Am J Transl Res 2022;14(9):6368-6374
www.ajtr.org /ISSN:1943-8141/AJTR0143723

Original Article

Medial column reinforcement for the correction of flatfoot deformity with accessory navicular bone

Feng Tian, Junhu Wang, Cheng Liu, Yi Li, Xiaojun Liang, Xinwen Wang

Department of Foot and Ankle Surgery, Honghui Hospital, Xi'an Jiaotong University, Xi'an, Shaanxi Province, P. R. China

Received April 24, 2022; Accepted August 3, 2022; Epub September 15, 2022; Published September 30, 2022

Abstract: Objectives: This study aimed to evaluate the clinical effects of reinforcement of the medial column in the treatment of flatfoot deformity with accessory navicular bone. Methods: A retrospective analysis of 32 patients (46 feet) of flatfoot deformity with accessory navicular bone were reviewed. All patients underwent the reinforcement of their medial column in the midfoot, mainly including spring ligament repair, posterior tibial tendon reconstruction, and cotton osteotomy. Clinical evaluation adopted American Orthopaedic Foot and Ankle Society (AOFAS) score and pain visual analogue scale (VAS) was used to evaluate foot function and pain. Radiographic evaluation was performed, and Meary's angle, calcaneal pitch angle, talonavicular coverage angle (TCA), talar 2th metatarsal angle (T2MT) and calcaneal valgus angle (CVA) were measured. Results: All patients were followed up for an average duration of 24.3±3.6 months. At the final follow-up, the patient's foot pain was relieved and the foot deformity was improved. The data indicated that the mean functional AOFAS score was significantly improved and the mean VAS score was significantly decreased postoperatively at final follow-up. Additionally, Meary's angle, TCA, T2MT and CVA were all significantly decreased, and calcaneal pitch angle was significantly increased after surgery. Conclusion: We found that reinforcement of the medial column can effectively maintain medial longitudinal arch, correct flatfoot deformity with accessory navicular bone.

Keywords: Flatfoot, medial column, spring ligament, posterior tibial tendon, medial cuneiform

Introduction

Flatfoot is a type of foot deformity characterized by medial arch collapse, calcaneus valgus, and forefoot abduction [1, 2]. Flatfoot with accessory navicular bone is a common type of flatfoot deformity [3]. When flatfeet with accessory navicular bone are symptomatic, they mainly manifest as medical pain in the midfoot, lowering of the arch of the foot, and valgus deformity of the hindfoot, which causes instability of the subtalar joint, and may cause excessive tension of the posterior tibial tendon [3-5]. These factors can lead to symptoms such as protrusion of the accessory navicular bone, pain at the insertion of the tendon, and abnormal gait [3].

Usually, surgery is required for the patients with accessory navicular bone. The surgical treatment aims to relieve pain at the accessory navicular bone and correct foot deformities. So far, there is no unified surgical method for the surgical correction of a flatfoot with accessory navicular bone. Most reported cases require resection of the accessory navicular bone and reconstruction of the posterior tibial tendon surgery combined with calcaneal medial osteotomy and lengthening of the lateral calcaneus column [6, 7]. However, reports on the structural reinforcement of the medial column of the midfoot are rare, especially the repair of the spring ligament.

The spring ligament sustains the medial longitudinal arch of the foot and its failure can lead to flatfoot deformity. The dynamic stability of the medial longitudinal arch is supported by the posterior tibial tendon and the static stability is supported by the spring ligament [8]. The stability of the spring ligament can prevent the development of the talo-navicular joint deformity. When the spring ligament is damaged, it can lead to the loss of the longitudinal arch and

forefoot abduction deformity [9]. Studies have shown that spring ligament tears are related to flatfoot, so spring ligament insufficiency has been proven to be one of the important causes for the occurrence of flexible flatfoot.

