Brief Communication

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Diagnosis and Operation Results for Chronic Lateral Ankle Instability with Subtle Cavovarus Deformity and a Peek-A-Boo Heel Sign

Dong Woo Shim[1], Jae Wan Suh[2] , Kwang Hwan Park[3], Jin Woo Lee[3], Junwoo Byun[3], and Seung Hwan Han[3]

[1]Department of Orthopedic Surgery, Catholic Kwandong University College of Medicine, Incheon;
[2]Department of Orthopedic Surgery, Dankook University College of Medicine, Cheonan;
[3]Department of Orthopedic Surgery, Yonsei University College of Medicine, Seoul, Korea.

Cavovarus deformity is considered an anatomical risk factor for chronic lateral ankle instability (CLAI). However, subtle deformity can be difficult to detect, and its correction is controversial. The current study aimed to evaluate clinical and radiographic outcomes of a modified Broström procedure (MBP) with additional procedures for CLAI with subtle cavovarus deformity and a positive peek-a-boo heel sign. We reviewed the records of 15 patients who underwent MBP with additional procedures for CLAI with a positive peek-a-boo heel sign between August 2009 and April 2015. Consecutive physical and radiographic examinations were performed. The visual analog scale (VAS) for pain, the American Orthopedic Foot and Ankle Society (AOFAS) ankle-hindfoot score, and the Karlsson-Peterson (KP) ankle score were applied to assess clinical outcomes. Weight bearing radiographs, hindfoot alignment view, and ankle stress radiographs were also examined. The mean follow-up period was 58.5 months. Calcaneal lateral closing wedge osteotomy was performed in seven patients to correct fixed hindfoot varus, and first metatarsal dorsiflexion osteotomy was performed in 11 patients to correct plantarflexion of the first ray. Three patients underwent both procedures. Mean VAS, AOFAS, and KP ankle scores improved significantly (p=0.001), and instability did not recur. Radiographically, all stress parameters improved significantly (p=0.007). Simultaneous correction of a positive peek-a-boo heel sign and cavovarus deformity with MBP for CLAI improves clinical outcomes and prevents recurrent instability. A comprehensive evaluation and cautious approach for subtle cavovarus deformity should be followed when treating patients with CLAI. This trial is registered on Clinical Research Information Service (CRiS, KCT0003287).

Key Words: Ankle, joint instability, reconstructive surgical procedures, foot deformities, osteotomy

Ankle sprains are common among recreational and professional athletes, accounting for 85% of ankle lesions.[1,2] Although almost all acute ankle sprains can be successfully managed with rehabilitation, including bracing and physical therapy, approximately 20–40% of patients continue to suffer from chronic lateral ankle instability (CLAI).[3-7]

The modified Broström procedure (MBP) has been shown in multiple studies to yield good to excellent results in nearly 90% of patients[8,9] and has become the standard procedure for treating CLAI. However, other conditions that may predispose individuals to CLAI must be treated at the time of surgery to enable better results; these conditions include cavovarus deformity, tarsal coalitions, peroneal muscle insufficiency, and os trigonum.[10-13]

Cavovarus deformity is recognized as an anatomic risk factor that promotes CLAI.[14-16] However, the outcomes of primary correction of cavovarus deformity concomitant with the MBP have not been studied. This study aimed to evaluate the outcomes of MBP for primary correction of CLAI in combination

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Corresponding author: Seung Hwan Han, MD, PhD, Department of Orthopedic Surgery, Yonsei University College of Medicine, 211 Eonju-ro, Gangnam-gu, Seoul 06273, Korea.
Tel: 82-2-2019-3410, Fax: 82-2-573-5393, E-mail: osmedic@yuhs.ac

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with procedures for the restoration of cavovarus deformity.

We retrospectively analyzed 332 ankles of 319 patients who underwent MBP between August 2009 and April 2015 for the treatment of CLAI. Patients with generalized laxity, obesity, osteoarthritis of the ankle, deformed heel pad, or neurological deficits were excluded.

All of the patients suffered episodes of subjective ankle instability at least three times over a 6-month interval. Surgery was performed on patients who had sustained recurrent ankle sprain injuries or subjective instability with pain greater than grade 2 on an anterior drawer test, despite more than 6 months of conservative treatment. This study was approved by the Institutional Review Board in Severance Hospital (4-2016-0885).

