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Comparison of Midterm Outcomes between All-Inside Arthroscopic and Open Modified Broström Procedures as Treatment for Chronic Ankle Instability

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Background: Although the all-inside arthroscopic modified Broström operation (AMBO) and open modified Broström operation (OMBO) for chronic lateral ankle instability (CLAI) showed favorable outcomes up to 1-year short-term follow-up, concerns about the long-term stability of AMBO are still present. Therefore, we aimed to compare midterm outcomes between the 2 methods by extending the observation period.

Methods: Fifty-four patients undergoing ankle surgery between August 2013 and July 2017 were included in the AMBO (n = 37) and OMBO (n = 17) groups. The American Orthopaedic Foot and Ankle Society (AOFAS) ankle-hindfoot scale and a visual analog scale (VAS) were used to evaluate the clinical outcomes. Anterior drawer test and talar tilt angle were used to evaluate the radiological outcomes. The mean follow-up duration was 59.69 months.

Results: The 2 groups both showed improved clinical and radiological results statistically. In addition, they did not differ in age, sex, or preoperative AOFAS ankle-hindfoot scale score, VAS score, anterior drawer test, or talar tilt angle. No significant difference in the final follow-up postoperative clinical scores or radiological outcomes was observed.

Conclusions: AMBO and OMBO as treatments for CLAI did not yield differing clinical or radiological outcomes at a mean follow-up time point of 59.69 months.

Keywords: *All-inside arthroscopic modified Broström operation, Open modified Broström operation, Chronic lateral ankle instability*

Lateral ankle sprains are common lower-extremity injuries among athletes.[1] Acute lateral ankle sprains are managed conservatively with rehabilitation, bracing, and physical therapy.[2] Rest, ice application, compression, limb elevation, and functional rehabilitation are recommended for acute lateral ligament injuries.[3] Although surgical treatment is not required in most cases, some patients report chronic pain and/or swelling after conservative treatment and may experience lateral ankle sprain recurrence.[4] Operative treatment can improve the outcomes of patients with chronic symptoms after conservative treatment.[5]

Currently, the open modified Broström operation (OMBO) is the standard procedure for the treatment of chronic lateral ankle instability (CLAI).[6] In the short term, however, no significant difference in clinical or radiological outcomes or biomechanics was found between the arthroscopic modified Broström operation (AMBO) and

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OMBO.[7-11] The AMBO procedure also showed favorable short-term outcomes for patients who had generalized laxity.[12] It additionally enabled a quicker return to sports compared to the OMBO for chronic ankle instability.[13] Intra-articular lesions were identified in 10% to 50% of patients who underwent operative treatment, demonstrating the advantages of the arthroscopic procedure.[8,9,14] Nonetheless, prior studies have indicated that the AMBO may lead to complications, primarily involving nerve damage.[9] Moreover, most studies primarily focused on short-term outcomes with small sample sizes. Concerns persist regarding not only complications but also the long-term stability of the AMBO. Consequently, it is imperative to compare outcomes between the arthroscopic and open techniques with a relatively extended follow-up to gain a more comprehensive understanding.

We hypothesized that there would be no significant difference in the clinical or radiological outcomes between the all-inside AMBO and the OMBO at midterm follow-up. In this study, we compared the clinical and radiological outcomes of the all-inside AMBO and OMBO as treatments for CLAI.

METHODS

The study was conducted in accordance with the Declaration of Helsinki and approved by the Institutional Review Board and Human Research Ethics Committee of Soonchunhyang University Bucheon Hospital (IRB No. 2022-10-020, 08 November 2022). The requirement for informed consent was waived.

Patient Enrollment

We retrospectively enrolled 126 patients who underwent modified Broström operation for CLAI between August 2013 and July 2017. CLAI was diagnosed based on recurrent ankle instability secondary to injury of the lateral ligament complex after the failure of > 6 months of conservative management, including physical therapy, bracing, and immobilization, with symptoms of giving way and persistent pain. Individuals with histories of fracture of the affected ankle and those who had previously undergone operative treatment, had foot misalignment, or had any neuromuscular disorder were excluded, as all these conditions could affect patient outcomes. A total of 87 patients underwent surgery, with 56 individuals opting for AMBO and 31 undergoing OMBO. Out of 87 patients who passed the exclusion criteria, 3 refused to participate and 30 were not followed up for at least 3 years. Ultimately, 54 patients (27 men and 27 women) were enrolled in the study and assigned to the AMBO (n = 37) and OMBO (n = 17) groups. Whether to undergo AMBO or OMBO was randomly assigned (Fig. 1).

