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Safety and clinical efficacy of double posterolateral coaxial portals for endoscopic management of posterior ankle impingement syndrome

Rui Li [a,1], Yuan-Qiang Li [a,1], Kun-Gao He [a,1], Xiao-Li Gou [a], Chen-Ke Zhang [a], Wan Chen [a,**], Fang-Yuan Wei [b,c,***], Cheng-Song Yuan [a,*]

[a] Sports Medicine Center, Southwest Hospital, The Army Military Medical University, No. 30, Gaotanyan Street, Chongqing, 400038, China
[b] Department of Hand and Foot Surgery, Beijing University of Chinese Medicine Third Affiliated Hospital, Beijing, 100029, China
[c] Engineering Research Center of Chinese Orthopaedic and Sports Rehabilitation Artificial Intelligent, Ministry of Education, Beijing, 100029, China

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ABSTRACT

Background: This study aims to analyze the safety and clinical efficacy of using double posterolateral coaxial portals for endoscopic treatment of posterior ankle impingement syndrome (PAIS), a procedure that has gained popularity in recent times.
Methods: Six fresh foot samples were randomly selected to measure the distances of two posterolateral portals to the sural nerve in different positions (plantar flexion 10°, dorsiflexion 30°, and plantar flexion 30°) for safety evaluation. A prospective analysis was conducted on the clinical efficacy of the operative approach for endoscopic management of posterior ankle impingement syndrome, including evaluation of effectiveness and complications.
Results: In this study, the mean distances of the first and second portals to the sural nerve were measured in different ankle positions. The distances were found to be 2.26 ± 0.22 cm and 1.59 ± 0.12 cm in the plantar flexion 10° position, 2.21 ± 0.21 cm and 1.55 ± 0.12 cm in the dorsiflexion 30° position, and 2.46 ± 0.29 cm and 1.73 ± 0.19 cm in the plantar flexion 30° position, demonstrating a significant safety margin from the nerve. A total of 38 patients underwent endoscopic treatment for posterior ankle impingement syndrome using double posterolateral coaxial portals between January 2012 and December 2017. This surgical approach provided access to the subtalar joint and posterior ankle region. The patients were followed up for an average of 38.2 months (24–72 months), with a satisfaction rate of 94.7%. There were no reported complications, and significant improvements were observed in both visual analogue scale (VAS) and The American Orthopedic Foot and Ankle Society Score (AOFAS) scores postoperatively. The VAS score decreased from 5.68 to 0.51 ($P < 0.001$), while the AOFAS score increased from 71.68 to 92.34 ($P < 0.001$), resulting in an excellent/good rate of 97.3%.
Conclusion: The use of double posterolateral coaxial portals in the treatment of posterior ankle impingement syndrome offers several advantages, including improved safety, reduced risk of nerve injury, enhanced visualization of the posterior ankle and subtalar joint, favorable clinical outcomes, and minimal complications.

1. Introduction

Posterior ankle impingement syndrome (PAIS) is a clinical condition characterized by posterior ankle pain during plantar hyperflexion. This pain is caused by repeated excessive plantar flexion or sudden acute plantar flexion of the ankle. PAIS is commonly observed in ballet dancers, soccer players, and volleyball players.[1,2] The etiology can be divided into three main categories: overuse, trauma, and anatomic abnormalities.[3–7] The abnormal factors for PAIS include soft tissue and bone abnormalities.[8,9] There are two types of treatment for posterior ankle impingement syndrome: conservative treatment and surgical treatment.[10] Early non-surgical treatment is recommended for ankle

* Corresponding author.
** Corresponding author.
*** Corresponding author. Department of Hand and Foot Surgery, Beijing University of Chinese Medicine Third Affiliated Hospital, Beijing, 100029, China.
E-mail addresses: footwfy@126.com (F.-Y. Wei), 530270472@qq.com (C.-S. Yuan).
[1] A represents co first authors who have made equal contributions to the article.