Consecutive physical and radiographic examinations were performed as follows. Initially, the anterior drawer test and varus stress test were manually performed to evaluate ankle instability. The peek-a-boo heel sign was checked with the patient in a standing position to detect subtle cavovarus deformity (Fig. 1).[11,12] The Coleman block test was then performed to evaluate flexible hindfoot varus.[17,18] If the hindfoot deformity was flexible, the level of the first ray, compared to the lesser metatarsals on the plantar side, was checked with the ankle in a neutral position to evaluate forefoot pronation.[19] The Silfverskiöld test was performed to examine the presence and severity of equinus.

After applying the exclusion criteria to 332 ankles in 319 patients, 15 ankles (4.5%) in 15 patients showed the peek-a-boo heel sign with accompanying CLAI and were included in this study. All patients were male, with a mean age of 25.7 (range, 19–49) years; the mean follow-up period was 58.5 (range, 37–104) months (Table 1). Rigid cavovarus deformity was discovered in seven cases (46.7%) using the Coleman block test; the Silfverskiöld test was positive in two cases (13.3%).

MBP was performed in all 15 patients. The following procedures for cavovarus deformity were based on the physical exam: Calcaneal lateral closing wedge osteotomy was performed in seven patients (46.7%) to correct fixed hindfoot varus deformity, and first metatarsal dorsiflexion osteotomy was performed in 11 patients (73.3%) to correct plantarflexion of the first ray. Three (20%) of 15 patients underwent both calcaneal and first metatarsal osteotomies. Gastrocnemius recession was performed in two patients (13.3%) based on the results of the Silfverskiöld test (Table 2).

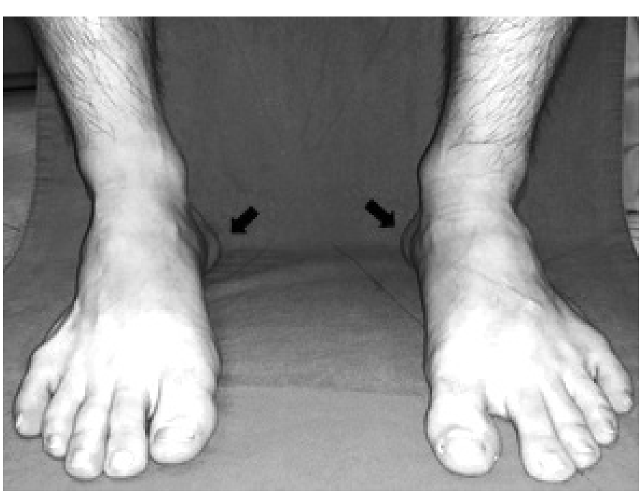

Fig. 1. The peek-a-boo heel sign. Subtle, but definite, bilateral cavus feet with the majority of the heel pad visible from the front (black arrows).

Radiologic assessments included standing anteroposterior and lateral radiographs of the ankle, as well as stress radiography using the TELOS stress device (Telos GmbH, Marburg, Germany). The talar tilt angle and anterior displacement of the talus were studied on ankle stress radiographs. If the peek-a-boo heel sign was positive, the Meary angle was evaluated on a lateral standing foot radiograph, as was the arch height between the cuneiform and fifth metatarsal base and the calcaneal pitch, which provided information about the site of foot deformity. The hindfoot alignment view was utilized to evaluate axial alignment. Two of the authors reviewed all of the radiographic parameters.

MBP was performed through a standard surgical approach.[20,21] Intraoperatively, the Silfverskiöld test was repeated. In cases where an isolated gastrocnemius contracture was present, an isolated gastrocnemius recession was performed using a postero-medial approach.

