthritis, neuropathic arthritis, gout, talus necrosis, and postinfection arthritis [5, 6]. Regardless of the cause, the treatment of ankle osteoarthritis depends on the stage of the disease. Takakura classified the severity of ankle osteoarthritis into four stages, with patients in stages I and II being candidates for conservative treatment and joint-preserving surgery, whereas those in stages III and IV do not respond well to conservative treatment, making surgery the only viable treatment option. Tanaka et al. suggested that for stage 3B ankle osteoarthritis, owing to the poor prognosis, joint-preserving surgery is no longer suitable, and patients tend to choose ankle arthrodesis or total ankle replacement [7].

Ankle arthrodesis has long been considered the gold standard for treating end-stage ankle arthritis [8, 9]. Although more patients are now undergoing total ankle replacement surgery as a result of advances in the technology, ankle arthrodesis remains an effective treatment for end-stage ankle arthritis because of its ability to achieve joint stability, relieve pain, and keep the foot in a plantigrade position [10, 11]. Specific techniques include open ankle arthrodesis, arthroscopic ankle arthrodesis, and minimally invasive ankle arthrodesis; approaches include the anterior approach, lateral approach, posterior approach, or a combined internal and external approach; and fixation methods include screws, plates, external fixation, or a combination of both. The most commonly used approaches are the anterior approach and lateral approach [12–14]. However, although ankle arthrodesis is a classic surgical procedure, many postoperative complications, such as nonunion, wound infection, malalignment, and secondary OA of adjacent joints, still exist, with different approaches resulting in varying rates of union and complications [15–18]. Therefore, exploring the clinical efficacy of ankle arthrodesis and preventing postoperative complications is particularly critical.

In this retrospective study, the data of patients with ankle osteoarthritis treated with ankle arthrodesis via anterior and lateral approaches were evaluated and the joint fusion union time, patient satisfaction and occurrence of complications were systematically evaluated. The objectives of this study were to explore the clinical

efficacy of ankle arthrodesis performed using anterior and lateral approaches in the treatment of ankle arthritis.

Materials and methods

Time frame of the study

A retrospective analysis was conducted on 86 patients who underwent ankle arthrodesis through an anterior or lateral approach between January 2019 and December 2022. The follow-up times ranged from 15 to 48 months, with an average follow-up time of 22.8 months.

Database used

All the patients' data were collected from the electronic medical records system (Winning Health Technology Group Co., Ltd.) of Tianjin Hospital.

Inclusion and exclusion criteria

The inclusion criteria were as follows: ① diagnosis of ankle arthritis by radiological examination; ② Takakura stage IIIB/IV ankle osteoarthritis; ③ symptoms persisting or becoming gradually worse after more than six months of conservative treatment; and ④ treatment with ankle arthrodesis via anterior or lateral approaches.

The exclusion criteria were as follows: ① individuals with hip and knee joint deformities; ② those with subtalar and foot joint arthritis; ③ those with peripheral neuropathy; ④ those with severe osteoporosis; and ⑤ those with incomplete clinical follow-up and imaging data.

Surgical indications

Preoperative weight-bearing radiographs included full-length lower limbs, ankle/foot (anteroposterior/lateral), and dedicated hindfoot views to evaluate the severity of ankle joint disease, changes in alignment (medial distal tibial angle (MDTA), anterior distal tibial angle (ADTA), talar tilt angle (TTA)) [19], and the state of adjacent joints.

The severity of arthritis was evaluated using the Takakura classification for varus-type osteoarthritis of the ankle [20]. The stages include the following: ① Stage I, no joint-space narrowing but early sclerosis and osteophyte formation; ② Stage II, medial joint space narrowing without subchondral bone contact; ③ Stage IIIa, disappearance of the medial joint space with medial subchondral bone contact; ④ Stage IIIB, disappearance of the medial joint space with subchondral bone contact extending to the talar dome; and ⑤ Stage IV, disappearance of the joint space with complete bone contact.

Surgical indications: For patients who were classified with Takakura stage IIIB/IV ankle arthritis on the basis of preoperative imaging examinations, ankle arthrodesis surgery was performed. For patients with a TTA of less

than 10 degrees, the anterior approach was used; a TTA greater than 10 degrees, a lateral approach was used.