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impingement syndrome to alleviate symptoms like posterior ankle pain and improve the patient's quality of life. Various methods, including rest, ice compression, compression bandaging, elevation of the affected limb, exercise therapy, and ankle brace protection, can effectively reduce local pain symptoms. In cases of posterior ankle pain due to soft tissue impacts like flexor longus tenosynovitis, early treatment may involve local steroid injections and oral nonsteroidal anti-inflammatory drugs.[11,12]

When nonoperative treatment fails, surgical treatment may be considered. This can involve either open surgery or arthroscopic surgery. Studies have shown that there is no statistically significant difference between the open procedure and the endoscopic approach, with endoscopic treatment being considered safe and associated with lower complication rates.[1,9,13,14] Open surgery has shortcomings, such as exposure difficulty, extensive trauma, and easy injury to blood vessels and nerves.[15] Therefore, endoscopic surgery has become a fashion and trend, and the reasonable selection of portals is essential for surgical operation and efficacy.[11]

The current arthroscopic portals include: 1) Bilateral paramedical procedures have certain drawbacks, such as the need to change the patient's body position during surgery for treating anterior ankle lesions and a blind spot in the observation of the posterior ankle[16,17]; 2) lateral portal, with a defect of easy injury to the sural nerve [16,18]; 3) medial portal, with a defect of easy injury to the tarsal tunnel[19,20]; 4) anterior portal, with some defects, e.g., operation difficulty, requiring full traction, and failure to observe subtalar joint synchronously[21,22]; 5) bilateral coaxial portal, with a defect of easy injury to tarsal tunnel.[23,24] An operative approach that minimizes nerve and blood vessel injury, offers a clear intraoperative view, and can address both anterior and posterior lesions is essential. To achieve this, we developed double posterolateral coaxial portals that carefully avoid key structures such as the peroneus longus tendon, peroneus brevis tendon, and lateral collateral ligament, while ensuring the protection of the sural nerve. These portals provide complete exposure and a clear view of the posterior subtalar joint and ankle articular cavity. Through a study involving foot samples and subsequent prospective investigation, we were able to confirm the safety and efficacy of these designed portals.

This study aims to validate the safety of the proposed approach by conducting a foot specimen study. Subsequently, we plan to investigate the clinical efficacy of this approach in treating posterior malleolus impingement syndrome through a prospective study. The enhanced surgical approach is anticipated to provide safe and dependable surgical access, resulting in satisfactory surgical outcomes.

2. Materials and methods

2.1. Anatomic measurement

Six fresh frozen cadaver samples, consisting of 4 males and 2 females, were utilized in this study. The first and second portals were established following standard surgical procedures. Subsequently, a trocar was inserted into the joint, and two Kirschner wires (1.5 mm and 1.0 mm in diameter) were placed along the trocar's direction and secured. Upon trocar removal, the samples were dissected to expose the sural nerve. The distances between the sural nerve and the Kirschner wires were then measured with a precision of 0.01 cm in the dorsiflexion 30°, plantar flexion 10°, and plantar flexion 30° positions of the ankle. (Fig. 1).

2.2. Clinical data

2.2.1. Study objects

The Ethics Committee of Southwest Hospital approved this prospective study. Before the operation, all patients received X-ray, CT, and MRI examinations and completed AOFAS scoring, VAS scoring, and routine admission assessment.

The inclusion criteria were: 1) severe posterior ankle impingement syndrome, i.e., posterior ankle pain, aggravated at plantar flexion, influencing daily life; 2) failure of conservative treatment for ≥6 months, including drugs, local hormonal blockade, and physical rehabilitation. The exclusion criteria were described below: 1) severe medical diseases and 2) serious infection.

From January 2012 to December 2017, 38 patients with posterior ankle impingement syndrome received endoscopic management by double posterolateral coaxial portals after a failure of conservative treatment. The preoperative course of the disease was 32 months (range: 6–360 months), and the average age of patients was 36.4 years (range: 18–62 years).

