



Modified L'Episcopo tendon transfer for isolated loss of active external rotation

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Background: Patients with isolated loss of active external rotation (ILER) but preserved active forward elevation have recently been identified as a rare and distinct clinical entity. The modified L'Episcopo procedure attempts to restore horizontal muscle balance and restore active external rotation.

Methods: A retrospective study was performed for all patients with ILER and preserved forward elevation with Hamada stage ≤ 2 changes undergoing the modified L'Episcopo tendon transfer. Preoperative rotator cuff fatty infiltration and morphology was reported. Clinical, radiographic, and functional outcomes were recorded preoperatively and compared to postoperative outcomes at a minimum of 24 months' follow-up.

Results: Nine patients (8 male, 1 female) with a mean age of 58.4 years (range, 51-67 years) were evaluated at a mean follow-up of 64.3 months (range, 24-126 months). Significant improvement was demonstrated in active external rotation with the arm at the side (mean increase of 47°; range, 30°-60°, $P = .004$) and at 90° abduction (mean increase of 41°; range, 20°-70°, $P = .004$). The mean Constant score and pain score significantly improved at final follow-up ($P = .004$). All patients were either very satisfied or satisfied, with a mean subjective shoulder value of 74% (range, 60%-99%).

Conclusion: In appropriately selected patients with ILER and preserved active forward elevation, the modified L'Episcopo procedure can restore horizontal muscle balance and produce significant improvements in active external rotation, Constant score, and pain.

Level of evidence: Level IV; Case Series; Treatment Study

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Patients with chronic massive posterosuperior rotator cuff tears with isolated loss of active external rotation (ILER) but preserved active forward elevation have recently been identified as a rare and distinct clinical entity.^{3,5} Unlike anterosuperior rotator cuff tears or isolated

tears of the supraspinatus and/or infraspinatus, insufficiency of the infraspinatus and teres minor leads to a profound external rotation deficit and horizontal muscular imbalance.^{3,4,44} These patients have significant difficulty positioning their arm away from their body, particularly with overhead tasks and during some of the most basic activities of daily living including eating, drinking, and basic hygiene/grooming.^{3,5}

Tendon transfers are often considered either in isolation or combination with reverse shoulder arthroplasty in

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patients who have massive rotator cuff tears that are deemed irreparable.^{3-7,10,13,17,21,25,28,45} Transfer of the latissimus dorsi (LD) and teres major (TM) was originally described in the setting of obstetric brachial plexus injuries;³⁵ however, Boileau et al³⁻⁶ proposed a modified procedure to restore active external rotation in patients with horizontal imbalance secondary to deficient infraspinatus and teres minor. Recently, the lower trapezius transfer has been described by Elhassan et al²¹ for patients with massive posterosuperior rotator cuff tears; however, it has not been reported in patients with ILER with preserved active forward elevation.

The purpose of this study was to evaluate the clinical and radiographic outcomes of patients undergoing the modified L'Episcopo procedure for ILER with preserved active forward elevation without glenohumeral arthritis. We hypothesized that the modified L'Episcopo procedure would restore active external rotation both at the side and in abduction without compromising active forward elevation or internal rotation and would result in significant clinical improvement as previously demonstrated by Boileau et al.^{3,5}

Material and methods

Patient selection

A retrospective review from 2008-2016 was performed for all patients undergoing the modified L'Episcopo procedure for ILER at a single institution by a single surgeon (L.N.). Inclusion criteria were defined as follows: (1) massive posterosuperior rotator cuff tears with isolated loss of external rotation on physical examination (ie, without deficit of active elevation compared with opposite healthy side), (2) subscapularis integrity, (3) no glenohumeral osteoarthritis on plain films (Hamada stage ≤ 2),²⁹ (4) treatment with the modified L'Episcopo procedure, and (5) minimum 2-year follow-up with clinical and radiographic assessment. Exclusion criteria were (1) massive posterosuperior rotator cuff tears with combined loss of external rotation and active elevation, (2) combination of modified L'Episcopo procedure with reverse shoulder arthroplasty, and (3) shoulder stiffness (limited passive range of motion) on preoperative examination. During the study period, we identified 9 patients (8 male and 1 female) that met the inclusion criteria. The mean age at surgery was 58.4 years (range, 51-67 years). Mean follow-up was 64.3 months (range, 24-126 months).

