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# Partial ligamentum teres tears are associated with larger acetabular labra and less damage to the labrum than complete ligamentum teres tears

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## ABSTRACT

The purpose of this study was to investigate the association between ligamentum teres (LT) tears with hypertrophy of the acetabular labrum and cartilage and labral damage. Surgeries (1723) were performed from February 2010 to March 2016 with arthroscopic measurement of the labrum and assessment of the LT, labrum and acetabular cartilage. Labral width was measured in the anterosuperior (AS), anteroinferior (AI), posteroinferior (PI) and posterosuperior (PS) quadrants. Grade 2 (50–99% torn) LT tears had larger labra in all four quadrants (AS = 5.64 ± 1.97 mm; AI = 5.23 ± 1.51; PS = 5.58 ± 1.39; PI = 4.60 ± 1.13) than grade 3 (100% torn) (AS = 5.50 ± 1.94; AI 4.90 ± 1.43; PS 5.43 ± 1.32; PI 4.42 ± 1.03), grade 1 (<50% torn) (AS 5.30 ± 1.68; AI 4.96 ± 1.32; PS = 5.38 ± 1.13; PI = 4.45 ± 1.04) and no tear (AS = 5.09 ± 1.51; AI = 4.92 ± 1.24; PS = 5.24 ± 1.09; PI = 4.37 ± .93); $P < 0.01$ in all quadrants. Grade 3 LT tears had more damage to the labrum than grade 2, grade 1 and no tear; $P < 0.001$. ALAD tears were larger in grade 3 and grade 2 than grade 1 and non-torn LTs; $P < 0.001$. Grade 3 tears had a higher percentage of high-grade cartilage tears than grade 2 LT tears; $P < 0.001$. Degenerative tears had larger labra, labral tears and acetabular cartilage tears than full- and partial-thickness LT tears; $P < 0.01$. Patients with partial-thickness LT tears had larger labra in all four quadrants than full-thickness tears in the Percentile and Villar classifications. Full-thickness tears had more severe labral damage and higher-grade chondral damage than partial-thickness tears. Degenerative tears demonstrated the largest labra, labral tears and ALAD tears. The condition of the LT demonstrated an association with acetabular cartilage injury and should be evaluated when considering hip preservation surgery.

**LEVEL OF EVIDENCE:** Level IV Case Series.

## INTRODUCTION

The ligamentum teres (LT) is a triangular band made of multiple bundles (anterior, posterior ± medial bundles [1]) that attaches the femoral head to the acetabulum and was long thought of as a vestigial organ with little importance in biomechanics or vascularity. However, recent studies have shown that the LT possesses both nociceptors and mechanoreceptors, suggesting its importance in joint protection, pain and proprioception [2, 3]. Additional suggested functions of the LT include distribution of synovial fluid through the joint [4], blood supply to the femoral head [1] and as an intrinsic stabilizer similar to the anterior cruciate ligament (ACL) [1]. Most importantly, pathology of the ligamentum teres has been associated with hip pain [1, 4–9], increased hip joint laxity [5, 10] and damage to the acetabular labrum and articular cartilage [5, 6, 8, 10]. The acetabular labrum, a fibrocartilaginous ring attached to the acetabular rim, has been shown to increase the depth of the acetabulum, leading to increased coverage of the femoral head and stability of the hip joint [11–13]. Recent [12, 13] studies have shown an association between acetabular depth and labral width, suggesting a possible compensatory response to joint instability [12, 13]. In addition to labral hypertrophy [12, 13], acetabular undercoverage has been associated with an increased incidence of ligamentum teres tears [6].

The purpose of this study is to determine if tears of the ligamentum teres, as a surrogate for hip instability, are associated with hypertrophy of the labrum and damage to the articular cartilage and labrum. Because larger labra have been associated with hip instability [12, 13], we hypothesize that larger labra will be associated with more severe tears of the ligamentum teres, and that more severe LT tears will be associated with greater damage to the acetabular labrum and cartilage.

## PATIENTS AND METHODS

### Patient inclusion and data collection

From February 2010 to March 2016, data was prospectively collected for all patients undergoing hip arthroscopy at our institution. 2007 hip arthroscopies with intraoperative measurement of the acetabular labrum and assessment of the LT were performed by the senior author (B.G.D.) during this time period. Exclusion criteria included previous hip surgery or pre-existing hip disease including history of acetabular or femoral neck fractures and dislocations, slipped capital femoral epiphysis (SCFE), osteogenesis imperfecta, rheumatoid or inflammatory arthritis, developmental dysplasia of the hip, Ehlers–Danlos and avascular necrosis of the femoral head. 1723 hips met our inclusion criteria. All patients participated in the American Hip Institute Hip Preservation Registry. While this study represents a unique analysis, data on some patients in this study may have been reported in other studies. All data collection received Institutional Review Board approval.