Surgical techniques

1. Anaesthesia and positioning: All patients in this group were placed under continuous epidural anaesthesia and placed in the supine position. During the procedure, a pillow was placed under the ipsilateral hip joint, and a tourniquet was applied to the thigh.
2. Surgical approach: The anterior approach was used for patients whose preoperative imaging evaluation revealed a TTA of less than 10 degrees. The skin incision started 8–10 cm proximal to the ankle joint along the anterior midline of the leg, extending distally over the dorsal talonavicular joint (Fig. 1A). The extensor retinaculum was exposed through the interval between the tibialis anterior and the exten-

sor hallucis longus tendons, preserving the tendon sheath of the tibialis anterior tendon. The joint capsule was incised to expose the ankle joint (Fig. 1B), osteophytes of the tibia and talus were removed, and sclerotic bone was removed from the tibiotalar joint until the cancellous bone surface bled, followed by Kirschner wire drilling.

For patients with a TTA greater than 10 degrees, a lateral approach was used. A lateral incision was made along the posterior border of the lateral malleolus, extending to the base of the fourth metatarsal (Fig. 2A). Structures such as the anterior inferior tibiofibular ligament, anterior talofibular ligament, and calcaneofibular ligament were exposed. The lateral joint capsule of the ankle was incised, and a short oblique osteotomy of the fibula was performed approximately 6 cm proximal to its distal tip, which was approximately 1 cm in length. The lateral

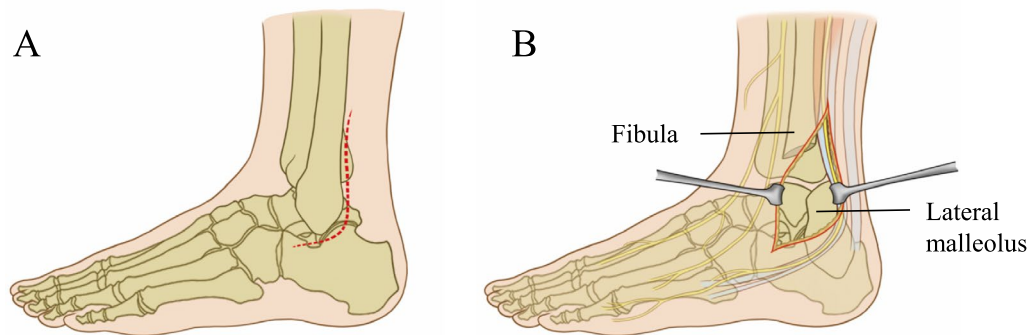


Fig. 1 Schematic diagram illustrating ankle arthrodesis with the anterior approach. **A.** Skin incision. **B.** The ankle joint was exposed between the tibialis anterior and extensor hallucis longus tendons

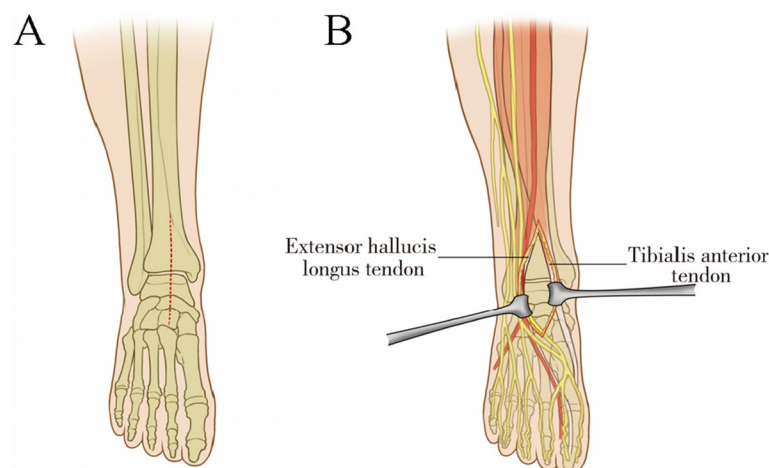


Fig. 2 Schematic diagram illustrating ankle arthrodesis with the lateral approach. **A.** Skin incision. **B.** Oblique osteotomy of the fibula, with shortening by approximately 1 cm. The lateral ligaments were cut, and the distal fibula was flipped over to expose the ankle joint

ligaments were cut, and the distal fibula was completely flipped over (Fig. 2B). The soft tissues on the posterior aspects of the talus and lateral and posterior aspects of the distal tibia were incised, the osteophytes of the tibia and talus were removed, and the sclerotic bone from the tibiotalar joint was removed until the cancellous bone surface bled, followed by Kirschner wire drilling. If the varus deformity could not be corrected, an incision was made on the medial side 4 cm proximal to the anterior medial malleolus, and the soft tissues on both sides of the medial ankle joint were stripped to clear the medial space.