2.2.2. Surgical methods and equipment

Following anesthesia, patients were positioned in a lateral decubitus position with the ankle joint maintained in a resting state (plantar flexed at 10°). A 2.7 mm arthroscope with a 30-degree angle of view was typically utilized during the procedure. The soft tissue debridement planer had a size of 4.5 mm, while the bone resection osteotomy grinding drill had a size of 4.0 mm (Fig. 2). The portal was established using the tourniquet with an inflation pressure of 270 mmHg. The specific procedures were as follows:The first approach is a 5 mm soft spot located in front of the outer ankle apex, which is the lower edge of the fibular apex. In the soft angle area at the angle between the anterior fibular ligament and the calcaneofibular ligament. The skin is slitted, and the subcutaneous tissue is separated using straight forceps. The angle between the grinding drill and the skin is approximately 30–45°, pointing towards the posterior ankle. Passing through the deep layer of the tendon sheath of the long and short fibular muscles and the latent space in the superficial layer of the calcaneofibular ligament to reach the posterior malleolus. When fluid flows out, a 2.7 mm arthroscope is inserted. The second approach is to create a parallel line with the sole at the level of the fibular apex, intersecting 5–10 mm next to the lateral

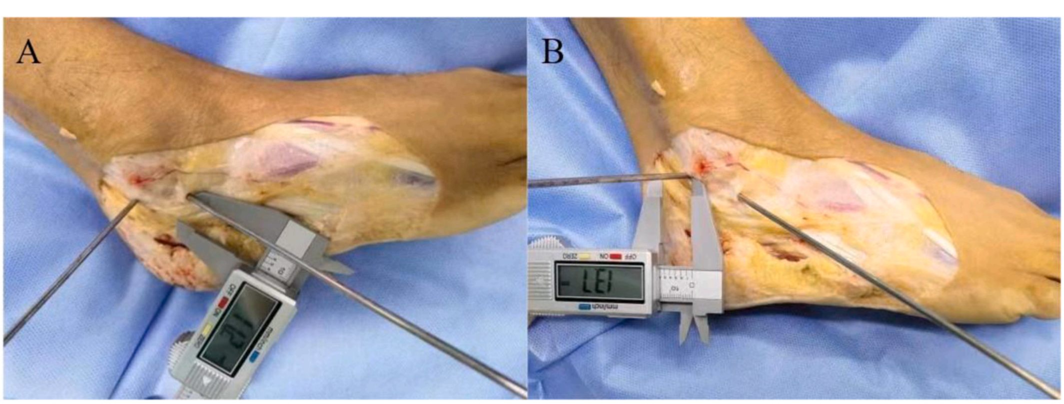

Fig. 1. A. Distance of the first portal to the sural nerve, B. Distance of the second portal to the sural nerve.

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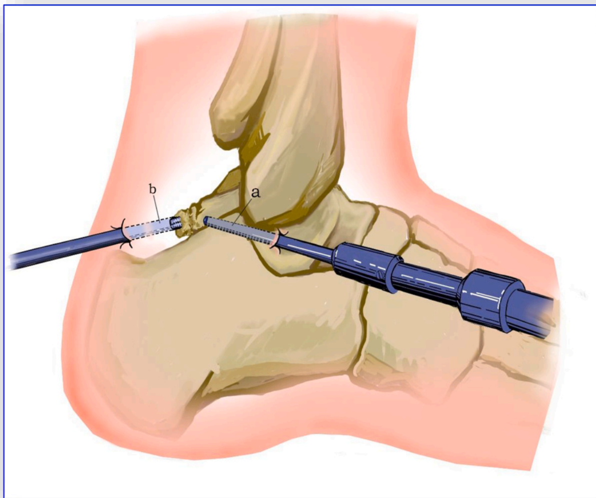

Fig. 2. Surgical schematic diagram of arthroscopic clearance of posterior ankle lesions through double posterolateral coaxial portals. a:2.7 mm arthroscope with a 30-degree angle of view, b:4.5 mm planer or 4.0 mm grinding drill.

side of the Achilles tendon. The direction of the working pathway is determined using an "outside-in" method with an epidural guide needle under arthroscopic monitoring (Fig. 3), Two portals could be alternatively used as observation and operation portals. The lesion tissues were removed with a planer, grinding drill, flat-nose pliers, and blue pliers. A negative pressure drainage tube was dwelled in the wound after hemostasis by plasma radio-frequency ablation, or a C-arm X-ray system for bony impingement confirmed the complete removal of lesions. Then, the wound was sutured layer by layer.

