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LIGAMENTUM TERES TRANSFER DURING MEDIAL OPEN REDUCTION IN PATIENTS WITH DEVELOPMENTAL DYSPLASIA OF THE HIP

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ABSTRACT

Background: The ligamentum teres (LT) is believed to have a number of functions, including a role in hip stability, nociception, proprioception, vascular supply to the femoral head, and synovial fluid circulation. The LT is often excised in the process of performing a medial open reduction (MOR) of the hip. We sought to conduct a retrospective review of hips undergoing a MOR for dislocated infantile developmental dysplasia of the hip (DDH) to compare clinical and radiographic outcomes for patients with and without LT reconstruction.

Methods: We performed a retrospective review of 38 hips treated with MOR with or without LT reconstruction with minimum two-year follow-up. Radiographic outcomes were determined using the Severin score. Information regarding avascular necrosis (AVN), concomitant surgical procedures, repeat dislocation, subsequent surgery, limp, pain, and range of motion symmetry was recorded.

Results: Eighteen hips that underwent MOR with LT reconstruction were compared to 20 hips that underwent MOR without LT reconstruction. Mean follow up for this cohort was 70.1 months (median: 61.8; Range: 24.2 to 182.2 months). The group with LT reconstruction had an 11% rate of AVN, the group without LT reconstruction had a 15% rate of AVN (p=1.0) No hips in either group re-dislocated or had pain at final follow up. Two hips (5%) had a limp at most recent follow up, all were in the group that did not receive a LT reconstruction (p=0.488). Three hips (17%) in the LT reconstruction group and one hip (5%) in the other group had asymmetrical hip range of motion at final follow up (p=0.328).

Conclusion: This study offers preliminary data to suggest that ligamentum teres reconstruction is a safe procedure that can minimize the risk for subluxation or re-dislocation that can occur within the post reduction hip spica cast. Although in this study, the patients who did not have LT reconstruction had a similar re-dislocation rate, we believe that ligamentum teres preservation is a useful adjunct to medial open reduction, especially in centers that may only treat occasional cases or have less experience in applying an excellent hip spica cast.

Level of Evidence: III

Keywords: developmental dysplasia of the hip, ddh, medial open reduction, ligamentum teres transfer, ligamentum teres reconstruction

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INTRODUCTION

Infants with hip dislocation secondary to DDH are best managed initially with closed reduction. However, in cases where closed methods fail to achieve concentric reduction, or when substantial abduction is necessary to maintain the reduction, open reduction is warranted. The final decision is made intra-operatively after a diagnostic arthrogram has been performed and evaluated. Historically, the open reduction is performed through a standard anterior ilio-femoral approach.

The medial approach was first introduced by Ludloff in 1908, and subsequently modified by Mau in 1971, Ferguson in 1973, and Weinstein and Ponseti in 1979.[1–4] These

approaches vary slightly based on the intramuscular interval through the adductors.[5–7] Proponents of the medial approach point to decreased dissection and operative time, and more direct visualization of common impediments to reduction. The most significant disadvantages are the risk of avascular necrosis stemming from potential damage to the medial femoral circumflex vessels (which lie in the surgical field but are sometimes not easily visualized) and an inability to perform a capsulorrhaphy to increase hip stability.[8,9]

Because there is a no capsular repair performed with medial open reduction, there is a potential risk for early post-operative redislocation after medial open reduction. As will be noted later, maintenance of reduction requires an excellent hip spica cast, applied in a precise position. Ideally all centers would have both excellent surgical technique and exacting hip spica application techniques, however because this ideal does not always exist, further aids for optimizing stability have been sought out.

Wenger et al., in recognizing the significant biomechanical properties of the ligamentum, particularly the stability it adds to the hip joint, proposed a technique of ligamentum transfer, tethering the femoral head with the shortened ligamentum to the inferior acetabulum, providing additional restraint to dislocation.[8] Two groups, Wenger et al.[8] and Bache et al.,[10] simultaneously reported on this technique which serves to shorten and transfer the ligamentum to improve hip stability during medial open reduction.