3. **Bone Graft:** After the tibiotalar joint is exposed during surgery and before the joint was prematurely fixed, temporary fixation was performed using Kirschner wires. If the tibiotalar joint did not make complete contact according to the intraoperative fluoroscopy results and there was a gap between the two surfaces, a bone graft was performed using autologous cancellous bone from the ipsilateral Gerdy's tubercle regardless of the type of approach being used. If the fluoroscopy results reveal good contact between the tibiotalar joints without a significant gap, a bone graft was not necessary.
4. **Fixation:** The ankle joint was maintained in a neutral position, with 5 degrees of eversion and 5 degrees of

external rotation of the hindfoot, and slight posterior displacement of the talus relative to the distal tibia. Anterior approach: Fixation was achieved using a plate and 4.0 mm cannulated screws (Double Medical, Xiamen, People's Republic of China) (Fig. 3). Lateral approach: Fixation of the tibiotalar joint was achieved using two 6.5 mm cannulated screws, and fixation of the lateral malleolus was achieved using two 3.5 mm cortical bone screws (Ruihe Medical, Shijiazhuang, People's Republic of China) (Fig. 4).

All surgeries in this study were performed by two experienced chief surgeons from our department of foot and ankle surgery, ensuring standardization and homogeneity of the surgical procedures.

Postoperative management

Short leg cast immobilization; anti-inflammatory, analgesic and oedema reduction treatments; and subcutaneous injection of low-molecular-weight heparin were performed after surgery to prevent deep vein thrombosis in the lower limbs. Active toe flexion and extension exercises began on the first day after surgery, the sutures were removed at 14 days postsurgery, the cast was removed at 4 weeks postoperation, and non-weight-bearing walking with a limb protection brace began. Once postoperative imaging showed partial union of the joint fusion site,

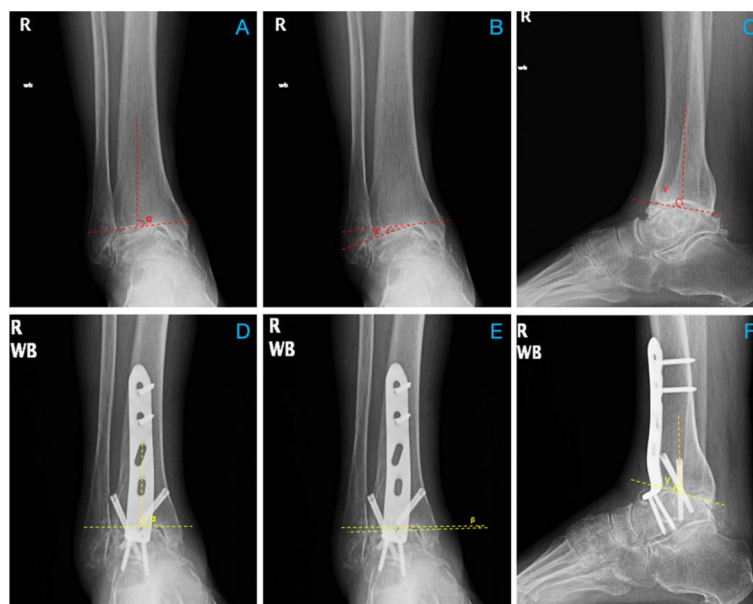


Fig. 3 Preoperative weight-bearing X-ray images of the right ankle showing Takakura stage III B arthritis and the radiographic alignment indicators at the last follow-up, after ankle arthrodesis was performed using two 4.0 mm cannulated screws and plate fixation through the anterior approach. The union status was good at the last follow-up. **A.** Preoperative anteroposterior X-ray shows the medial distal tibia (MDTA) (α). **B.** Preoperative anteroposterior X-ray shows the talus tilt angle (TTA) (β). **C.** Preoperative lateral X-ray shows the anterior distal tibia angle (ADTA) (γ). **D.** Anteroposterior X-ray at the last follow-up shows MDTA (α). **E.** Anteroposterior X-ray at the last follow-up shows TTA (β). **F.** Lateral X-ray at the last follow-up shows ADTA (γ)