2.2.3. Preoperative and postoperative function follow-up

During the 3-month follow-up visit after the operation, the assessment of function and satisfaction was conducted using VAS pain scoring and AOFAS hindfoot function scoring. The ankle-hindfoot function scores were categorized as follows: 90–100 scores for excellent, 72–89 scores for good, 41–71 scores for medium, and 1–40 scores for poor. Results falling in the excellent and good categories were considered satisfactory, while those in the medium and poor categories were deemed unsatisfactory. Within 1 day post-operation, an X-ray examination confirmed the complete removal of bony impingement, with the observation of postoperative complications.

2.2.4. Statistical analysis

The measurement data were presented as $\bar{x} \pm s$. SPSS 26.0 statistical software was used. The AOFAS score and VAS score before and after the operation were analyzed by pair-wise *t*-test. $P < 0.05$ suggested that a difference was statistically significant.

3. Results

3.1. Safety analysis

Both portals maintained a safe distance from the sural nerve, reducing the risk of injury in the plantar flexion 10°, dorsiflexion 30°and plantar flexion 30° positions for 6 samples. Our study suggests that a safe distance between the approach and the nerve is 5 mm. The maximum, minimum, and mean distances of the two portals to the sural nerve were found to be more than 1.0 cm in specific positions, confirming a significant safety distance. (Table 1).

3.2. Effectiveness analysis

The entire posterior ankle area, including the medial flexor hallucis longus tendon and posterior talar bursa, was carefully examined. When the ankle was dorsiflexed, the entire posterior talar apex was visible. These portals provided access to the entire posterior subtalar joint, allowing for the deepening of the arthroscopic lens and operating devices to access and operate on the medial subtalar joint. (Fig. 4).

Since January 2012, 38 patients were effectively followed up, including 22 males and 16 females, 20 cases of right ankle, and 18 cases of left ankle. These patients were aged 36.4 years (18–62 years). The follow-up time was 38.2 months (24–72 months). The surgical time ranges from 33 to 96 min, with an average of 56 min, Thirty-six patients achieved satisfactory efficacy, with a satisfaction rate of 94.7%, and two patients experienced residual walking pain postoperatively for traumatic subtalar arthritis. Thus, the efficacy was just acceptable. After the operation, an X-ray examination showed that all bony impingements