Previous theories of the ligamentum teres (LT) being an embryonic remnant are no longer well supported in the literature. It is now believed to have a number of potential functions, including a role in hip stability, nociception, proprioception, vascular supply to the femoral head, and synovial fluid circulation. The LT serves as a hip stabilizer in a variety of ranges of motion such as external rotation/flexion (squatting) and internal rotation/extension (crossing one leg over other), as well as resisting hip adduction.[11–13] The LT thus prevents hip microinstability, femoral head subluxation, and dislocation.[8,14,15] Animal models have demonstrated increased rates of hip dislocation after the LT was severed.[16,17] The function of the LT as a hip stabilizer may be even more important in patients with developmental dysplasia of the hip (DDH) and joint hypermobility where primary stabilizers are often deficient.[18]

Histologic investigation has revealed the presence of pain-associated free nerve endings in the center of the LT indicating a role in nociception.[19] Lesions of the LT are the third most common cause of hip pain in athletes undergoing hip arthroscopy.[20] It likely has an additional proprioceptive function as type IVa somatosensory receptors have been discovered within the LT as well.[21,22] As for vascular supply, The LT contains a branch of the obturator artery that supplies the femoral head of the juvenile hip with fluctuating importance through early development.[23] In adulthood, the vessels of the LT rarely supply more than a small subfoveal area at its insertion site.[24] The LT has also been theorized to assist in the distribution of synovial fluid within the hip joint through a "windshield wiper" effect, however this has not been well researched.[25]

Previous studies of the LT reconstruction technique have demonstrated good short term results in a small series of patients with DDH.[8,10,26] A comparative analysis, however, has not been performed. We sought to conduct a retrospective review of two groups of patients undergoing medial open reduction (MOR) by the same technique with one having the standard approach and the other having LT reconstruction. We reviewed clinical and radiographic outcomes in both groups with minimum 2-year follow-up.

METHODS

Subjects were included from two institutions. The first institution (I-1) routinely includes a ligamentum teres reconstruction when performing a medial open reduction to treat hip dislocations associated with infantile DDH. The second institution (I-2) does not include a ligamentum teres reconstruction when performing a medial open reduction for this condition. Otherwise, the two institutions have a similar protocol for initial treatment of infants with dislocated hips including use of the Pavlik harness, and a step-wise approach to medial open reduction if all other techniques to achieve reduction fail. The surgical technique is identical except for LT reconstruction in I-1.

Institutional review board approval was obtained from both institutions prior to data collection for this retrospective study. Subjects from I-1 were identified by a surgical database query for patients with a dislocated hip treated with an open reduction from 2001 to the year 2015. Subjects from I-2 were identified by surgical database query using associated procedure codes from 2009 to 2017. Inclusion criteria were hips treated with a medial open reduction for a dislocated hip at less than 18 months of age with a minimum of two years follow up.

All subject's charts and radiographs were retrospectively reviewed to collect demographic and radiographic outcomes of interest. Limp, pain, and range of motion symmetry at most recent follow up was recorded. Radiographic outcomes were determined using the Severin score.[27] Avascular necrosis (AVN) was assessed using the Kalamchi and MacEwen criteria.[27] Concomitant bony procedures, repeat dislocation, and additional surgeries were recorded.