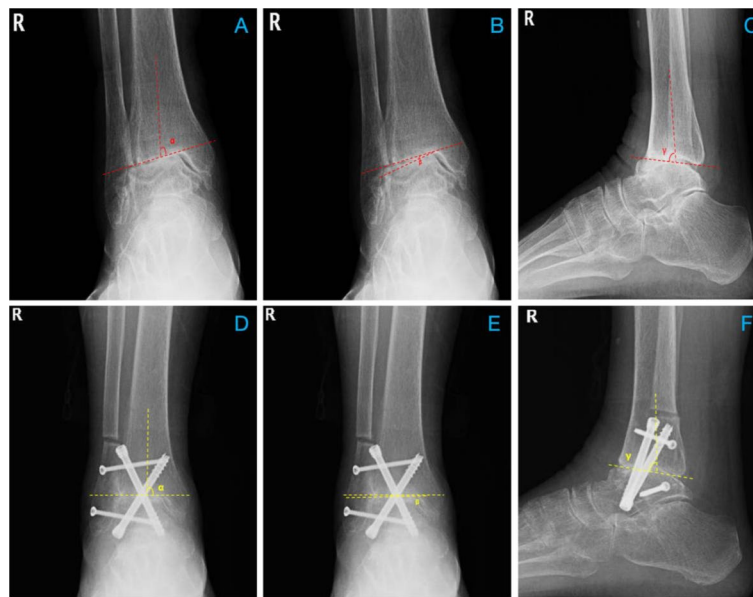


Fig. 4 Preoperative X-ray images of the right ankle taken in a weight-bearing position showing Takakura stage IV arthritis and postoperative images showing the two 6.5 mm double compression screws used to fix the tibiotalar joint and the two 3.5 mm cortical bone screws used to fix the lateral malleolus during ankle arthrodesis with the lateral approach. The radiological alignment indicators at the last follow-up after treatment are shown as well. At the last follow-up, the union status was good. **A.** Preoperative anteroposterior X-ray shows the medial distal tibia (MDTA) (α). **B.** Preoperative anteroposterior X-ray shows the talus tilt angle (TTA) (β). **C.** Preoperative lateral X-ray shows the anterior distal tibia angle (ADTA) (γ). **D.** Anteroposterior X-ray at the last follow-up shows MDTA (α). **E.** Anteroposterior X-ray at the last follow-up shows TTA (β). **F.** Lateral X-ray at the last follow-up shows ADTA (γ)

partial weight-bearing walking began, and full weight-bearing walking was initiated after complete union of the joint fusion site.

Indicators for assessment

1. Clinical evaluation: The bone union rate, time to bone union, incidence of adjacent joint progressive arthritis, and incidence of implant-related issues (screw breakage or protrusion) were assessed on the basis of imaging results during follow-up. Bone union was defined as the disappearance of the joint space at the fusion site as revealed via X-ray examination. Delayed union was defined as a healing time exceeding 6 months. Nonunion was defined as the presence of a joint space at the fusion site within 9 months postoperation, with no signs of progression within three consecutive months.
2. Ankle osteoarthritis score (AOS): The AOS is used to evaluate functional outcomes [21]. The AOS consists of two subscales: pain (9 items) and disability (9 items). A score of 0 indicates "no pain or difficulty," whereas a score of 100 indicates "the most severe pain imaginable or unimaginable."
3. The American Orthopaedic Foot and Ankle Society (AOFAS) ankle and hindfoot scoring system [22]
4. Radiological assessment: Measurements of the MDTA, ADTA, and TTA(20) on weight-bearing X-rays of the affected ankle were taken before surgery and at the last follow-up. The measurements were performed by two orthopaedic surgeons using the Picture Archiving and Communication System (PACS) (Philips (China) Investment Co., Ltd.).

Statistical analysis

Statistical processing was performed using SPSS 21.0 (IBM, USA) statistical software. The data (age, AOS, AOFAS score, MDTA, TTA, and ADTA) were normally distributed and are expressed as the means \pm standard deviations ($x \pm s$). Count data (sex, side, Takakura stage, complications) are expressed as percentages (cases, %), and comparisons between groups were made using the chi-square test. The test level α was set at two-sided 0.05.

Ethical issues

The Ethical Committee of Tianjin Hospital approved this study (No. 2025020). All patients provided written informed consent.