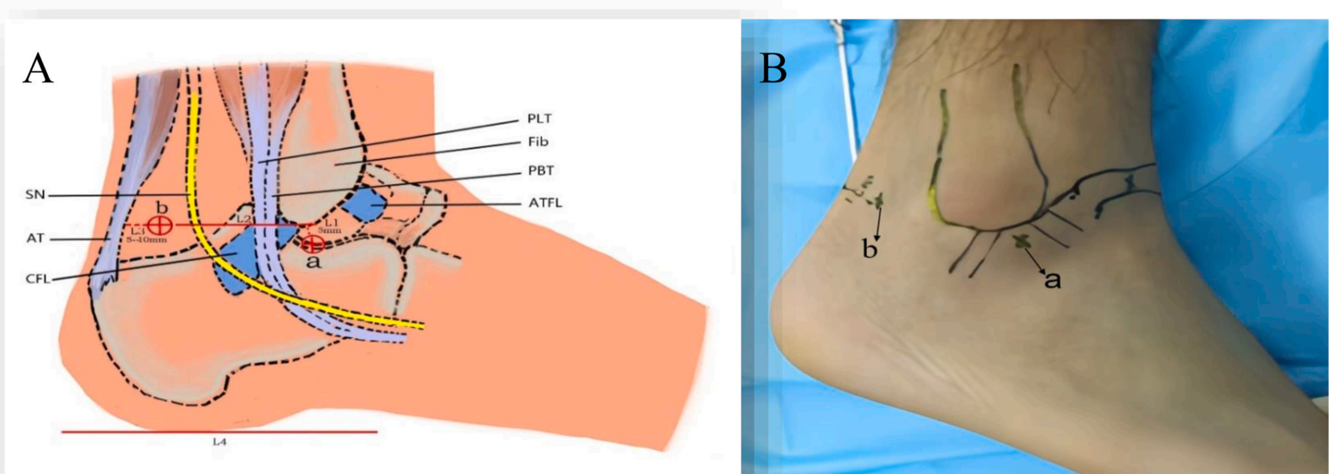

Fig. 3. A. The schematic diagram of the surgical approach; B. Physical image of ankle joint surface marking. (a: the first portal, b: the second portal, L_1: The distance between the anterior edge of the fibular apex and the soft spot is 5 mm, L_2: a parallel line with the sole at the level of the fibular apex, L_3: The distance between the second portal and the lateral side of the Achilles tendon is 5–10 mm, L_4:Plantar horizontal line, AT: Achilles Tendon, PLT: Peroneus Longus Tendon, PBT: Peroneus Brevis Tendon, SN: Sural Nerve, Fib: Fibula, ATFL: Anterior Talofibular Ligament, CFL: Calcaneus Fibular Ligament.)

Table 1
The maximum and minimum distances of the first and second portals to the sural nerve.

Plantar flexion 10° position				Dorsiflexion 30°position			Plantar flexion 30° position		
	A	B	C	A	B	C	A	B	C
1st portal (cm)	1.86	2.47	2.26 ± 0.22	1.76	2.42	2.21 ± 0.21	1.96	2.82	2.46 ± 0.29
2nd portal (cm)	1.45	1.81	1.59 ± 0.12	1.41	1.76	1.55 ± 0.12	1.48	2.05	1.73 ± 0.19

*A is minimum distances of two portals to the sural nerve,B is maximum distances of two portals to the sural nerve,C is mean distances of two portals to the sural nerve, the unit of the distances is cm.

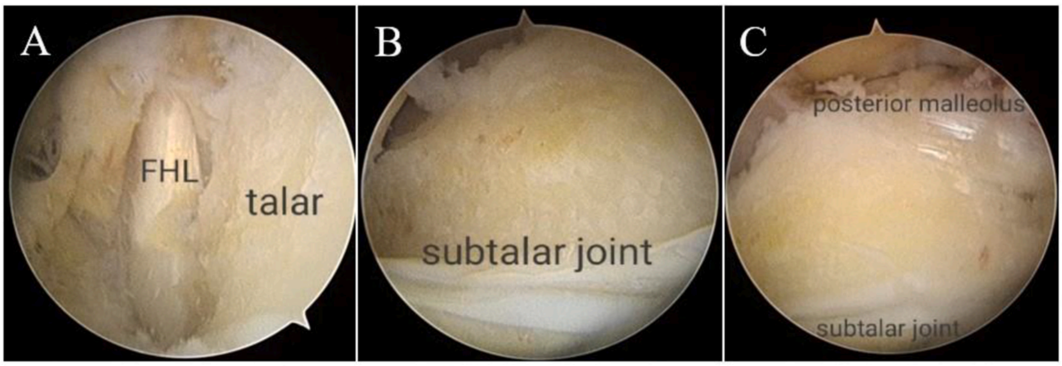

Fig. 4. Illustrates the treatment of posterior ankle impingement syndrome using arthroscopic double posterolateral coaxial portals. In section A, the structures observed during surgery include the flexor hallucis longus tendon (FHL) and the talar bone. In section B, the structures observed are related to the subtalar joint.

were completely removed (Fig. 5). Three patients underwent removal of a posterior subtalar joint cavity free ossicle using this approach, while two patients underwent clearance of posterior subtalar joint cavity synovitis. All patients achieved satisfactory clinical outcomes during follow-up. The VSA score decreased to 0.51 ± 0.44 from 5.68 ± 1.61 before the operation. The AOFAS score increased to 92.34 ± 5.30 from 71.68 ± 6.10, and the differences were statistically significant ($p < 0.05$). The excellent/good rate was 97.3%. None of the 38 patients developed complications.