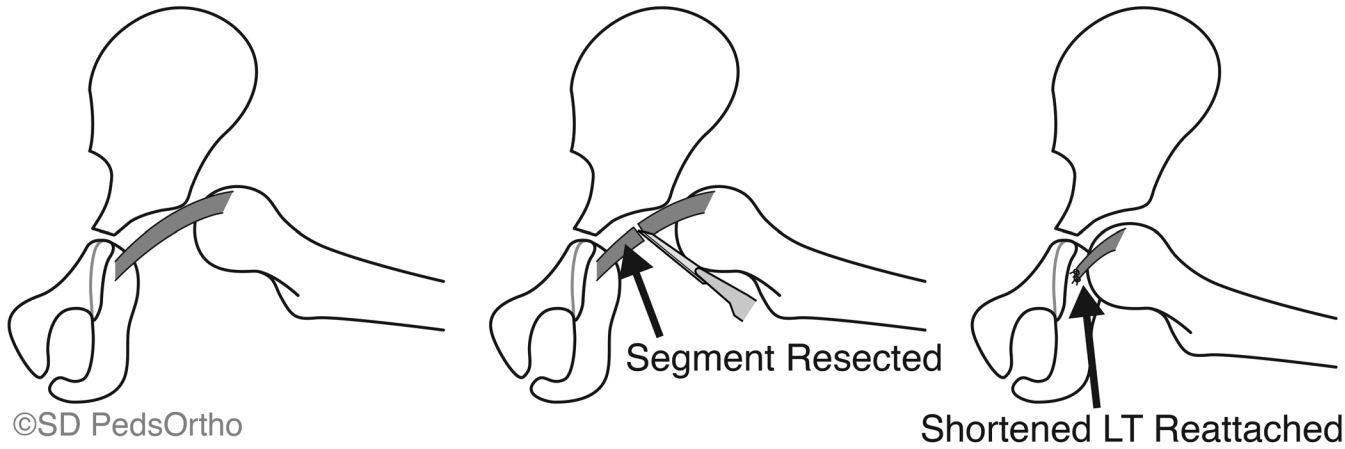

Figure 1. Sequence of drawings demonstrating the technique for ligamentum teres shortening and reattachment when performing the medial Ludloff open reduction. Left image) Femoral head in the dislocated position with elongated ligamentum teres. Center image) Ligamentum teres detached from its origin from the inferior acetabulum, with a segment resected to normalize the ligamentum teres length (approximately 1 cm resected). Right image) The shortened ligamentum teres is sutured into the anterior-inferior acetabular rim using a non-absorbable suture with a Bunnell type suture pattern.

Surgical Technique

The surgical technique used at I-1 was similar to that proposed by Mau, as well as Weinstein and Ponseti.[2,4,8] A transverse incision is made 1 cm distal to the groin crease. The adductor longus can be divided and lengthened intramuscularly, allowing for blunt dissection above the pectineus muscle. The psoas tendon is identified with an intramuscular lengthening performed, bringing the capsule into view. Care is taken at this point to identify and protect the medial femoral circumflex artery. The capsule is opened in a T-fashion. The LT is identified and transected at its insertion into the base of the acetabulum. The acetabulum is inspected and any residual, excessive fatty tissue is removed and the transverse acetabular ligament is incised. The LT, which remains attached to the femoral head, is then used to pull the femoral head distally into a reduced position. The LT is then shortened and reattached, using a Bunell type suture, into the anterior/inferior acetabular rim.[8] The suture is placed near the anterior attachment of the transverse ligament which has been transected (Fig. 1). The usual protocol is to keep the patient in a 1 1/2 hip spica for 6 weeks with the cast then change to a double short leg hip spica for an additional 6 weeks followed by 6 weeks in a hip abduction brace. This assures development of the acetabulum.

The hip stability in various positions is determined and the degree of flexion, abduction, and rotation that provides optimum stability is noted. The child is placed in a 1 1/2 hip spica with the hips held in the "human position"[28] with the hip casted in the exact position of optimum stability that was determined earlier.

The surgical technique used at I-2 is identical to the technique used at I-1 except that after opening the capsule, the LT is identified and resected at its origin at the base of the acetabulum and also detached from the femoral head and discarded. The casting position and protocol are as noted above.