Clinical assessment

Range of motion was recorded preoperatively and at final follow-up in active forward elevation, active external rotation with the elbow at side (AER1) and at 90° of abduction (AER2) and active internal rotation. The range of motion was assessed with a manual goniometer and recorded in degrees. Neutral position of the forearm perpendicular to the plane of the body with the elbow flexed to 90° was defined as the "zero-position" for assessment of AER1. Patients who were unable to externally rotate beyond the zero-position were defined as having negative AER1, whereas patients who were able to externally rotate beyond the zero-position had

positive AER1. The reference for zero-position in AER2 was the forearm parallel to the floor with 90° of shoulder abduction and 90° of elbow flexion. Active internal rotation was evaluated by the position of the hand when the patient was asked to reach behind his or her back and rated in points (hip, 0 points; buttock, 2 points; sacrum, 4 points; L3, 6 points; T12, 8 points; and T7, 10 points).¹⁶

The function of the rotator cuff was assessed with the external rotation lag sign (infraspinatus) and Hornblower sign (teres minor)^{15,44} (Fig. 1). The Constant-Murley score was assessed prior to surgery at final follow-up.¹⁶ For subjective assessment, the patients were questioned regarding their satisfaction with the outcome of surgery (very satisfied, satisfied, unsatisfied, and disappointed). Postoperative Subjective Shoulder Value was determined at final follow-up and reported as a percentage.²⁶

Radiographic assessment

All patients had anteroposterior and lateral radiographs of the shoulder before surgery and at follow-up. Plain films were graded according to Hamada.²⁹ Fatty infiltration of rotator cuff muscles (subscapularis, supraspinatus, infraspinatus, and teres minor) was assessed with either computed tomographic scan according to Goutallier et al²⁷ or magnetic resonance imaging according to Fuchs et al.²³ Morphology of the teres minor was rated according to Melis-Walch classification as normal, hypertrophic, atrophic, or absent.³⁶

Surgical technique

The surgical technique was performed as originally described by Boileau et al.⁵ The patient is placed in the beach chair position with general anesthesia and an interscalene block. The arm is draped free and laid on an arm support to allow mobilization. A deltopectoral approach is performed. The presence of a posterosuperior rotator cuff tear is confirmed and the integrity of the subscapularis is assessed. The biceps tendon is tenotomized from the glenoid and tenodesed to the transverse humeral ligament in the bicipital groove with the elbow extended. The coracoacromial ligament is preserved. The anterior axillary vessels and axillary nerve are identified. The pectoralis major tendon is tenotomized and tagged with sutures for retraction and identification prior to repair at the end of the procedure. The LD/TM tendons are detached together from their humeral insertion and tagged with temporary sutures. The 2 tendons are then progressively released using blunt dissection to gain enough length (3-4 cm) for transfer around to the lateral aspect of the humerus. A tunnel is created behind the humeral shaft for LD/TM passage. Three holes are drilled at the posterolateral aspect of the humerus at the same proximo-distal level as the initial position of the LD/TM tendons to preserve horizontal balance. An osteotome is used to partially decorticate the bone bed to enhance tendon healing. Nonabsorbable sutures are passed through transosseous tunnels, or suture anchors are used for fixation of the LD/TM tendons to bone based on surgeon's preference. The pectoralis major is then reattached in its anatomic position and the wound is closed.