4. Discussion

Posterior ankle impingement syndrome is a common clinical disorder resulting from repetitive subclinical trauma due to chronic, overuse injuries.[3–7] The main symptom is usually impingement pain and tenderness localized at the posterolateral aspect of the ankle behind the peroneal tendons.[25] The pain may be acute as a result of trauma or chronic from repetitive plantar flexion.[26,27] Abnormal factors contributing to impingement can be categorized into soft tissue and bone abnormalities. Soft tissue abnormalities may include posterior ankle soft tissue edema, hyperplasia of the posterior ankle bursa, and hypertrophy of the posterior capsule, tendinitis of the flexor hallucis longus, hypertrophy of the posterior ankle ligaments, among others. On the other hand, bone abnormalities could consist of posterior talar protuberance, os trigonum, fractures of the posterior talar tubercle, posterior tibial protuberance, calcification-free body, Haglund's deformity, and so forth.[25,28]

Operative treatment may be indicated when nonoperative measures have failed. Traditionally, operative treatment involves an open approach; however, more recently posterior ankle arthroscopy has been employed.[6] Bony avulsion fragment from the posterior ankle ligament complex causing impingement should be removed. Endoscopic management is associated with low morbidity, a short recovery time, and provides good/excellent results at 2–5 years follow-up in 80% of patients,[15] Coetzee et al. reported the study examined the outcomes of open approach for posterior impingement in 44 dancers and athletes. The procedure had a low complication rate, with 3 cases of transient sural nerve injuries and 1 case of complex regional pain syndrome reported. They reported an initial slow return to full activity with 46% good to excellent results at 3 months that improved to 96% at 1 year.[29] Therefore, endoscopic surgery has become a fashion and trend, but the correct selection of operative approaches plays a key role in clearly exposing the posterior ankle, [30] effectively protecting nerves and blood vessels, and reducing complications.[31,32] As the blood vessels and nerves

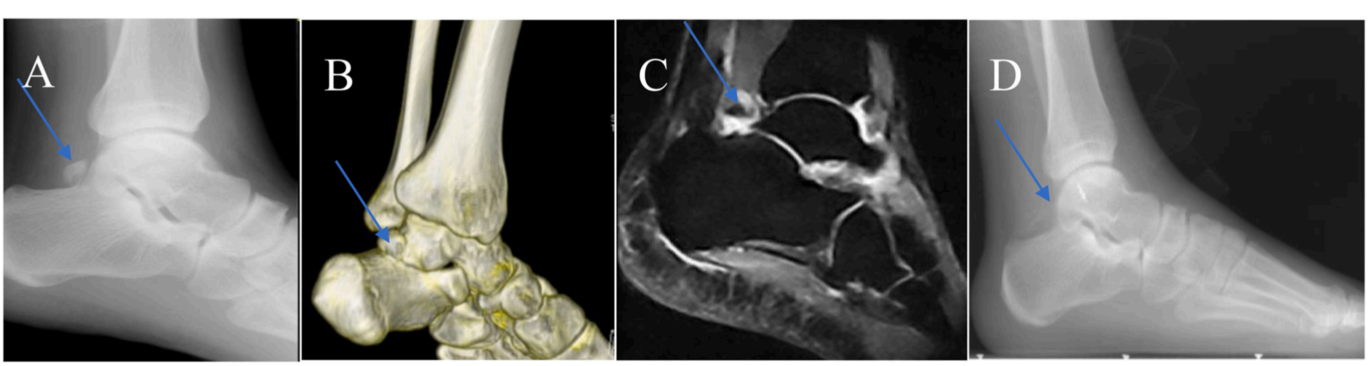

Fig. 5. This was a typical case: A、B、C.Pre-operation, X-ray, CT, and MRI examination showed that the patient suffered posterior ankle impingement syndrome. D. Post-operative X-ray examination showed that all bony impingements were removed entirely.