Statistical Analysis

Basic descriptive statistics are reported. The hip was used as the unit of analysis. Continuous data were evaluated for normality with the Shapiro-Wilk test of normality. Data identified as normal with the Shapiro-Wilk test was also evaluated with Levene's test of homogeneity of variances. Data identified as non-normal by either test was evaluated with the Mann-Whitney U, normally distributed data was evaluated with analysis of variance (ANOVA). Categorical data were evaluated with Pearson Chi-square and Fisher's exact test. All statistical analysis was performed using IBM SPSS Statistics (version 26; IBM, Armonk, New York). Statistical significance was defined as $p<0.05$. No a priori power analysis was performed.

RESULTS

Thirty-eight hips (30 patients) were included in the study – 18 were treated with ligamentum teres reconstruction, and 20 were treated without ligamentum teres reconstruction. The mean age of the cohort at the time of open reduction was 7.9±4.8 months (median: 5.7; range: 2.9 to 17.6 months). The mean follow up for the cohort was 70.1±36.7 months (median: 61.8; range: 24.2 to 182.2 months). The majority of subjects were female (82%). No hips underwent concomitant bony surgery. None of the hips re-dislocated after MOR. Four hips from each group were found to have AVN at most recent follow up ($p=0.714$). The hips treated with ligamentum teres recon-

Table 1. Distribution of Subsequent Procedures

	Ligamentum Teres Reconstruction	No Ligamentum Teres Reconstruction
San Diego acetabuloplasty	5	0
Pemberton	2	2
Dega	0	1
San Diego acetabuloplasty, VDRO	1	0
Pemberton, VDRO	0	1

VDRO = varus derotation osteotomy

struction had two hips with group I AVN and two hips with group II AVN. The hips treated without ligamentum teres reconstruction had one hip with group I AVN, two hips with group II AVN, and one hip with group IV AVN. Two hips (5%) had a limp at most recent follow up, both were in the group that did not have a ligamentum teres reconstruction. None of the hips had pain at most recent follow up. Four hips (11%) had asymmetrical hip range of motion at final follow up. Twelve hips (32%) underwent later bony surgery to correct residual dysplasia (Table 1). Additional cohort characteristics and outcomes of interest can be found in Table 2.

Table 2. Cohort Characteristics and Outcomes of Interest

		Ligamentum Teres Reconstruction	No Ligamentum Teres Reconstruction
Age at surgery (months)	Mean±SD	7.3±4.7	8.5±5.0
	Median	5.6	6.35
	Range	3.0 to 16.4	2.9 to 17.6
Sex	Male	2	5
	Female	16	15
Concomitant bony procedure		0	0
Re-dislocation		0	0
Severin grade at final follow up	1	15	4
	2	2	14
	3	1	1
	4	0	1
AVN grade at final follow up	0	14	16
	1	2	1
	2	2	2
	3	0	0
	4	0	1
IHDI grade at final follow up	I	18	19
	II	0	1
Limp at final follow up		0	2
Pain at final follow up		0	0
Asymmetrical ROM at final follow up		3	1
Acetabular index (degrees) at final follow up	Mean±SD	17.7±10.7°	21.6±7.8°
	Median	20°	23°
	Range	-5° to 44°	12° to 36°
Follow up (months)	Mean±SD	73.4±44.1	61.7±29.3
	Median	66.93	60.96
	Range	24.2 to 182.2	28.5 to 122.8

DISCUSSION

The LT is believed to have a number of important functions, contributing to hip stability, sensory information,[19–22] femoral head vascularity,[23,24] and synovial fluid circulation.[25] The LT serves as a hip stabilizer in a variety of ranges of motion[11–13] thus preventing hip microinstability, femoral head subluxation, and dislocation.[8,14,15] This has been supported in animal models which demonstrated increased rates of hip dislocation after the LT was severed.[16,17] The function of the LT as a hip stabilizer may be even more important in patients with developmental dysplasia of the hip (DDH) and joint hypermobility where primary stabilizers are often deficient.[18]