Results

Demographics

A retrospective analysis was conducted on 86 patients who underwent ankle arthrodesis through an anterior or lateral approach between January 2019 and December 2022; 16 patients were lost to follow-up, and 5 patients did not meet the inclusion criteria. On the basis of the inclusion and exclusion criteria, 65 patients were ultimately included in this study. In the anterior approach group, there were 24 males (54.55%) and 20 females (45.54%), with an average age of 63.48 ± 8.79 years. In the lateral approach group, there were 11 males (52.38%) and 10 females (47.62%), with an average age of 62.05 ± 7.24 years. In the anterior approach group, 26 patients (59.09%) were in Takakura stage IIIB, and 18 patients (40.91%) were in stage IV. In the lateral approach group, 5 patients (23.81%) were in Stage IIIB, and 16 patients (76.19%) were in Stage IV.

All 65 patients in this group successfully underwent surgery, with 44 receiving surgery via the anterior approach and 21 receiving surgery via the lateral approach. No significant differences were observed between the two groups in terms of age, sex, or surgery side ($p > 0.05$, Table 1). The operative time for the anterior approach group was 93.68 ± 23.53 min, and for the lateral approach group, it was 101.67 ± 17.13 min, which was not significantly different ($p > 0.05$, Table 1). All 65 patients were followed up postoperatively, with follow-up times ranging from 15 to 48 months and an average follow-up time of 22.8 months.

Table 1 Basic Informations of the two groups of patients

Variable	Anterior (n = 44)	Lateral (n = 21)	p value
Gender			
Male (n, %)	24 (54.55%)	11 (52.38%)	0.870
Female (n, %)	20 (45.45%)	10 (47.62%)	
Age (years)	63.48 ± 8.79	62.05 ± 7.24	0.520
Side			
Left (n, %)	21 (47.73%)	11 (52.38%)	0.726
Right (n, %)	23 (52.27%)	10 (47.62%)	
Takakura Stage			
Stage III B (n, %)	26 (59.09%)	5 (23.81%)	0.008*
Stage IV (n, %)	18 (40.91%)	16 (76.19%)	
Duration of surgery(min)	93.68 ± 23.53	101.67 ± 17.13	0.170

* statistically significant at $P < 0.05$

Efficacy evaluation

There were no nonunion cases in either group of patients, with a union rate of 100%. The average time to bone union for the anterior approach group was 16.75 ± 4.61 weeks (excluding delayed union cases, 16.21 ± 2.93 weeks), and for the lateral approach group, it was 17.95 ± 4.12 weeks (excluding delayed union cases, 17.25 ± 2.63 weeks). There was no statistically significant difference in union time between the two groups, regardless of whether delayed union patients were included ($p = 0.313, 0.181$; Table 2).

The average AOS in the anterior approach group decreased from 57.61 ± 3.64 points preoperatively to 19.34 ± 2.19 points at the last follow-up ($p = 0.001$, Table 2), and the average AOFAS score increased from 38.64 ± 2.52 points preoperatively to 79.75 ± 4.85 points at the last follow-up ($p = 0.001$, Table 2). In the lateral approach group, the AOS decreased from 56.62 ± 3.49 points preoperatively to 19.76 ± 2.39 points at the last follow-up ($p = 0.001$, Table 2), and the average AOFAS score increased from 37.33 ± 2.18 points preoperatively to 80.00 ± 3.70 points at the last follow-up ($p = 0.001$, Table 2). Both groups of patients had good therapeutic effects before and after treatment, and there was no significant difference in AOSs or AOFAS scores between the two groups at the last follow-up ($p = 0.485, 0.835$; Table 2).

We observed and analysed the MDTAs, ADTAs, and TTAs of both groups of patients before surgery and at the last follow-up. There was significant changes in the MDTAs, TATs, and ADTAs in both groups before and after treatment ($p = 0.001$, Table 2). The results showed that both the anterior and lateral approach corrected the ankle alignment of patients, and at the last follow-up, there was no significant difference in the MDTA, TTA, or ADTA between the two groups ($p > 0.05$, Table 2). The difference in TTA correction after different surgical treatments was significant, with the lateral approach being more effective in correcting the TTA ($p = 0.001$, Table 2).

Postoperative complications

The overall incidence of postoperative complications was 13.64% in the anterior approach group and 14.29% in the lateral approach group. No significant differences were observed between the two groups in terms of overall complication rates or the incidence of each type of complication ($p > 0.05$, Table 3). The treatment strategies and outcomes of each type of complication are summarized in Table 4.