Postoperative protocol

The arm is placed in a 20° abduction brace with 30° of external rotation (DonJoy Ultrasling; DJO Global Inc., Vista, CA, USA)

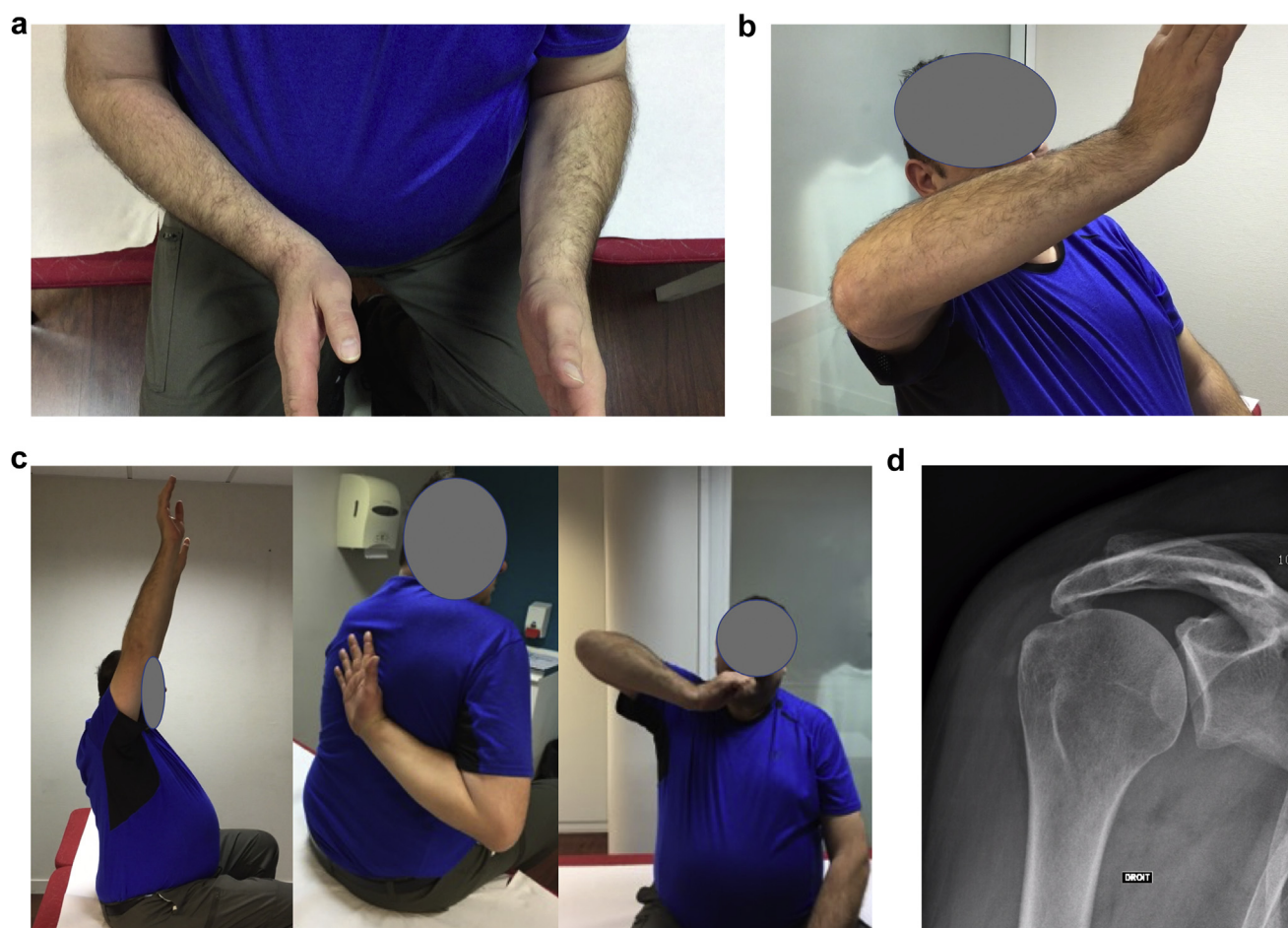


Figure 1 Preoperative clinical and radiographic presentation. Male, 52-year-old, right nondominant side. (a) Negative external rotation with elbow at the side (ER1). (b) Limited external rotation in abduction (ER2). (c) Normal active forward elevation and internal rotation. Positive hornblower sign. (d) Anteroposterior view. Hamada stage 2.

for 6 weeks. A self-stretching program with or without hydrotherapy is initiated at 3 weeks after surgery. Patients gradually regained full mobilization of the shoulder. Activities of daily living can be expected to resume on a normal basis at 3 months, postoperatively; all activities are permitted as tolerated 6 months postoperatively. No specific strengthening exercises are used. Biofeedback training was not used in the postoperative period.