Since Weinstein et al. reported results following their modification of the Ludloff procedure in 1997, interest has expanded on the medial open reduction as an alternative to the traditional anterior approach in North America. Although multiple studies have demonstrated favorable outcomes following this procedure, re-dislocation continues to be a challenge. This sometimes occurs within the cast soon after surgery, a circumstance that is very stressful for both the family and the surgeon. Tonnis et al. noted a 5-14% dislocation rate following the medial open reduction, compared to a 3% with an anterior approach.[8,29]

More recent studies note lower rates, ranging from 0% to 6.1% in our literature review.[5–7,30–40]

Infant hip spica cast application, to maintain hip reduction, is a critical part of medial open reduction. Ideal spica casting is often hard to achieve, particularly in institutions that have a modest volume of DDH cases that would be treated with medial open reduction in this age group. Maintaining the LT may be a useful adjunct to minimize the chance for re-dislocation.

Traditionally, the LT has been thought to be a block to reduction in congenitally dislocated hips. Additionally, it is thought that the increased stress on the ligament in hip dysplasia results in hypertrophy of both the LT and the transverse ligament, decreasing the volume of the acetabulum and making concentric reduction more difficult.[41] Thus, almost all types of open reduction of the hip in young children have included removal of the LT.

Biomechanical properties of the ligamentum have been elucidated in animal models in several studies.[17,26] In humans, Demange et al. found that resection of the ligamentum increased the maximum adduction of the hip in cadavers.[13] Phillipon et al. demonstrated a maximum load to failure of 204N using a human cadaver model.[42] Adaptation to continued strain has been noted in patients with DDH, with elongation and hypertrophy of the ligamentum.[41,43] Martin et al. additionally noted that the ligamentum is taut in positions of potential hip instability, and hypothesized a potential role in constraining the hip in DDH.[11]

In this study, we observed no re-dislocations in either group. Rates of avascular necrosis of up to 67% have been reported in the literature with the medial approach.[9,35,39] Our report compared favorably to this, and is similar to rates of AVN seen with anterior open reductions or closed reduction and casting without open reduction. However, our follow-up is limited with a minimum of 24 months and the true incidence of AVN may increase over time. Clearly, placing an infant in a hip spica, no matter how well designed and applied, increases the chance for AVN. Hip abduction in the hip spica is clearly a double-edged sword, because with too little abduction, the hip is more likely to re-dislocate in the hip spica – while excessive abduction can increase the risk for AVN. Proponents of LT maintenance and re-attachment would suggest that the procedure provides greater hip stability, thus allowing less forced hip abduction in the spica cast.

Twelve of the 38 hips (32%) in our cohort required additional bony surgery for residual dysplasia. Similar results have been noted in other reports of medial open reduction, without ligamentum teres tenodesis.[6,33,35,37] Bache et al., in their large case series of 109 hips that underwent medial open reduction with ligamentum teres tenodesis, noted additional surgery in 35% of hips.[10] Additionally, they found a dislocation rate of 2.8%, and 89% of hips demonstrated good or excellent radiographic results on the Severin scale. The AVN rate in their study was 41%, compared to the 21% noted in our study, however their study had longer follow up with more time to detect possible residuals of AVN.

The lack of any cases with re-dislocation in either series is of interest. One reason may be that the cases treated with traditional LT excision occurred in a children's hospital (I-2) with a long history of experience with the medial approach and is a center that helped introduce this technique to North America. In addition, I-2 has a strong tradition for superb casting techniques. In such circumstances, LT maintenance may not be an important component of medial open reduction. In less ideal circumstances, LT re-attachment can be an important addition to medial open reduction, minimizing the risk for early post-operative re-dislocation.

Our findings are primarily limited by a modest sample size and relatively short follow up. It is possible that rates of repeat surgery and AVN could increase with time. Although our study cannot produce definite conclusions due to the magnitude of these limitations, it does offer preliminary data to suggest that ligamentum teres reconstruction is a safe and effective procedure.

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