Table 2 Comparison of surgical outcomes between two groups of patients

Variable	Anterior (n = 44)	Lateral (n = 21)	p value
Duration for union (wk)	16.75 ± 4.61	17.95 ± 4.12	0.313
Week for union exclude delayed(wk)	16.21 ± 2.93	17.25 ± 2.63	0.181
AOS			
Baseline	57.61 ± 3.64	56.62 ± 3.49	0.301
Last follow-up	19.34 ± 2.19	19.76 ± 2.39	0.485
p value [#]	0.001**	0.001**	
AOFAS			
Baseline	38.64 ± 2.52	37.33 ± 2.18	0.046*
Last follow-up	79.75 ± 4.85	80.00 ± 3.70	0.835
p value [#]	0.001**	0.001**	
MDTA (°)			
Baseline	86.97 ± 4.51	85.84 ± 3.65	0.318
Last follow-up	90.86 ± 0.77	90.81 ± 0.46	0.813
Difference	3.89 ± 4.74	4.98 ± 3.95	0.364
p value [#]	0.001**	0.001**	
TTA(°)			
Baseline	5.02 ± 2.67	14.28 ± 5.08	0.001**
Last follow-up	0.34 ± 0.25	0.37 ± 0.11	0.668
Difference	-4.68 ± 2.62	-13.92 ± 5.11	0.001**
p value [#]	0.001**	0.001**	
ADTA (°)			
Baseline	76.38 ± 3.06	74.89 ± 3.76	0.095
Last follow-up	78.84 ± 2.08	78.36 ± 1.70	0.365
Difference	2.46 ± 3.23	3.47 ± 3.27	0.247
p value [#]	0.001**	0.001**	

AOS Ankle osteoarthritis score, AOFAS American Orthopaedic Foot and Ankle Society, MDTA medial distal tibial angle, TTA Talar tilt angle, ADTA Anterior distal tibial angle

* statistically significant at $P < 0.05$

** statistically significant at $P < 0.001$

[#] p value between baseline and ending in the same group

Table 3 Complications between two groups of patients

Variable	Anterior (n = 44)	Lateral (n = 21)	p value
Overall complication rate (n,%)	6 (13.64%)	3 (14.29%)	0.943
Types of complications			
Infection (n,%)	4 (9.09%)	1 (4.76%)	0.540
Delayed union (n,%)	1 (2.27%)	1 (4.76%)	0.545
Secondary adjacent arthritis (n,%)	1 (2.27%)	0 (0%)	0.375
Internal fixation Prominence (n,%)	0 (0%)	1 (4.76%)	0.323

Table 4 9 Complication management and outcomes

Types of complications	N (%)	Management	Outcome
Infection	5 (7.69%)	Regular dressing changes	Union
Delayed union	2 (3.07%)	Strict weight-bearing control	Union
Secondary adjacent arthritis	1 (1.54%)	No further treatment	Function well
Internal fixation Prominence	1 (1.54%)	Remove implants after 1 year	Union

Infection

In the anterior approach group, there were 4 cases (9.09%) of wound infection, including 1 case of deep infection. The wound of the patient with the deep infection was regularly dressed at the outpatient clinic, and complete union was achieved 5 months postoperatively. One year postoperatively, the internal fixator and debridement were removed, and the wound healed 2 weeks later. This patient also had hyperthyroidism. The other 3 patients had superficial infections, and after regular dressing changes, the wounds healed approximately 3 weeks after surgery.

In the lateral approach group, there was 1 patient (4.76%) with a wound infection, which was a superficial infection. After regular dressing changes, the wound healed approximately 2 weeks after surgery. This patient also had diabetes with poor blood sugar control.

Nonunion or delayed union

In the anterior approach group, delayed union was observed in 1 male patient (2.27%) with no smoking history. This patient had previously undergone surgery for pilon fracture. After close follow-up and strict control of weight-bearing time and degree, complete fusion was achieved 8 months postoperatively.

In the lateral approach group, delayed union was also observed in 1 male patient (4.76%) with no smoking history. This patient was weight-bearing walking too early after the operation, and after close follow-up and strict control of weight-bearing time and degree, complete fusion was achieved 10 months postoperatively.

Secondary adjacent arthritis

In the anterior approach group, 1 case (2.27%) of secondary subtalar arthritis occurred 4 years postoperatively. The symptoms were mild, and the patient refused further treatment. During the follow-up period, there were no changes, such as talonavicular arthritis or other degenerative changes in the midfoot joint.

Implant prominence

In the lateral approach group, 1 case (4.76%) of internal fixation prominence occurred. One screw was found to be prominent at the subtalar joint at 4 months postsurgery. There were no clinical symptoms, no destruction or arthritis of the subtalar joint, and good union. No special treatment was given, and the internal fixation was removed 12 months postoperatively.