When fixed hindfoot varus deformity was noted, a lateral closing wedge osteotomy was performed. The lateral closing calcaneal osteotomy was created in an oblique fashion from lateral to medial until the hindfoot was in neutral to mild valgus. The osteotomy was fixated with two parallel 6.5-mm partially threaded cancellous screws. Following the correction of hindfoot deformity, forefoot posture was checked again under anesthesia. If the first ray regained its position in relation to the other lesser toes and was supple enough, no additional procedures were needed. However, if residual plantarflexion of the first ray was

Table 1. Clinical Characteristics of the Patients

Age (yr)	25.7±8.7 (19–49)
Sex (male:female)	12:0
Side (right:left)	6:6
Body mass index (kg/m^2)	24.3±1.9
Follow-up period (months)	58.5±5.7 (37–104)

Table 2. Additional Operations Performed Apart from the Modified Broström Procedure

Procedures	# of feet / patients (%)
First metatarsal dorsiflexion osteotomy	8 (53.3)
Calcaneal lateral closing wedge osteotomy	4 (26.7)
Both first metatarsal and calcaneal osteotomy	1 (6.7)
First metatarsal dorsiflexion osteotomy + gastrocnemius lengthening	0 (0)
Calcaneal lateral closing wedge osteotomy + gastrocnemius lengthening	0 (0)
Both first metatarsal and calcaneal osteotomy + gastrocnemius lengthening	2 (13.3)

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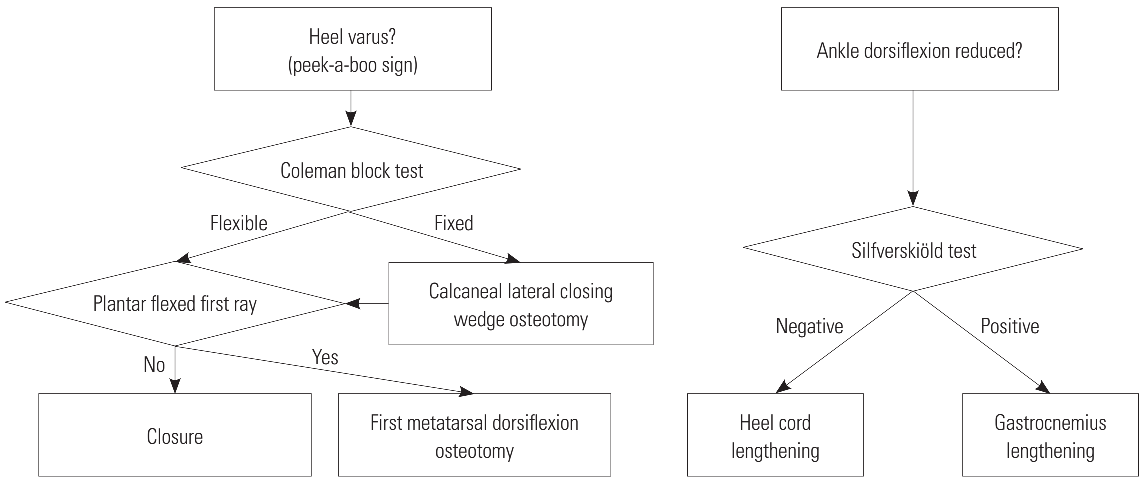

Fig. 2. Algorithm for additional procedures.

noted, a dorsiflexion osteotomy of the first metatarsal was performed. An incision was made over the first metatarsal and a piece of bone less than 5–7 mm wide was resected from the dorsum of the base of the first metatarsal and fixated with two 3.0-mm headless compression screws. This was usually performed within 1 cm of the tarsometatarsal joint.

If a flexible cavovarus deformity of the hindfoot was diagnosed after performing the Coleman block test, only a first metatarsal dorsiflexion osteotomy was performed (Fig. 2).

Postoperatively, the ankle was protected and immobilized in a short leg cast for 4 weeks. At 4 weeks, range of motion exercises and strengthening exercises of the peroneal muscles were initiated. After 6 weeks, progressive weight-bearing was allowed, and patients returned to their usual activity levels by 8 weeks.

Clinical evaluation of the patients included analysis of the visual analog scale (VAS) for pain, the American Orthopedic Foot and Ankle Society (AOFAS) ankle-hindfoot pain score, and the Karlsson-Peterson (KP) ankle scoring system, both preoperatively and postoperatively.