Clinical Evaluation

The patients were evaluated preoperatively, at 6, 12, and 24 months postoperatively, and the last follow-up visit. At each visit, a focused physical examination was performed to assess whether lateral ligament complex tenderness was triggered by direct palpation. All patients were evaluated clinically using the American Orthopaedic Foot and Ankle Society (AOFAS) ankle-hindfoot scale and a visual analog scale (VAS) for pain.

Radiological Evaluations

Stress radiographs were obtained preoperatively, at 6, 12, and 24 months postoperatively, and the last follow-up visit using a Telometer (Daeseung), and standardized measurements were made while performing the anterior drawer test (ADT) and talar tilt angle (TTA) test. Stress radiographs were taken with the foot held at up to 10° plantarflexion, and the ADT was measured on lateral radiographs taken with the leg held in slight internal rotation. For the stress radiographs, the ankles were loaded with 150 N in both planes (ADT and talar tilt), and the patients were instructed to relax the leg muscles.[15] The examinations did not cause any notable discomfort or pain. A senior radiologist specializing in musculoskeletal imaging (JKC) performed all radiographic examinations. Two orthopedic surgeons (SHK and SHL) blinded to the operative treatment evaluated the stress radiograph measurements using a picture archiving and communication system (PACS). To determine intra- and interobserver

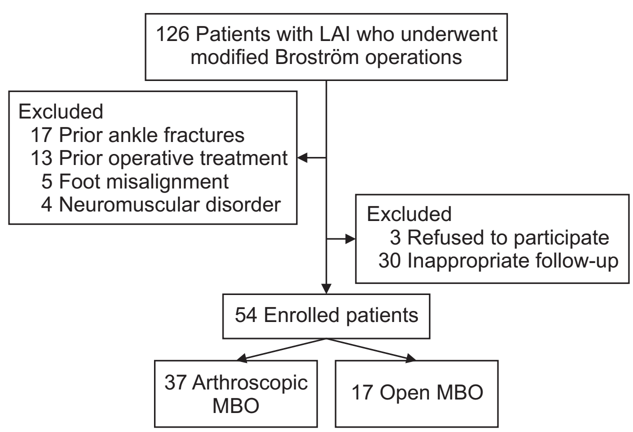

Fig. 1. Consort flowchart. LAI: lateral ankle instability, MBO: modified Broström operation.

reliability, both orthopedic surgeons repeated the measurements with the PACS 3 times at 2-week intervals. The width of the posterior area of the ankle joint was named ADT. The target points were located at the posterior border of the tibia and the proximal posterior articular surface of the talus. The shortest distance between those points was measured and recorded as ADT. When an observer draws a line between the reference points on the tibia and talus, the line and the tangent to the articular surface of the talus form a 90° angle. The TTA was defined as the angle between the articular surface on the distal portion of the tibia and the talus on anteroposterior stress radiographs.[15)]

Operative Techniques

A single surgeon (YKL) performed all procedures with the patients under spinal or general anesthesia with a thigh tourniquet. The patients were placed in the supine position with the ipsilateral buttock elevated.

Open Modified Broström Operation

Arthroscopic treatment of accompanying lesions is similar to that of diagnostic arthroscopy, which includes spur removal, drilling, or synovectomy. The operative procedure involved anterior talofibular ligament (ATFL) imbrication with inferior extensor retinaculum reinforcement. A curved 5-cm incision was made immediately anterior to the fibular border between the superficial peroneal and sural nerves. The gross findings for the ATFL and peroneal tendon were confirmed. The ruptured or redundant portion of the ATFL was partially removed; with the ankle in a neutral position, the remaining tissues were repaired with 2-0 ETHIBOND sutures (Ethicon). Then, the extensor retinaculum was used to reinforce the repair by suturing it to the periosteum over the fibula using the "pants-over-the-vest" technique described by Gould et al.[16)] Stability was then checked and the skin was closed (Fig. 2).[17)]