This study is a retrospective study of 46 feet in 32 patients with flatfoot deformity with accessory navicular bone. The medial column of the midfoot was reinforced through spring ligament repair, reconstruction of the posterior tibial tendon and cotton osteotomy in medial cuneiform. The goal of this study was to evaluate the clinical effects of medial column reinforcement in the treatment of flatfoot deformity with accessory navicular bone. This would provide a new strategy for the treatment of the flatfoot deformity with accessory navicular bone.

Materials and methods

Patients

A total of 46 feet from 32 patients were analyzed retrospectively in our department from June 2017 to December 2019, which included 18 unilateral cases (10 cases on the left foot, 8 cases on the right foot) and 6 cases of feet on both sides. Among them, there were 18 males (26 feet) and 14 females (20 feet), aged from 13 to 42 years, with an average age of 26.3±4.2 years. All of them had accessory navicular bone. These patients complained of medial midfoot pain with hindfoot valgus and forefoot abduction, which affect normal walking. All patients were followed up for an average duration of 24.3±3.6 months, and the minimum follow-up time was 1 year. This study was performed in accordance with the Declaration of Helsinki and was approved o by the institutional research committee of Honghui Hospital, Xi'an Jiaotong University (Protocol Number 20210419). As the patients were scattered in various places, all patients participating in this study were contacted by telephone to obtain verbal informed consent. In addition, written informed consent was obtained from a parent or guardian for participants under 16 years old.

The inclusion criteria were (1) those diagnosed with flatfoot deformity with accessory navicular bone and failed to improve with conservative treatment for 6 months, (2) those who conformed to the surgical indications and underwent foot surgery for the first time, (3) patients older than 13 years old, (4) calcaneal valgus angle (CVA) larger than 10° and (5) talonavicular coverage angle (TCA) less than 30°. The exclusion criteria were (1) a history of surgery on the foot, (2) rigid flatfoot, tarsal coalition and congenital vertical talus, (3) neuromuscular disease, (4) midfoot or hindfoot arthritis and (5) patients who were lost to follow-up.

Operative technique

General anesthesia combined with lower limb nerve block was applied to all patients in the supine position. The leg was exsanguinated with an elastic bandage, and a pneumatic tourniquet was placed on the proximal thigh of the affected limb. In order to remove the accessory navicular bone, a 7-cm longitudinal incision was made at the navicular bone on the medial side of the foot to expose the accessory navicular bone and navicular tuberosity. Then the accessory navicular bone was removed and the inflammatory lesions were cleaned up around the posterior tibial tendon. The plantar aspect of the navicular tuberosity was polished to the fresh bone surface, and a 3.9 mm absorbable anchor (Johnson, USA) was implanted into the navicular bone.

Subsequently, the spring ligament was slack, and 5-mm of the ligament was resected and then the spring ligament was sutured with an anchor tail-line. Or we used the anchor tail-line to implement the compression repair of the spring ligament through overlapping sutures. Later, the posterior tibial tendon was reconstructed. Another tail thread of the anchor was used to suture the posterior tibial tendon to the navicular bone with a certain tension. Finally, the fixed forefoot supination deformity was managed with cotton osteotomy in medial cuneiform. After flushing and suturing the wound, the affected foot was fixed in a neutral position with a short-leg plaster cast.

Clinical and radiographic evaluation

The American Orthopaedic Foot and Ankle Society (AOFAS) score was used for the clinical evaluation as previously described [10]. Visual analogue scale (VAS) score was used for the quantification of pain degrees from 0 to 10, with 0 representing no pain and 10, the worst pain [11]. VAS evaluation can directly reflect the pain relief of patients before and after surgery,