The Statistical Package for the Social Sciences (SPSS, version 21.0, IBM Corp., Armonk, NY, USA) was used for all statistical analyses. The Wilcoxon signed rank test was performed to evaluate changes in clinical and radiographic outcomes by comparing pre- and postoperative parameters. The level of significance was set at $p<0.05$. Interobserver reliability for the radiographic parameters was evaluated using interclass correlation coefficients (ICCs). All ICCs were interpreted as poor (<0.4), fair to good (0.4–0.75), and excellent (0.75<).[22]

The talar tilt angle, assessed in varus stress view, decreased from 12.3±3.4 degrees preoperatively to 5.6±3.1 degrees postoperatively (p=0.001). Talar anterior translation, assessed in the anterior drawer stress view, decreased from 7.9±2.7 mm preoperatively to 4.8±2.9 mm postoperatively (p=0.007). The Meary angle was reduced from a preoperative mean value of 10.7±5.5 degrees to a postoperative mean value of 5.5±3.4 degrees, while arch height decreased from a preoperative mean value of 20.0±8.4 mm to a postoperative mean value of 15.7±7.5 mm (p=0.001, p=0.003). The calcaneal pitch angle improved from a preoperative value of 26.4±4.3 degrees to a postoperative value of 25.2±4.1 degrees; however, this change was not statistically significant due to the number of patients included in the study (p=0.066). The heel alignment view distance decreased significantly from -6.5±4.9 mm preoperatively to 4.9±4.9 mm postoperatively (p=0.001) (Table 3).

Table 3. Preoperative and Postoperative Radiographic Assessments on Standing Lateral Foot and Ankle Radiographs

Standing lateral radiograph	Preoperative	Postoperative	*p* value
Meary angle (°)*	10.7±5.5	5.5±3.4	0.001
Arch height (mm)†	20.0±8.4	15.7±7.5	0.003
Calcaneal pitch angle (°)‡	26.4±4.3	25.2±4.1	0.066
Hindfoot alignment view distance (mm)§	-6.5±4.9	4.9±4.9	0.001

*The Meary angle refers to the talonavicular-first metatarsal angle, 0±4° normally, †Arch height refers to the distance from the base of the medial cuneiform to the base of the fifth metatarsal bone, approximately 10 mm normally, ‡The calcaneal pitch angle refers to the angle formed by a horizontal line (the support surface) and a line from the base of the heel and inferior cortex of the calcaneus along the inclination axis, 20–25° normally, §The hindfoot alignment view distance refers to the difference in millimeters between the bisecting axis of the tibia and the lowest contact point of the calcaneus with the floor, -1.6 normally (negative value=varus, positive value=valgus).[31]

Clinically, VAS score improved significantly from a preoperative mean value of 5.5±1.8 to a postoperative mean value of 1.7±1.5 (p=0.002). AOFAS and KP scores were elevated from preoperative mean values of 61.0±15.3 and 56.8±11.2 to postoperative mean values of 85.3±8.4 and 83.1±10.6 ($p<0.001$ and $p<0.001$, respectively). No patient complained of recurrent ankle sprains.

The results of interobserver reliability analysis are provided in Table 4. The ICC values for the interobserver reliability of all radiologic parameters were excellent.

CLAI has many concomitant conditions that should be assessed on initial treatment. Cavovarus deformity is one of the pathologies that can lead to failure of primary repair of the lat-

Table 4. Interobserver Agreement for Radiologic Outcome Measurements

Variables	Preoperative	*p* value	Postoperative	*p* value
Talar tilt angle	0.932	0.001	0.929	0.001
Anterior talar translation	0.959	0.001	0.895	0.001
Meary angle	0.982	0.001	0.966	0.001
Arch height	0.915	0.001	0.934	0.001
Calcaneal pitch angle	0.980	0.001	0.937	0.001
Hindfoot alignment view distance	0.919	0.001	0.872	0.001

eral ligament complex. The treatment of CLAI has been studied by many researchers but the validation of existing cavovarus deformity has seldom been examined. Fortin, et al.[23] investigated treatment options for patients with concomitant CLAI and idiopathic cavovarus deformity. In their study, few patients underwent a calcaneal osteotomy; however, they concluded that correction of cavovarus deformity may help to normalize the forces acting across the ankle, aiding in the effectiveness of a lateral soft tissue repair. Vienne, et al.[24] reported on eight patients with pes cavovarus and failed prior lateral ankle stabilization surgery. In their study, all patients underwent lateral displacement calcaneal osteotomy. These patients showed clinical and radiological improvement after deformity correction. Strauss, et al.[10] reported associated extra-articular conditions in 180 ankles with CLAI. Hindfoot varus alignment was present in 8% of ankles with CLAI (4.5% in our study) and in 28% of 20 revisional lateral ankle ligament repairs. Other antecedent investigations have emphasized the importance of the realignment of hindfoot varus on lateral ankle ligament repair, but we found no outcome studies for primary MBP combined with cavovarus deformity repair. Our investigation concludes that combined surgeries for ankle instability and cavovarus deformity yield good outcomes that are comparable with those addressing ankle instability alone.[20,21,25,26]