All-Inside AMBO

The arthroscopic treatment of accompanying lesions was done as in the OMBO. Before anchor insertion, the distal tibiofibular ligament's accessory fiber was shaved down. The synovial tissue and periosteum were removed immediately using a shaver and a vapor distal to the anterior tibiofibular ligament. By cutting the bony section using a motorized burr, a bleeding bony surface was exposed. A drill hole was made perpendicular to the anterior surface of the fibula, and the anchor was inserted through the anterolateral portal. A single absorbable Bio-Suture Tak anchor was tagged with 2 sutures (3.0 mm; FiberWire and TigerWire, Arthrex Inc.). Around the sinus tarsi area, an accessory anteroinferior portal was made to tie the anchor's wire. A far-lateral portal was also made over the anterior fibula. A penetrator grasping one end of the sutures was passed through the anterolateral portal to the accessory anteroinferior portal intra-articularly. The other end of each suture was pulled out through the far-lateral portal using the penetrator. A suture retriever was placed through the far-lateral portal to the accessory anteroinferior portal to pull the sutures subcutaneously. Holding the patient's foot everted and dorsiflexed, the knot was finally tightened (Fig. 3).[18)] By using an anchor, we augmented the inferior extensor retinaculum, ATFL remnant, and fibrous tissue to the fibula attachment site.

Rehabilitation Protocol

Each patient was placed in a well-padded posterior splint with the foot in slight dorsiflexion and did not bear weight on the affected side until the 2-week follow-up visit. At

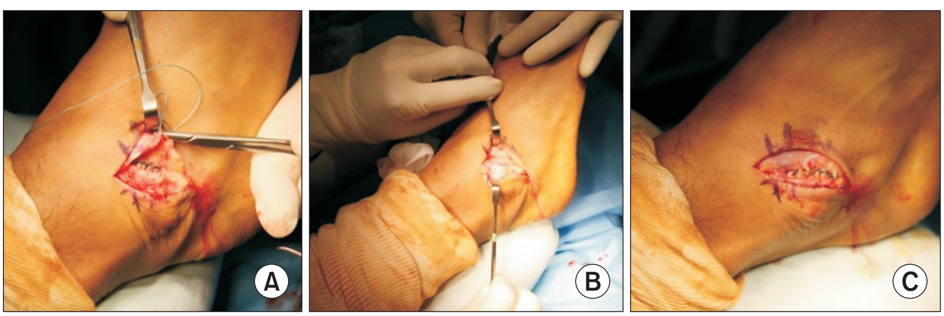

Fig. 2. Photographs of the foot during open modified Broström operation (OMBO). Surgical procedures of the OMBO are shown. (A) A curved incision measuring 5 cm is meticulously placed immediately anterior to the fibular border. (B) The redundant portion of the anterior talofibular ligament is judiciously excised, and the residual tissues are meticulously reconstructed utilizing 2-0 Ethibond sutures. Following the repair, the extensor retinaculum was utilized to enhance reinforcement, securing it to the periosteum over the fibula through the application of the "pants-over-the-vest" technique. (C) After repair, a thorough assessment of stability is conducted, culminating in the closure of the incision.

Fig. 3. Photographs of the foot during arthroscopic modified Broström operation (AMBO). Surgical procedures of the all-inside AMBO are shown. (A) A drill hole is created perpendicular to the anterior surface of the fibula, through which an anchor is carefully inserted via the anterolateral portal. A singular absorbable Bio-Suture Tak anchor, affixed with 2 sutures (3.0 mm), is deployed. To secure the anchor's wire, an accessory anteroinferior portal is established in the vicinity of the sinus tarsi. Additionally, a far-lateral portal is meticulously fashioned over the anterior fibula. (B) A penetrator, adeptly grasping one end of the sutures, traverses from the anterolateral portal to the accessory anteroinferior portal intra-articularly. Simultaneously, the other end of each suture is drawn through the far-lateral portal using the penetrator. A suture retriever is introduced through the far-lateral portal to the accessory anteroinferior portal. (C) The final tightening of the knot marks the meticulous completion of the procedure.

weeks 2 to 4 after the operation, a half-removed cast or splint was applied and patients were allowed to begin a gentle active-assisted range of motion of the ankle joint and exercises designed to reinforce peroneal strength with progressive weight-bearing. Then, the patients were instructed to perform full weight-bearing running and functional daily activities at 6 weeks after the operation. Cutting and sport-specific drills were performed around week 10. Shortly thereafter, the patients were allowed to return to their previous sports without restriction.