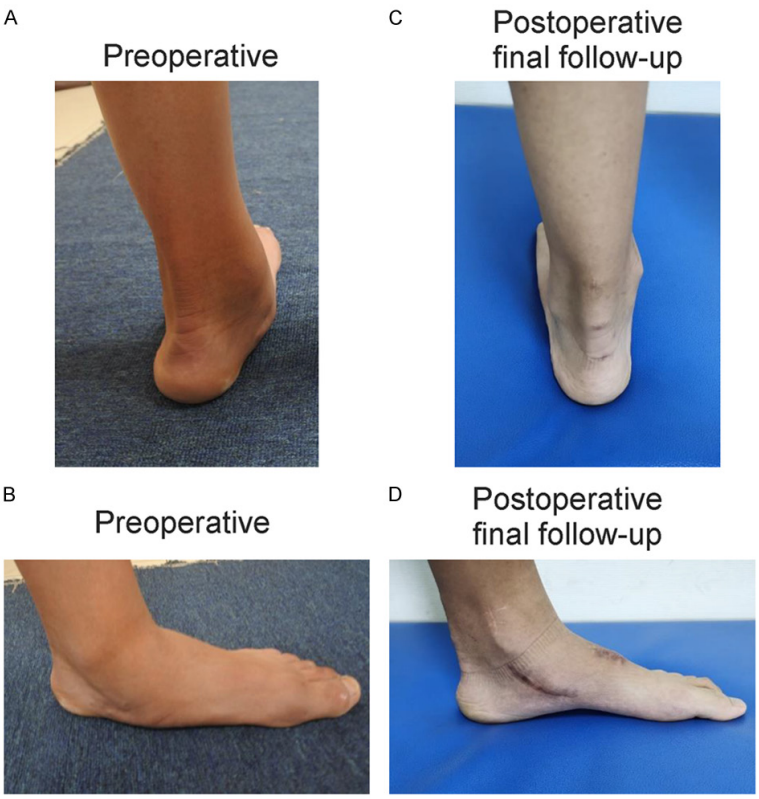

Figure 1. A 14-year-old boy with left flexible flatfoot deformity underwent the strengthening of medial column, which included removing accessory navicular bone, repairing the spring ligament, reconstructing posterior tibial tendon and cotton osteotomy. A. The hindfoot valgus was apparent. B. Meanwhile, the medial longitudinal arch was diminished preoperatively. Compared to the preoperative appearance, C. hindfoot alignment was restored neutrally and D. longitudinal arch was appeared at the final follow-up.

while AOFAS is a more authoritative international evaluation system, which better comprehensively reflects the improvement of the foot.

In terms of imaging, Meary's angle and calcaneal pitch angle are the main indicators to reflect flat feet, and CVA is the main indicator to reflect the alignment of the hindfoot. The secondary indicators are TCA and talar 2th metatarsal angle (T2MT). Radiographic evaluation should include weight bearing anteroposterior and lateral views of the foot and Saltzman view. Meary's angle and pitch angle were measured by weight-bearing lateral X-ray, TCA and T2MT were measured by weight-bearing anteroposterior X-ray, and CVA was measured by Saltzman X-ray. The angles were measured pre- and postoperatively.

Statistical analysis

The software SPSS 21.0 was used for statistical analysis. The data were expressed as mean ± standard deviation (SD). The preoperative and postoperative comparisons were performed by paired Student's t-test. *P* value <0.05 was considered statistically significant.

Results

Flatfeet deformity with accessory navicular bone were corrected via medial column reinforcement

All patients were followed up for an average duration of 24.3±3.6 months, and the minimum follow-up time was 1 year. A total of 46 feet from 32 patients who obtained good clinical follow-up were enrolled in the current study. All of them had accessory navicular bone and these patients complained of medial midfoot pain with hindfoot valgus and forefoot abduction, which affect normal walking. All patients underwent reinforcement of the medial column in the midfoot, mainly including spring ligament repair, posterior tibial tendon reconstruction, and cotton osteotomy. After the surgeries, the foot deformity was significantly improved. All the patients with calcaneal valgus and forefoot abduction deformities were corrected after the surgery, and the medial longitudinal arch was well recovered (**Figure 1A-D**).