Cavovarus deformity has not been studied in detail, but some recent studies have shown that its prevalence is comparable with that of pes planus. This deformity is estimated to exist in approximately 25% of the normal population.[11,27] Detection of the deformity is important because it can induce lateral column overload. Larsen and Angermann[14] noted a higher frequency of cavovarus deformity in patients with CLAI than in the normal population. A gait analysis study of 24 patients with functional instability by Delahunt, et al.[28] showed increased inversion movement before and at initial contact. A hindfoot varus deformity would therefore increase the likelihood of ankle reinjury.

Cavovarus deformity can be induced via two mechanisms; an existing hindfoot varus deformity leads to compensatory pronation of the first ray or an existing forefoot pronation deformity leads to compensatory hindfoot varus in weight bearing. However, neither mechanism has been proven to be the exact cause.[17,29] Based on the etiology, correctional osteotomies were performed on all patients in this study following the algorithm shown in Fig. 1. Ankle equinus is also frequently related to cavovarus deformity. The peroneus longus can be hyperactive compared to the tibialis anterior in equinus, worsening the forefoot pronation and cavus deformity.[12,30] We performed calcaneal lateral closing osteotomies in seven cases (46.7%) and first metatarsal dorsiflexion osteotomies in eleven cases (73.3%). Three patients underwent both calcaneal lateral closing osteotomies and first metatarsal dorsiflexion osteotomies. Moreover, 2 of them (13.3%) required gastrocnemius lengthening. Maskill, et al.[17] performed lateral displacement calcaneal osteotomies in 100% and first metatarsal dorsiflexion osteotomies in 86% of 29 patients with cavovarus deformity. Further, they reported 13 (45%) cases of triceps surae lengthening among the 29 cases of cavovarus deformity that they studied.

Our data showed significant postoperative improvements in the radiologic parameters except for calcaneal pitch angle. We speculate that the insignificant change in the pitch angle was related to the fact that the surgical procedure did not alter the calcaneal height, even though it changed the coronal axis.

In the current study, the clinical outcomes of the combined surgeries were comparable to those of MBP for isolated CLAI.[20,21,25,26] All patients improved postoperatively and were satisfied with their results. No patients suffered from recurrence of CLAI during an average follow-up period of 58.5 months. We have therefore assumed that there was no recurrent ankle instability due to the success of the cavovarus deformity correction.

The chief limitations of the current study are the relatively small number of patients and retrospective design. However, a relatively long follow-up period and use of suitable statistical methods were strengths of the study, which enabled us to obtain encouraging results. Future studies with large cohorts and a prospective design can correlate the effect of deformity correction with the outcome of the MBP more precisely.

AUTHOR CONTRIBUTIONS

Conceptualization: Jin Woo Lee. Data curation: Kwang Hwan Park, Jae Wan Suh, and Junwoo Byun. Formal analysis: Dong Woo Shim, Jae Wan Suh, and Junwoo Byun. Investigation: Kwang Hwan Park and Dong Woo Shim. Methodology: Jae Wan Suh and Dong Woo Shim. Project administration: Seung Hwan Han. Resources: Jin Woo Lee and Seung Hwan Han. Software: Dong Woo Shim and Jae Wan Suh. Supervision: Jin Woo Lee and Seung Hwan Han. Validation: Jin Woo Lee and Seung Hwan Han. Visualization: Kwang Hwan Park and Dong Woo Shim. Writing—original draft: Dong Woo Shim. Writing—review & editing: Seung Hwan Han. Approval of final manuscript: all authors.

ORCID iDs

Dong Woo Shim https://orcid.org/0000-0001-5763-7860
Jae Wan Suh https://orcid.org/0000-0001-9386-6484
Kwang Hwan Park https://orcid.org/0000-0002-2110-0559
Jin Woo Lee https://orcid.org/0000-0002-0293-9017
Junwoo Byun https://orcid.org/0000-0002-8372-5247
Seung Hwan Han https://orcid.org/0000-0002-7975-6067

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