Statistical Analysis

The demographic characteristics of the study groups are described differently depending on the variables. Qualitative variables are expressed as frequencies (percentages) and quantitative variables are expressed as means ± standard deviations. The normality test results indicated that the data satisfied the assumption of normality. Consequently, parametric methods were employed for the analysis. For group comparisons, we used chi-square tests for qualitative variables and independent 2-sample t-test for quantitative variables. All statistical analyses were performed using IBM SPSS Statistics version 25.0 (IBM Corp.) and R version 3.3.2 (The R Foundation for Statistical Computing). All p-values of less than 0.05 were considered to indicate statistical significance. Our comparisons were conducted at each visit, and group effects were tested at a 2-sided significance level of 0.05. The 95% confidence intervals for differences between the 2 operation method groups were calculated as AMBO–OMBO. The interobserver and intraobserver reliability of ADT and TTA estimates was evaluated using the interclass correlation coefficient (ICC).

RESULTS

A total of 54 patients (27 men, 27 women) were included in the study: 37 underwent AMBO and 17 underwent OMBO. The mean patient age was 54 years (range, 18–63 years). The mean follow-up period was 59.69 months. The AOFAS and VAS scores improved significantly at the final follow-up visit in both groups ($p < 0.001$). No significant difference was observed between the groups preoperatively, at 6, 12, or 24 months postoperatively, or the last follow-up visit ($p < 0.05$). The preoperative and final follow-up VAS scores did not differ significantly between the groups ($p < 0.05$) (Table 1).

Radiologically, the mean ADT improved significantly ($p < 0.001$) from 6.70 ± 2.12 mm preoperatively to 4.99 ± 1.86 mm at the final follow-up visit in the AMBO group and from 7.12 ± 1.98 mm to 4.82 ± 1.67 mm in the OMBO group. The mean TTA improved from 6.76° ± 4.19° preoperatively to 3.89° ± 3.14° at the final follow-up visit in the AMBO group and from 7.58° ± 5.02° to 4.14° ± 2.60° in the OMBO group (both $p < 0.001$). Radiographic values did not differ significantly between the groups ($p > 0.99$) (Table 2). The ICCs for the intra- and interobserver reliability of all radiological measurements showed values exceeding 0.98 (a value closer to 1 indicates better agreement), demonstrating excellent results (Table 3).

Accompanying Abnormalities and Additional Procedures

Additional procedures were performed at the time of the MBO to correct any accompanying synovitis, osteochondral lesions of the talus, anterior bony impingement,

Table 1. Mean Changes in Clinical Scores and Differences between AMBO and OMBO Groups

Variable	AMBO group (n = 37)		OMBO group (n = 17)		Δ* score	
	Mean ± SD	*p*-value	Mean ± SD	*p*-value	OR (95% CI)	*p*-value†
AOFAS score						
Preoperative	70.92 ± 15.35	Reference	72.53 ± 9.21	Reference	1.61 (–6.47 to 9.70)	0.691
6 Months	81.59 ± 10.72	< 0.001	84.82 ± 10.84	< 0.001	3.23 (–3.09 to 9.55)	0.310
12 Months	86.68 ± 9.97	< 0.001	84.65 ± 10.71	< 0.001	–2.03 (–7.92 to 3.86)	0.493
24 Months	88.81 ± 9.32	< 0.001	89.41 ± 8.81	< 0.001	0.60 (–4.78 to 5.99)	0.824
Last follow-up	94.97 ± 7.03	< 0.001	92.41 ± 6.65	< 0.001	–2.56 (–6.62 to 1.50)	0.218
VAS score						
Preoperative	4.65 ± 1.83	< 0.001	5.41 ± 1.50	< 0.001	0.76 (–0.26 to 1.78)	0.139
6 Months	3.16 ± 1.92	< 0.001	3.47 ± 2.43	< 0.001	0.31 (–0.92 to 1.53)	0.617
12 Months	2.30 ± 1.73	< 0.001	2.71 ± 1.72	< 0.001	0.41 (–0.61 to 1.42)	0.423
24 Months	1.73 ± 1.50	< 0.001	1.94 ± 1.64	< 0.001	0.21 (–0.70 to 1.12)	0.643
Last follow-up	0.86 ± 0.95	< 0.001	1.59 ± 1.70	< 0.001	0.73 (0.001 to 1.45)	0.116

Values are presented as mean ± standard deviation unless otherwise indicated. A $p < 0.05$ within-group change from preoperative to each time point.
AMBO: arthroscopic modified Broström operation, OMBO: open modified Broström operation, SD: standard deviation, OR: odds ratio, CI: confidence interval, AOFAS: the American Orthopaedic Foot and Ankle Society, VAS: visual analog scale.
*Δ: Between-group difference in the least square means of each score. †Adjusted *p*-values were calculated using a linear mixed model with compound symmetric covariance.