Two patients had complications. One patient had residual pain in the medial foot, which was relieved by using a custom-made shoe-pad and it gradually disappeared after five months. One patient had a superficial infection at the incision, which healed one month postoperatively by dressing changes and oral antibiotics. Nonunion or delayed union was not present in our study. All the patients were satisfied with the surgery.

Pre- and post-operative radiological scores

The Saltzman view demonstrated that calcaneal valgus angle (CVA) improved from

Table 1. Preoperative and postoperative final follow-up results of radiography

Time	Meary's angle (°)	Calcaneal pitch angle (°)	TCA (°)	T2MT (°)	CVA (°)
Preoperative	11.78±2.21	11.54±2.73	20.57±3.68	34.22±3.89	13.03±2.76
Final follow-up postoperative	3.63±1.73	20.79±1.24	11.24±3.22	18.64±2.44	3.92±1.53
P value	0.0021	0.0071	0.0059	0.0011	0.0034

Talonavicular coverage angle, TCA; Talar 2th metatarsal angle, T2MT; Calcaneal valgus angle, CVA. Data were presented as mean ± SD. The preoperative and postoperative comparisons were performed by paired Student's t-test.

Figure 2. Radiographs of preoperative and postoperative final follow-up examination. A. Forefoot abduction was corrected. B. Calcaneal valgus was rectified. C. The medial longitudinal arch was recovered. The preoperative radiograph demonstrated collapse of the arch with CVA of 15 degrees, T2MT of 25 degrees, Meary's angle of 8 degrees, TCA of 18 degrees and calcaneal pitch angle of 11 degrees. The postoperative radiograph demonstrated restoration of the arch with CVA of 3 degrees, T2MT of 18 degrees, Meary's angle of 3 degrees, TCA of 13 degrees and calcaneal pitch angle of 18 degrees.

13.03±2.76 to 3.92±1.53 (**Table 1**), talonavicular coverage angle (TCA; 20.57±3.68 *vs* 11.24±3.22) and talar 2th metatarsal angle (T2MT; 34.22±3.89 *vs* 18.64±2.44) were all significantly decreased on the anterior-posterior view (**Table 1**). Calcaneal pitch angle (11.54±2.73 *vs* 20.79±1.24) was increased after surgery and Meary's angle (11.78±2.21 *vs* 3.63±1.73) was significantly decreased after surgery on the lateral X-ray (**Table 1**; **Figure 2A-C**).

Pre- and post-operative results of AOFAS score and VAS score

The foot function of the patients was significantly improved after the surgery, and the foot pain was significantly relieved. The data indi-

Table 2. Preoperative and postoperative final follow-up results of AOFAS score and VAS score

Time	AOFAS	VAS
Preoperative	52.60±6.44	5.58±1.22
Final follow-up postoperative	89.22±2.13	1.54±0.71
P value	0.017	0.012

American Orthopedic Foot and Ankle Society, AOFAS; Visual analogue scale, VAS. Data were presented as mean ± SD. The preoperative and postoperative comparisons were performed by paired Student's t-test.

cated that AOFAS score was significantly improved from 52.6 (46.16-59.04) preoperatively to 89.22 (87.09-91.35) postoperatively at final follow-up (**Table 2**). Moreover, VAS score was significantly decreased from 5.58 (4.36-6.80) preoperatively to 1.54 (0.83-2.25) postoperatively at final follow-up (**Table 2**).