Discussion

Clinical efficacy of arthrodesis via anterior and lateral approaches in the treatment of ankle arthritis.

Ankle arthrodesis was first proposed in 1879 as a treatment strategy for end-stage ankle arthritis. The clinical efficacy of ankle arthrodesis has been widely recognized by many scholars, and it is considered the "gold standard" for the treatment of ankle arthritis [8, 9]. The criteria for assessing surgical outcomes include the union rate, functional improvement, and alignment correction. Kim et al. reported a union rate of 95.4% for the lateral approach group and 89.5% for the anterior approach group [23]. Van den Heuvel et al. reported a union rate of 98% for the anterior approach and 96% for the lateral approach [24]. In this study, the union rate for all 65 patients was 100%, with no significant difference between the two approaches. We believe that precise preoperative assessment of the severity of varus deformity in patients, choosing different approaches on the basis of the measured angle, thorough preparation of the fusion site during surgery, complete removal of the sclerotic bone, ensuring complete cancellous bone contact between the tibial and talus ends, and rigid fixation are crucial for union.

The AOS and AOFAS score can be used to evaluate the functional status of the foot and ankle. Suo et al. reported that ankle arthrodesis via the lateral approach with screw internal fixation for end-stage ankle arthritis increased the AOFAS score from 43.46 ± 4.39 preoperatively to 80.39 ± 5.37 at the last follow-up [25]. In a randomized study by Glazebrook et al., the AOS for ankle arthrodesis in the treatment of ankle arthritis decreased from 64.6 ± 19.7 preoperatively to 31.8 ± 16.5 [26]. Similar to the literature, in this study, both the anterior and lateral approaches significantly improved the AOSs and AOFAS scores at the last follow-up compared with the preoperative values, indicating that both approaches can achieve good clinical outcomes in the treatment of end-stage ankle arthritis.

Gordon et al. performed ankle arthrodesis through an anterior approach and reported that it was more difficult to correct coronal plane deformities via this approach than via the lateral approach, with 4% of patients still experiencing symptomatic varus deformity postoperation [27]. Kim et al. compared the two ankle arthrodesis approaches in treating ankle arthritis and concluded that the lateral approach does not require an additional medial approach [23]. Sung et al. suggested that through the lateral approach, the joint could fully exposed, cartilage and sclerotic bone can be thoroughly removed, the correction of varus deformities of the foot can be achieved, and an extensive contact area and good stability can be ensured [28]. In this study, patients who underwent the lateral approach had varus ankle deformities greater than 10 degrees, and the surgery was assisted by a medial approach. The advantage of the lateral approach is that it can completely loosen the posterior joint capsule

of the ankle joint, and the proliferative bone spurs on the medial side of the ankle joint can be removed and the medial tissues can be loosened via the medial approach. Through medial and lateral soft tissue release, varus deformities of the ankle joint can be effectively corrected. In this study, both groups of patients had significant corrections in MDTA, TTA, and ADTA before and after treatment. We believe that the lateral approach can achieve good results for ankle varus deformities greater than 10 degrees.

Analysis and preventive measures for complications of ankle arthrodesis through anterior and lateral approaches in the treatment of ankle arthritis.