Table 2. Mean Changes in Radiological Scores, Differences between AMBO (n = 37) and OMBO (n = 17) Groups

Variable	Evaluation time			Change	
	Preoperative	Last follow-up	*p*-value*	Last preoperative	*p*-value†
TTA					0.657
OMBO	7.58 ± 5.02	4.14 ± 2.60	0.006	–3.45 ± 4.88	
AMBO	6.76 ± 4.19	3.89 ± 3.14	< 0.001	–2.87 ± 3.07	
ADT					0.411
OMBO	7.12 ± 1.98	4.82 ± 1.67	0.0002	–2.3 ± 2.17	
AMBO	6.70 ± 2.12	4.99 ± 1.86	0.0004	–1.72 ± 2.79	

Values are presented as mean ± standard deviation.
AMBO: arthroscopic modified Broström operation, OMBO: open modified Broström operation, TTA: talar tilt angle, ADT: anterior draw test.
*Calculated using paired *t*-test. †Calculated using independent 2-sample *t*-test.

and/or ossicles at the lateral malleolus in 31 of 37 ankles (83.8%) in the AMBO group and 12 of 17 ankles (70.6%) in the OMBO group. Arthroscopic synovectomies were performed in 28 ankles (75.7%) in the AMBO group and 8 ankles (47.1%) in the OMBO group. Arthroscopic microfracture was performed in 15 ankles (40.5%) and 7 ankles (41.2%), arthroscopic bony spur resection was performed in 4 ankles (10.8%) and 5 ankles (29.4%), and arthroscopic ossicle excision was performed in 9 ankles (24.3%) and 3 ankles (17.6%), respectively, in the AMBO group and OMBO group. Four patients (10.8%) and 2 patients (11.8%) in the respective groups had generalized ligamentous laxity (generalized ligamentous laxity was defined as a Beighton score ≥ 4). The performance of additional procedures did

Table 3. Intraobserver and Interobserver Reliability of Radiographic Measurements

Variable	Observer A	Observer B	Interobserver
TTA			
Preoperative	0.995 (0.992–0.997)	0.989 (0.982–0.994)	0.977 (0.961–0.987)
Last follow-up	0.993 (0.989–0.996)	0.993 (0.987–0.996)	0.985 (0.98–0.992)
ADT			
Preoperative	0.978 (0.963–0.987)	0.974 (0.653–0.985)	0.943 (0.901–0.967)
Last follow-up	0.985 (0.975–0.992)	0.974 (0.950–0.986)	0.965 (0.939–0.980)

Values are presented as intraclass correlation coefficient (95% confidence interval).
TTA: talar tilt angle, ADT: anterior draw test.

Table 4. Preoperative Demographic Data and Accompanying Abnormalities

Variable	AMBO (n = 37)	OMBO (n = 17)	Total (n = 54)	*p*-value*
Preoperative demographic data				
Age (yr)	38.5 ± 15.2	34.5 ± 13.4	37.2 ± 14. 7	0.358
Sex				
Male	18 (48.6)	9 (52.9)	27 (50.0)	0.999
Female	19 (51.4)	8 (47.1)	27 (50.0)	
BMI (kg/m^2)	24.8 ± 3.2	24.6 ± 3.2	24.7 ± 3.2	0.879
Mean follow-up (mo)	64.8 ± 6.7	48.7 ± 14.2	59.7 ± 9.0	0.007
Accompanying abnormality				
Synovitis	28 (75.7)	8 (47.1)		0.078
Talus osteochondral lesion	15 (40.5)	7 (41.2)		0.999
Anterior bony impingement	3 (8.1)	4 (23.5)		0.258
Ossicles at lateral malleolus	9 (24.3)	3 (17.6)		0.845
Total	31 (83.8)	12 (70.6)		

Value are presented as mean ± standard deviation or number (%).
AMBO: arthroscopic modified Broström operation, OMBO: open modified Broström operation.
*Mann-Whitney *U*-test for age and chi-square test for the other variables.

not differ between the groups ($p > 0.05$) (Table 4).