Discussion

Flatfoot with accessory navicular bone is a common type of flatfoot deformity [3]. When the accessory navicular is present, the alignment and insertion of the posterior tibial tendon are changed, which weakens the ability of the posterior tibial tendon to lift the arch, resulting in flatfoot deformity. Some studies also reported that it is not the accessory navicular bone that causes the flat foot, but that the excessive tension and traction of the posterior tibial tendon induces the formation of the accessory navicular bone [4, 12]. Thus the flatfoot induces the formation of the accessory navicular bone. The relationship between accessory navicular bone and flatfoot is still controversial. In the current study, we found that reinforcement of the medial column can effectively maintain medial longitudinal arch, correct the flatfoot deformity with accessory navicular bone. For flatfoot deformity with accessory navicular bone, conservative treatment such as an orthopedic insole is feasible in the early stage. For most patients, surgery is required. Previous studies found that calcaneal medial osteotomy combined with modified Kidner surgery could not only effectively correct flatfoot deformity, but also treat symptomatic accessory navicular bone [13, 14]. Studies also suggested that lateral calcaneal column lengthening, accessory navicular resection, and posterior tibial tendon insertion reconstruction are effective methods for the treatment of symptomatic accessory navicular flatfoot [6, 15, 16]. However, lateral column lengthening fails to correct the varus deformity of the forefoot and increases the stress on the calcaneocuboid joint. Thus, we adopted a new strategy through reinforcement of the medial column of the midfoot via spring ligament repair, reconstruction of the posterior tibial tendon and cotton osteotomy in the medial cuneiform.

The spring ligament is important for the sustaining the medial longitudinal arch of the foot and its failure is related to flatfoot deformity [8]. Williams et al. also reported repair of the spring ligament should be used as an important correction method for flatfoot deformity surgery [17]. It can effectively reduce the subluxation of the talo-navicular joint. Moreover, it can also reduce the implementation of skeletal surgery and related complications [18]. Therefore, the treatment of flatfoot deformity through spring ligament repair is worth trying. For patients with flatfeet with accessory navicular bone, of which the spring ligaments are in a relaxed state, we have adopted a direct repair approach mainly through overlapping shortening suture or partial fusiform resection to suture directly. It was found that the valgus deformity of the calcaneus was greatly improved, which avoided the implementation of calcaneal medial displacement osteotomy. After correcting the hindfoot deformity, the residual supination deformity of the forefoot was checked, and routine medial cuneiform cotton osteotomy was performed. The results of the study showed that the symptoms and foot appearance of the patients were improved at the last follow-up after surgery, and the imaging parameters Meary's angle, Pitch angle, TCA and T2MA were all recovered better than those before surgery, suggesting that the medial arch and abduction of the forefoot was significantly improved. Moreover, the CVA recovered from 13.03°± 2.76° preoperatively to 3.92°±1.53° at the last follow-up, suggesting that the repair of the spring ligament can partially restore the hindfoot alignment.

However, this study has its limitations. First of all, this study is a retrospective study, and there are some biases that affect the outcome of surgery. Secondly, the sample size of this study is small, and it is the result of a single-center study, therefore the sample size needs to be

further expanded. This study mixed bony surgeries such as cotton osteotomy in medial cuneiform. In addition, the follow-up time of this study is relatively short, and further follow-up is needed to evaluate the long-term efficacy.

Conclusion

Reinforcement of medial column in the midfoot, mainly including spring ligament repair, posterior tibial tendon reconstruction, and cotton osteotomy can effectively sustain the medial longitudinal arch, and correct the foot deformity with accessory navicular bone. This provides a new strategy for the treatment of the flatfoot deformity with accessory navicular bone with less bony surgery implementation.

Acknowledgements

This study was supported by the Scientific and Technological Development Research Project Foundation of Shaanxi Province (No. 2020SF-097).

Disclosure of conflict of interest

None.

Abbreviations

AOFAS, American Orthopaedic Foot and Ankle Society; SD, standard deviation; TCA, talonavicular coverage angle; T2MT, talar 2th metatarsal angle; VAS, visual analogue scale.