- (1) Infection: Reb et al. reported a wound infection rate of 13.3%. They suggested that diabetes and the loss of extensor retinaculum constraint of the tibialis anterior tendon could be causes of wound infection [29]. Kim et al. studied the incidence of complications after surgery via the anterior approach with tibialis anterior tendon tenotomy in the treatment of ankle arthritis and reported that tibialis anterior tendon tenotomy could reduce the incidence of wound complications [30]. In this study, 5 patients (7.69%) had wound infections, which is slightly lower than that reported in the literature. We believe that in patients who had undergone ankle arthrodesis via the anterior approach, the extensor retinaculum should be sutured as much as possible to reduce the tension on the skin caused by the tibialis anterior tendon, preventing wound dehiscence and skin necrosis with tendon exposure. In patients who had undergone ankle arthrodesis via the lateral approach, the wound should also be sutured without tension, and drainage tubes should be applied to reduce the impact of bleeding on the wound. Most patients with ankle arthritis are elderly and have more comorbidities, and patients should be closely monitored during the perioperative period, especially those with diabetes, to reduce the risk of wound complications.
- (2) Nonunion and delayed union: Greene et al. reported that biological factors, including modifiable risk factors related to the patient, metabolic and endocrine factors, systemic diseases, previous surgeries, medications, weight loss treatment, history of foot and ankle trauma, and postoperative factors, significantly influence the occurrence of nonunion [31]. Potte et al. reported that although the literature is not sufficient to draw a clear conclusion, the results of ankle arthrodesis seem to be similar regardless of how long the non-weight-bearing period lasts post-operation, and they suggest that early weight-bearing does not affect union [32]. In addition, bone grafts also affect union, and a study by DiGiovanni et al. revealed that bone grafts are associated with a higher fusion rate at 24 weeks after surgery [33]. However, Heifner et al. reported that bone grafts do not significantly affect the union rate of primary ankle arthrodesis and that bone grafts should not be a routine choice in ankle arthrodesis surgery [34]. In this study, bone grafting was performed only when there was a gap after tibiotalar joint fixation. Furthermore, we found sclerosis at the lateral malleolar region during the lateral approach, and the lateral malleolar region could not be used as a bone graft source. We believe that bone grafts should be performed on the basis of the intraoperative situation. In this study, 2 patients experienced delayed union, neither of whom had a smoking history nor underwent autologous bone grafting during surgery. One patient began weight-bearing without protection in the fourth week after the operation, and the other had previously undergone surgery for pilon fracture. After the duration and degree of weight-bearing were strictly controlled, both patients achieved full union. We propose that the cause of delayed union may be related to early weight-bearing and previous trauma, but there is still a lack of high-level evidence on this topic. We will conduct further observations in the future.
- (3) Secondary adjacent arthritis: Valderrabano et al. reported that ankle fusion leads to reduced eversion/inversion and internal/external rotation of the subtalar joint, which increases the mechanical stress of the subtalar joint during walking. Increased stress can lead to progressive joint degeneration, which subsequently leads to arthritis of adjacent joints [35]. Ling et al. argued that the majority of biomechanical studies have shown altered biomechanics in the fused ankle; however, there is no clear consensus as to whether these findings are causes of adjacent joint arthritis. The correlation between imaging findings of adjacent joint arthritis and patient symptoms has also not been demonstrated in many clinical studies [36]. Coester et al. reported that most patients developed substantial, accelerated arthritic changes in the ipsilateral foot (not the knee) during an average follow-up of 22 years [37]. In this study, only 1 patient developed secondary arthritis, which was considered related to the short follow-up time.
- (4) Internal fixation prominence: In this study, one patient that underwent ankle arthrodesis via the lateral approach achieved internal fixation prominence. Postoperative internal fixation prominence is

most common when the screws used in screw fixation protrude into the subtalar joint, and in severe cases it can cause pain and other complications. Due to osteoporosis and daily activities, screw loosening may occur in the later stage of ankle fusion, causing skin irritation symptoms. During the operation, repeated fluoroscopy examinations should be used to determine the length and position of the screw, which can effectively prevent improper screw placement, causing internal fixation prominence. For elderly patients, regular monitoring of bone mineral density after surgery is recommended to prevent osteoporosis and reduce the risk of screw loosening.

This study has a few limitations. First, this was a retrospective study. Second, the sample size was small, especially for the lateral approach group. Finally, the follow-up time was relatively short, and long-term complications need further observation. In the future, we will conduct a prospective clinical study to compare the efficacy of ankle arthrodesis via the lateral approach and anterior approach, and more patients will be included. We will continue to follow up the medium-term and long-term clinical effects of ankle arthrodesis through the lateral approach and anterior approach.

In summary, in this study, ankle arthritis through the anterior approach and lateral approach achieved good therapeutic effects, and the lateral approach had a very good therapeutic effect on severe varus ankle arthritis.

Abbreviations

OA	Osteoarthritis
AOS	Ankle osteoarthritis score
AOFAS	American Orthopaedic Foot and Ankle Society
MDTA	Medial distal tibial angle
ADTA	Anterior distal tibial angle
TTA	Talus tilt angle

Authors' contributions

HC and JH contributed to the conception and design of the study. NL and GW contributed to the acquisition of the data. JL and HH contributed to the surgical procedures. HC contributed to the drafting of the manuscripts. HC and JH were responsible for the revision of the manuscript. All the authors read and approved the final manuscript.

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Data availability

No datasets were generated or analysed during the current study.

Declarations

Ethics approval and consent to participate

With the approval of our institutional review board, all the information was collected in accordance with the World Medical Association Declaration of Helsinki. Written consent was obtained from all the patients.

Consent for publication

Not applicable.

Competing interests

The authors declare no competing interests.

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