in the medial ankle have a complex structure, the posteromedial ankle portal for arthroscopy will greatly injure medial blood vessels and nerves when being established medially. The bilateral coaxial portal supports the entry into the articular cavity in the back of the posterior tibial muscle tendon,[24] but only provides a limited space for surgical operation due to the obstruction of the above tendon which reduces the risk of vascular and nerve injury. The medial portal designed by Sim and Allegra offers a certain safe space but enables limited observation of the subtalar joint.[33,34] Double paramedical portals designed by Van Dijk are a classic approach for posterior ankle arthroscopy, and their safety has been investigated in many studies[35] The advantages of this approach are relatively simple operation, clear view of the posterior ankle, and easy operation. Therefore, it is widely used in posterior ankle arthroscopic surgery. However, the observation of the posterior subtalar joint and anterior aspect of the Achilles tendon in this approach is limited due to the obstruction caused by the anatomical morphology of the calcaneus and talus. In cases where treatment of anterior or lateral ankle lesions is required, the anatomical structure must be flipped 180°and the position during surgery needs to be changed. However, changing the position presents several challenges. Firstly, prolonged exposure to the incision increases the risk of infection. Secondly, after suturing and bandaging the incision, it is necessary to transition back to a supine position, disinfect, and lay out new sheets, significantly extending the surgical time. The side-lying position was chosen for its facilitation of arthroscopic operations on the ankle and hindfoot, providing a good field and operating space. Cadaver studies have shown a low risk of nerve damage with this approach, ensuring a safe operating environment. Transitioning from posterior to anterior ankle lesions is smooth, allowing for efficient conversion to a supine position, reducing surgical time and infection risks. This position also offers greater comfort and ease of intraoperative monitoring for anesthesiologists.[36] Sitler et al. evaluated the safety of the paramedical portal for posterior ankle arthroscopy against small saphenous vein and proved that this portal had a certain safety distance to the small saphenous vein.[37] Therefore, the distances between double posterolateral coaxial portals and the sural nerve were measured to assess safety. The measurements indicated a safe distance between these portals and the sural nerve.

Ribbans et al. compared open and arthroscopic debridement. Open cases had a 4.2% incidence of nerve injury and a wound complication and infection rate of 2.8%. Arthroscopic cases had a 3.7% incidence of nerve injury and 0.96% incidence of wound complication and infection rate.[32] Guo et al. compared open and arthroscopic os trigonum excision in 41 patients (16 open and 25 arthroscopic). They found similar results to other studies in that there was no significant difference in American Orthopaedic Foot and Ankle Society (AOFAS) and visual analog scale scores. However, the time for return to sports was almost 6 weeks earlier for the arthroscopic patients (6 vs 11.9 weeks).[38] Valerio et a reported on the arthroscopic excision of an os trigonum in 20 soccer players. Studies have shown that the average time for returning to sports after surgery is around 47 days, with no complications reported. Most research indicates that athletes typically resume sports activities after approximately 8 weeks. However, in cases where the open approach was used, the recovery time varied between 11.9 and 25 weeks.