Statistical analysis

Descriptive statistics were determined and expressed as means, medians, and standard deviations for continuous data or as frequency counts and percentages for categorical data. The nonparametric Wilcoxon signed-rank test was used to compare values of the functional score and pain between pre- and postoperative data. The alpha risk was set to 0.05 for all tests to estimate statistical significance, and all of the tests were 2-tailed. SAS, version 9.4 (SAS Institute, College Station, TX, USA), was used for all statistical analysis.

Results

Clinical presentation

At the time of preoperative evaluation, all patients had negative AER1 with a mean of $-28.3^\circ \pm 9.4^\circ$ (range, -45° to -10°) and limited AER2 with a mean of $+15.6^\circ \pm 15.1^\circ$ (range, 0° - 30°). Mean active forward elevation was $164^\circ \pm 8.8^\circ$ (range, 150° - 180°). Mean internal rotation was between L3 and T12 according to the Constant scoring system with a mean 7.3 ± 1.7 points (range, 4-10 points) (Table I). Additionally, all patients had a positive external rotation lag sign and Hornblower sign before surgery.

Preoperative imaging

All patients had massive supraspinatus and infraspinatus tendon tears with intact subscapularis tendons. The mean fatty infiltration of the rotator cuff muscles was 0.2 ± 0.4

Table I Individual demographics, clinical assessment, and patient-reported outcomes

| Patient | Sex / age at surgery, yr | Involved/ dominant side | Final follow-up, mo | AER 1, degrees, preop./ postop | AER 2, degrees, preop./ postop | AFE, degrees, preop./ postop | IR, points, preop./ postop | Pain, points (0-15), preop./ postop | Constant, points, preop./ postop | SSV, %, preop./ postop | Satisfaction |
|---------|--------------------------|-------------------------|---------------------|--------------------------------|--------------------------------|------------------------------|----------------------------|-------------------------------------|----------------------------------|------------------------|--------------|
| 1 | M/54 | R/R | 58 | -20/25 | 0/40 | 160/150 | 8/10 | 6/15 | 36/68 | 70 | S |
| 2 | M/57 | L/R | 92 | -30/30 | 30/80 | 160/170 | 6/6 | 6/15 | 45/70 | 70 | S |
| 3 | M/66 | R/R | 120 | -30/20 | 0/30 | 160/150 | 8/8 | 6/11 | 35/65 | 70 | S |
| 4 | M/61 | L/L | 44 | -30/10 | 30/70 | 150/170 | 10/8 | 8/14 | 59/81 | 80 | VS |
| 5 | F/67 | R/R | 31 | -10/45 | 30/80 | 170/180 | 8/10 | 8/15 | 37/77 | 80 | VS |
| 6 | M/60 | L/R | 126 | -30/10 | 30/50 | 170/170 | 8/8 | 8/10 | 42/69 | 70 | S |
| 7 | M/57 | R/R | 24 | -30/20 | 0/20 | 180/180 | 4/6 | 3/15 | 26/83 | 60 | S |
| 8 | M/51 | L/R | 60 | -30/0 | 0/70 | 160/170 | 6/8 | 8/13 | 33/73 | 70 | S |
| 9 | M/52 | R/L | 24 | -45/10 | 20/70 | 170/170 | 8/8 | 6/15 | 57/83 | 99 | VS |
| Mean | 58.3 | | 64.3 | -28/19 | 15/57 | 164/168 | 7.3/8 | 6.5/13.6 | 41.1/74.3 | 74.3 | |

M, male; F, female; R, right; L, left; AER 1, active external rotation with elbow at side; preop., preoperation; postop., postoperation; AER 2, active external rotation at 90° abduction; AFE, active forward elevation; IR, internal rotation; SSV, Subjective Shoulder Value; S, satisfied; VS, very satisfied. Descriptive demographics, clinical outcomes (pre- and postoperative), and patient-reported outcomes (pre- and postoperative) for each patient in the cohort.