Complications

Of the 37 patients in the AMBO group, 7 (18.9%) had complications: 6 had knot-induced pain and 1 had re-rupture. All patients experiencing knot-induced pain underwent knot removal, which was performed in the surgical room under local anesthesia following hospital admission. After knot removal, all knot-induced pain improved. A single patient who had re-rupture experienced a recurrence of giving way after the surgery and subsequently underwent a redo MBO (revision surgery). After revision surgery, the issue of giving way was improved. Of the 17 patients in the OMBO group, 1 (5.9%) had the complication of superficial peroneal nerve injury, which improved without further treatment.

DISCUSSION

The most important finding of this study is the lack of significant difference in the outcomes of CLAI treatment between the AMBO and OMBO groups at midterm follow-up. Several researchers have reported similar clinical outcomes between these groups after short-term follow-up. For example, Li et al.[14] reported similarly favorable outcomes in AMBO and OMBO groups after ≥ 2 years of follow-up, based on the AOFAS score, Karlsson ankle functional score, Tegner activity score for subjective functional examinations, and ADT. Rigby and Cottom[9] found no significant difference at 16-month follow-up in function or satisfaction, according to AOFAS ankle-hindfoot, Karlsson and Peterson, and VAS scores. In a randomized controlled trial, Yeo et al.[8] found no significant difference in clinical or radiological outcomes at 1 year, according to AOFAS, Karlsson ankle functional, and VAS scores for clinical outcomes and ADT and TTA for radiological outcomes. In our study, AMBO and OMBO had similarly favorable outcomes at up to 59.69 months.

We performed OMBO with a modified open Broström-Gould repair, which involves reconstruction of the ATFL and calcaneofibular ligaments (CFL) by overlaying the 2 ligaments along the joint capsule and their reinforcement with the inferior extensor retinaculum.[19] Lee et al.[17] reported that the OMBO without CFL reconstruction for CLAI yields good to excellent long-term functional, clinical, and radiological results. Hence, we performed open Broström-Gould repair without CFL repair. We performed the AMBO using suture anchors. Several variations of this arthroscopic technique, involving staples, suture anchors, thermal shrinkage, and plication techniques, have been used.[9] In a biomechanical study, Lee et al.[7] performed the AMBO using a suture anchor or the OMBO in 11 pairs of cadaver specimens; they observed no significant difference between the 2 operations in terms of torque to failure, degrees to failure, and working construct stiffness. Giza et al.[20] reported similar results.

In our study, 7 of the 37 patients (18.9%) in the AMBO group and 1 of the 17 patients (5.9%) in the OMBO group developed complications. In the AMBO group, 6 patients had knot-induced pain, which subsided after knot removal operations within 5 months. After the patient who experienced re-rupture underwent reconstruction, his symptoms improved. The patient in the OMBO group with a complication had a superficial peroneal nerve injury and underwent electromyography. His condition eventually improved after 6 months without further treatment. Wang et al.[21] found that the complication rate increased from 0% to 41.9% and reported superficial peroneal nerve numbness, sural nerve neuritis, and knot pain. We changed the suture anchor used in the AMBO from a Bio-Suture Tak to a knotless Biocomposite suture anchor in March 2017. After this change, no patient experienced knot pain.

In our series, 83.8% of the patients in the AMBO group and 70.6% of those in the OMBO group had accompanying abnormalities. Hintermann et al.[22] reported that chondral damage was found in 66% of their patients during CLAI treatment in arthroscopy. Komenda and Ferkel[23] reported that 93% of their patients developed intra-articular abnormalities during treatment. Our results were similar. AMBO is preferred for the treatment of accompanying diseases for many reasons.

This study has several limitations. First, the sample size was small, the results were not distributed normally, and the conclusions were drawn using parametric statistical analysis. Second, we assessed outcomes at a midterm follow-up time point. Long-term follow-up is warranted to determine whether the observed trends continue. Third, subjective satisfaction was not evaluated. Subjective satisfaction provides a good clue for the recommendation of operative treatment. Despite these limitations, we found no difference in clinical or radiological outcomes of AMBO and OMBO as treatments for CLAI at midterm follow-up ($p > 0.05$).

The clinical and radiological outcomes of the AMBO and OMBO as treatments for CLAI did not differ at up to 59.69 months. Following a review of the causes of complications and improvement of the operation technique, AMBO can be used for patients with CLAI.

CONFLICT OF INTEREST

No potential conflict of interest relevant to this article was reported.

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