Postoperative complications of posterior ankle and hindfoot arthroscopy were reported by Nickisch et al. in a retrospective study of 189 subjects. Sixteen complications were observed (7 nerve, 2 infections, 4 Achilles tightness, 1 portal cyst, and 2 cases of complex regional pain syndrome). Five of the 7 cases of nerve injury (3.7% nerve injury incidence) were completely resolved. Two of the 3 sural nerve cases were caused by an accessory posterolateral portal. Within the cohort of 189 subjects, 46 cases of subtalar arthritis and 20 cases of ankle arthritis were treated. This distribution deviates from the norm observed in other studies that report outcomes and complications of surgical treatment for PAIS.[39] Nickisch et al. compares favorably to Abramowitz et al. who reported a 20% (8 out of 41 cases) sural nerve neuropraxia incidence in the open treatment of posterior ankle impingement.[40] The clinical efficacy of endoscopic treatment through double posterolateral coaxial portals for posterior ankle impingement syndrome was demonstrated in the follow-up of 38 patients. Satisfactory improvement of symptoms was observed, with no reported cases of injury to nerves, blood vessels, peroneus longus tendon, or peroneus brevis tendon.

During postoperative follow-up, the patient did not report pain in the surrounding structures of the entrance. However, the location of the entrance may still pose a risk of injury to other important structures like ATFL, CFL, Peroneal brevis, Peroneal longus, and fibrous cartilage. To prevent collateral damage to these structures from puncture, the following preventive measures can be implemented in the design of the entrance. During the puncture process, a No.11 sharp blade is used to make an incision starting 5 mm in front of the outer ankle tip, taking care to avoid damaging subcutaneous nerves by separating the tissue with straight forceps. The anterior approach is situated between the anterior fibular ligament and the calcaneofibular ligament. When puncturing, the cannula should be closely positioned along the inner side of the tendon sheath of the long and short fibular muscles to reach the posterior ankle joint. However, studying these specimens necessitates prolonged observation and analysis, placing significant demands on the patience and perseverance of researchers.

While this study presented a technique and its clinically significant outcomes, it is important to note the limitations of the procedure. The technique described in the study can only address the portion of the flexor hallucis longus tendon passing through the posterior ankle, and deeper areas may not be accessible for treatment. In theory, this approach could be utilized for treating Haglund deformity, but it necessitates extensive removal of adipose and synovial tissue in front of the Achilles tendon before addressing the lesion, which could potentially impede patient recovery. Future research will focus on refining surgical techniques to enhance the applicability of this approach. In addition, The study of fresh specimens used in this study were taken from the samples voluntarily donated by the patients, passed the ethical review, and signed a voluntary donation consent with the patients (3 cases of diabetes feet, 1 case of traffic accident injury, and 2 cases of tibial malignant tumors) involves knowledge of biology, pathology, anatomy, and other disciplines, which requires high skills of researchers.

5. Conclusion

In the treatment of posterior ankle impingement syndrome, the use of double posterolateral coaxial portals provides several benefits such as increased safety, decreased risk of nerve injury, better visualization of the posterior ankle and subtalar joint, positive clinical results, and minimal complications.

Consent for publication

All patients enrolled into the study agreed the use of patients' data for research.

Availability of supporting data

All data and materials were in full compliance with the journal's policy.

Funding

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Authors' contributions

All surgical procedures were carried out by Rui Li, Yuan-qiang Li , Cheng-song Yuan , Wan Chen and Fang-yuan Wei in this study. The

Data measurement of cadaver specimens was performed by Kun-gao He and Xiao-li Gou participated in the patient selection, investigation on the outpatient clinic and radiographic assessments, literature search, and data monitoring. , Chen-ke Zhang completed the statistical analysis and manuscript writing. All authors have read and approved the final manuscript.

Compliance with ethical standards

All data and materials were in full compliance with the journal's policy.

Informed consent

Informed consent was obtained from the patient in the study.

Declaration of competing interest

All surgical procedures were carried out by Rui Li, Yuan-qiang Li, Cheng-song Yuan, Wan Chen and Fang-yuan Wei in this study. The Data measurement of cadaver specimens was performed by Kun-gao He and Xiao-li Gou participated in the patient selection, investigation on the outpatient clinic and radiographic assessments, literature search, and data monitoring. Chen-ke Zhang completed the statistical analysis and manuscript writing. All authors have read and approved the final manuscript. All authors declared that they have no conflict of interest.

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