Address correspondence to: Dr. Xinwen Wang, Department of Foot and Ankle Surgery, Honghui Hospital, Xi'an Jiaotong University, Xi'an 710054, Shaanxi Province, P. R. China. Tel: +86-18802-940285; Fax: +86-18802940285; E-mail: wangxinwen139@163.com

References

[1] Atik A and Ozyurek S. Flexible flatfoot. North Clin Istanb 2014; 1: 57-64.
[2] Mosca VS. Flexible flatfoot in children and adolescents. J Child Orthop 2010; 4: 107-121.
[3] Kurashige T and Tsunoda Y. Adult flat foot with multiple accessory navicular bones treated surgically: a case report and review of the literature. J Foot Ankle Surg 2019; 58: 1019-1024.
[4] Sullivan JA and Miller WA. The relationship of the accessory navicular to the development of the flat foot. Clin Orthop Relat Res 1979; 233-237.
[5] Kakihana M, Tochigi Y, Yamazaki T, Ohashi M and Ozeki S. Suture anchor stabilization of symptomatic accessory navicular in adolescents: clinical and radiographic outcomes. J Orthop Surg (Hong Kong) 2020; 28: 2309499020918949.
[6] Pretell-Mazzini J, Murphy RF, Sawyer JR, Spence DD, Warner WC Jr, Beaty JH, Moisan A and Kelly DM. Surgical treatment of symptomatic accessory navicular in children and adolescents. Am J Orthop (Belle Mead NJ) 2014; 43: 110-113.
[7] Jasiewicz B, Potaczek T, Kacki W, Tesiorowski M and Lipik E. Results of simple excision technique in the surgical treatment of symptomatic accessory navicular bones. Foot Ankle Surg 2008; 14: 57-61.
[8] Deland JT, Ellis SJ, Day J, de Cesar Netto C, Hintermann B, Myerson MS, Sangeorzan BJ, Schon LC, Thordarson DB and Johnson JE. Indications for deltoid and spring ligament reconstruction in progressive collapsing foot deformity. Foot Ankle Int 2020; 41: 1302-1306.
[9] Steginsky B and Vora A. What to do with the spring ligament. Foot Ankle Clin 2017; 22: 515-527.
[10] Van Lieshout EM, De Boer AS, Meuffels DE, Den Hoed PT, Van der Vlies CH, Tuinebreijer WE and Verhofstad MH. American Orthopaedic Foot and Ankle Society (AOFAS) Ankle-Hindfoot score: a study protocol for the translation and validation of the Dutch language version. BMJ Open 2017; 7: e012884.
[11] Bodian CA, Freedman G, Hossain S, Eisenkraft JB and Beilin Y. The visual analog scale for pain: clinical significance in postoperative patients. Anesthesiology 2001; 95: 1356-1361.
[12] Park H, Hwang JH, Seo JO and Kim HW. The relationship between accessory navicular and flat foot: a radiologic study. J Pediatr Orthop 2015; 35: 739-745.
[13] Cha SM, Shin HD, Kim KC and Lee JK. Simple excision vs the Kidner procedure for type 2 accessory navicular associated with flatfoot in pediatric population. Foot Ankle Int 2013; 34: 167-172.
[14] Kim JR, Park CI, Moon YJ, Wang SI and Kwon KS. Concomitant calcaneo-cuboid-cuneiform osteotomies and the modified Kidner procedure for severe flatfoot associated with symptomatic accessory navicular in children and adolescents. J Orthop Surg Res 2014; 9: 131.
[15] Bernasconi A, Lintz F and Sadile F. The role of arthroereisis of the subtalar joint for flatfoot in children and adults. EFORT Open Rev 2017; 2: 438-446.

[16] Flores DV, Mejía Gómez C, Fernández Hernando M, Davis MA and Pathria MN. Adult acquired flatfoot deformity: anatomy, biomechanics, staging, and imaging findings. Radiographics 2019; 39: 1437-1460.

[17] Williams G, Widnall J, Evans P and Platt S. Could failure of the spring ligament complex be the driving force behind the development of the adult flatfoot deformity? J Foot Ankle Surg 2014; 53: 152-155.

[18] Omar H, Saini V, Wadhwa V, Liu G and Chhabra A. Spring ligament complex: Illustrated normal anatomy and spectrum of pathologies on 3T MR imaging. Eur J Radiol 2016; 85: 2133-2143.