(range, 0-1) for the subscapularis, 2.3 ± 0.7 (range, 1-3) for the supraspinatus, and 3.2 ± 1 (range, 2-4) for the infraspinatus. Teres minor morphology was graded as normal in 2 cases, atrophic in 4 cases, and absent in 3 cases. Fatty infiltration of the teres minor grade was grade 3 or 4 when present. All patients were Hamada stage 2 (Table II).

Postoperative range of motion and functional outcomes

At final follow-up, there was significant improvement in the active external rotation for all patients with preservation of forward elevation and internal rotation. The mean postoperative AER1 was $18.9^\circ \pm 13.4^\circ$ (range, 0° - 45°) with a mean gain of 47° (range, 30° - 60°) ($P = .004$). The mean AER2 was $56.7^\circ \pm 22.4^\circ$ (range, 20° - 80°) with a mean gain of 41° (range, 20° - 70°) ($P = .004$). Active forward elevation and active internal rotation were unchanged ($P = .53$ and $P = .37$, respectively) (Table III). All patients but one had a negative Hornblower sign at final follow-up.

The mean Constant score significantly improved from 41.1 ± 11 points to 74.3 ± 6.9 points ($P = .004$) at final follow-up and the final Subjective Shoulder Value was 74% (range, 60-99 points). The mean Constant pain score was 13.7 ± 1.9 points (range, 10-15 points). All patients were either very satisfied (33.3%) or satisfied (66.7%) with their outcome at final follow-up. Pectoralis major reattachment was intact in all patients. There were no complications or reoperations required.

Radiographic outcomes

At final follow-up, 4 patients had plain radiographs that demonstrated no progression of cuff tear arthropathy

according to the Hamada grade, whereas 5 patients demonstrated progression of 1 grade. All of these patients evolved from Hamada stage 2 preoperatively to stage 3 at final follow-up (Fig. 2).

Discussion

The results of this study demonstrate that in appropriately selected patients with ILER and preserved active forward elevation, the modified L'Episcopo procedure is effective at significantly improving active external rotation without compromising active forward elevation and internal rotation. Furthermore, significant functional and subjective improvement was demonstrated in these patients. These results support our hypothesis and the previously reported findings of Boileau et al^{3,5} in this unique clinical population.

The management of massive rotator cuff tears remains controversial and challenging. Massive rotator cuff tears can account for up to 40% of all rotator cuff tears,² with approximately 12% being deemed as irreparable.⁴² Failure rates following attempted repair ranging from 20%-94%^{1,12,24,31-33,40,46} have resulted in numerous treatment strategies being proposed to manage these difficult situations with no clear consensus.^{3,5,8-10,13,17-19,25,37,39,41}

Patients with ILER represent a unique population, which must be viewed as distinct from other patients with massive irreparable rotator cuff tears because of the disruption in the horizontal muscular balance of the shoulder.^{3,5} The teres minor provides approximately 40% of the external rotation strength of the shoulder,⁴⁴ with 90% of the external rotation torque generated from the infraspinatus and teres minor.³⁴ Patients with deficient infraspinatus and teres

Table II Rotator cuff fatty infiltration and morphology

| Patient | SS (FI) | IS (FI) | SSc (FI) | Tm (FI) | Tm (morphology) |
|---------|---------|---------|----------|---------|-----------------|
| 1 | 1 | 2 | 0 | 3 | Atrophic |
| 2 | 2 | 4 | 0 | 3 | Atrophic |
| 3 | 3 | 4 | 0 | 4 | Atrophic |
| 4 | 2 | 2 | 1 | – | Absent |
| 5 | 3 | 4 | 0 | – | Absent |
| 6 | 3 | 4 | 0 | – | Absent |
| 7 | 2 | 3 | 0 | 4 | Atrophic |
| 8 | 3 | 4 | 0 | 4 | Normal |
| 9 | 2 | 2 | 1 | 4 | Normal |

SS, supraspinatus; FI, fatty infiltration; IS, infraspinatus; SSc, subscapularis; Tm, teres minor.

Goutallier/Fuchs and Melis-Walch classification for rotator cuff FI and morphology.

minor largely lose the ability to externally rotate the arm and position the limb in space as the remaining internal rotators (subscapularis, pectoralis major, LD, and TM) overpower the arm. The concept of the modified L'Episcopo procedure is to rebalance the lost external rotation force by transferring 2 of the internal rotators (LD and TM) to restore external rotation.

Although several authors have reported on the use of tendon transfers in patients with massive irreparable rotator cuff tears,^{10,13,17,21,25,28} only the studies by Boileau et al^{3,5} are comparable to this investigation as this represents a similar cohort of patients based on tightly defined clinicopathology. In the largest cohort of patients with ILER undergoing the modified L'Episcopo procedure, Boileau et al³ reported on 26 patients over a 10-year period with a mean follow-up of 52 months. These patients were similar in demographics and baseline clinical presentation to those reported in our series. Following the modified L'Episcopo tendon transfer, active external rotation at the side improved from -19.2° to 6.6° (25.8° change), and active external rotation in abduction improved from 21.5° to 40° (18.5° change).³ Similarly, the patients in our series improved from -28° to 19° (change of 47°) with the arm at the side and from 15° to 56° (change of 41°) with the arm in abduction. Interestingly, the teres minor was found to be in continuity in 6 of 9 cases in our series; however, the teres minor was clinically nonfunctional in all 6 patients as evidenced by Goutallier grade 3 and 4 changes in all patients with loss of active external rotation and the presence of a Hornblower sign. The current study demonstrates that although the modified L'Episcopo procedure can significantly improve active external rotation, these patients do not recover a normal range of motion. All patients in this series preoperatively had negative external rotation (permanent internal rotation relative to the neutral or "zero position"). Postoperatively, all patients but one had positive active external rotation with the arm at the side.

Recent evidence suggests that it is not only the degree of rotator cuff pathology but the overall pattern of rotator cuff dysfunction that leads to the clinical loss of active motion. Patients with complete tears of the supraspinatus and infraspinatus with an intact teres minor may present with combined loss of active elevation and external rotation.^{14,15} Even in the setting of an intact teres minor, if significant fatty atrophy is present, patients may have loss of active external rotation.²¹ The underlying etiology of fatty infiltration of the teres minor in the absence of a tear is unclear;^{11,22,38} however, radiographic evidence suggests that isolated teres minor fatty infiltration is present in approximately 3% of patients.⁴³

Both in the series by Boileau et al³ and in our series, there was no loss of active forward elevation or internal rotation as a consequence of the tendon transfer. The improvement in Subjective Shoulder Value, Constant score, and final patient satisfaction reported by Boileau et al³ are all similar to our reported functional and subjective outcomes. In the series by Boileau et al,³ 38% of patients had progression of the radiographic appearance of cuff tear arthropathy by the Hamada classification,²⁹ whereas 55% progressed in our population. Lastly, despite good functional outcomes and high patient satisfaction, 50% of the patients reported by Boileau et al³ had a persistent Hornblower sign clinically, as opposed to 11% in this series.

The use of the lower trapezius transfer as reported by Elhassan et al^{20,21} has recently garnered a lot of interest for patients with massive irreparable rotator cuff tears. Biomechanical evidence suggests that with the arm at the side, the lower trapezius transfer has a significantly larger effect on the external rotation moment arm compared with the LD or TM transfer; however, with the arm in 90° abduction, there was a larger effect of the LD and TM transfer (individual transfers) compared with the lower trapezius.³⁰ Of note, the combination of the LD and TM transfer was not compared in this study to the lower trapezius transfer. The authors concluded that the LD transfer may be a better transfer to restore external rotation if the shoulder could be abducted.³⁰ Clinically, Elhassan et al²¹ recently reported their results of lower trapezius transfer in patients with massive rotator cuff tears. Their patient cohort was more heterogeneous than that described by Boileau et al³ or in our series, with a mean preoperative external rotation of 20° (range, -50° to 40°) and mean active forward elevation of 70° (range, 20° - 120°). It is critical to note that this cohort likely does not represent a population of patients with ILER and therefore is a distinct clinical entity from that described in our series and by Boileau et al.³ This is evidenced by the fact that some patients had preserved external rotation (up to 40°) and that no patient in their series had preserved active forward elevation, thus precluding them from being defined as ILER.^{3,5}

There are several limitations in this study. The most obvious limitation is the small sample size; however, this is

Table III Statistical analysis of range of motion and functional outcomes from preoperative to postoperative

| | Preoperative (n = 9) | Postoperative (n = 9) | Change | P value |
|--------------------|-------------------------|--------------------------|--------|---------|
| AFE, degrees | 164.4 ± 8.8 | 167.8 ± 10.9 | +3.3 | .531 |
| AER 1, degrees | -28 ± 9.4 | 18.9 ± 13.4 | +47.2 | .004 |
| AER 2, degrees | 15.6 ± 15.1 | 56.7 ± 22.4 | +41.1 | .004 |
| IR, points | 7.3 ± 1.7 | 8.0 ± 1.4 | +0.7 | .375 |
| Pain, points, 0-15 | 6.6 ± 1.7 | 13.7 ± 1.9 | +7.1 | .004 |
| Constant, points | 41.1 ± 11.0 | 74.3 ± 6.9 | +33.2 | .004 |
| SSV, % | — | 74.3 (60-99) | N/A | N/A |

AFE, active forward elevation; AER 1, active external rotation with elbow at side; AER 2, active external rotation at 90° abduction; IR, internal rotation; SSV, Subjective Shoulder Value; N/A, not applicable.

Comparing pre- and postoperative range of motion, Constant score, and SSV. Data are expressed as either means and standard deviations or means with ranges in parentheses.



Figure 2 Postoperative clinical and radiographic presentation at 24-month follow-up. (a) Positive external rotation with elbow at the side (ER1). (b) Positive external rotation in abduction (ER2). (c) Normal active forward elevation and internal rotation. Negative hornblower sign. (d) Anteroposterior view. Hamada stage 3.

inevitable given the rarity of this distinct clinical entity. Furthermore, as with any retrospective study there are inherent limitations because of the potential for possible bias. Additionally, although we were able to clinically evaluate the outcome of the tendon transfer via physical examination, we did not have advanced imaging to report on the structural integrity or long-term changes following the tendon transfer.

This study also has numerous strengths. To our knowledge, this series represents the second largest report on the use of the modified L'Episcopo tendon transfer for patients with ILER. Our strict criteria for inclusion make this series directly comparable to that reported by Boileau et al³ and, therefore, can confirm their previously reported findings on this rare clinical entity. Additionally, this series represents the longest mean clinical and radiographic follow-up reported in the literature for this clinical entity by 12 months.

Conclusion

The results of this study confirm our initial hypothesis and the results previously demonstrated by Boileau et al^{3,5} regarding the use of the modified L'Episcopo procedure for patients with ILER with preserved active forward elevation. In appropriately selected patients, this procedure significantly improves active external rotation with the arm at the side and in the abducted position without compromising active forward elevation and internal rotation. Significant improvement in functional and subjective outcomes were evident at a mean follow-up of 64 months. Given the findings of this study, we recommend the modified L'Episcopo procedure as a salvage operation in patients with ILER with preserved active forward elevation, preserved subscapularis, and no glenohumeral osteoarthritis.

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