### Surgical procedure

All hip arthroscopies were performed by the senior author (B.G.D.) in the modified supine position with a minimum of two portals (anterolateral and mid-anterior) [14]. Hips were assessed arthroscopically for damage of the ligamentum teres, acetabular labrum and cartilage of the acetabulum and femoral head.

Tears of the ligamentum teres were defined using a descriptive classification, henceforth referred to as the Percentile classification (PC): Grade 0, no tear of the LT; Grade 1, a partial tear less than 50% thickness; Grade 2, partial tear of 50–99% and Grade 3, full-thickness tear [5]. They were also graded based on the Villar classification (VC): Grade 0, no tear of the LT; Grade 1, full-thickness tear; Grade 2, partial-thickness tear; Grade 3, degenerative tear [4]. We assessed for LT tears in neutral, internal and external rotation, to visualized the anterior and posterior bundles. In consideration of partial tears, we considered a partial tear to be a tear of any part of the LT. A tear of <50% was considered to be <50% of the entire thickness of the LT, whether it involved the anterior bundle, posterior bundle or both. So too with a tear of >50% of the entirety of the LT. A full-thickness tear was either complete absence of the LT, or lack of any continuous tendinous fibers.

Tears of the acetabular labrum were defined using the Seldes classification: Grade 0, no tear; Grade 1, detachment of the labrum from the articular cartilage surface at the transition zone; Grade 2, cleavage planes within the substance of the labrum or combined Grade 1 and Grade 2 tears [11]. The size of damaged labrum is used as a measurement of overall labral health and was calculated by identifying intraoperatively the anterior-most border of the tear on the 360° acetabular clock face and the posterior-most border of the tear; the absolute value of the difference of these two points is the distance (in degrees) of the affected labrum.

Acetabular cartilage damage was defined using the hip-specific Acetabular Labrum Articular Disruption (ALAD) classification system: Grade 0, no damage; Grade 1, softening of the adjacent cartilage; Grade 2, early peel of the cartilage (carpet delamination); Grade 3, large flap of cartilage and Grade 4, loss of cartilage/exposed bone [15].

Labral width was measured using a 5 mm probe in the anterosuperior (AS), anteroinferior (AI), posteroinferior (PI) and posterosuperior (PS) quadrants of the acetabulum. These quadrants represent 12–3, 3–6, 6–9 and 9–12 on the clock face, respectively. In each quadrant, the tip of the probe was placed on the articular edge of the labrum and measured to the capsulolabral junction.

### Statistical analysis

Single factor analysis of variance (ANOVA) was performed to compare means (labral width, labral tear size, ALAD size) between LT tear grades. Chi-square ($\chi^2$) analysis was used to compare the distribution of labral tear grading (Seldes) and cartilage damage (ALAD) between LT tear grades. Significance at the $P < 0.05$ level was set *a priori*. Statistical analysis was performed using Microsoft Excel 2013 (Microsoft Corp).

## RESULTS

### Ligamentum teres tears

Of 1723 hips, 807 hips (46.9%) had tears of the ligamentum teres and 915 (53.1%) had no tear of the LT. 427 hips (24.8%) had grade 1 (<50% torn) LT tears, 290 hips (16.8%) had grade 2 (50–99% torn) and 90 hips (5.2%) had grade 3 (100% torn). Using the VC, 53.1% had no tear, 3.6% had grade 1 (full-thickness tears), 18.8% had

**Table I. Average labral width in four quadrants for each grade of LT tear**

| | *Labral width* | | | |
|---|---|---|---|---|
| | *AS (mean mm ± SD)* | *AI (mean mm ± SD)* | *PS (mean mm ± SD)* | *PI (mean mm ± SD)* |
| *Percentile class* | | | | |
| 0 (Not torn) | 5.09 ± 1.51 | 4.92 ± 1.24 | 5.24 ± 1.09 | 4.37 ± 0.93 |
| 1 (<50% torn) | 5.30 ± 1.68 | 4.96 ± 1.32 | 5.38 ± 1.13 | 4.45 ± 1.04 |
| 2 (50–99% torn) | 5.64 ± 1.97 | 5.23 ± 1.51 | 5.58 ± 1.39 | 4.60 ± 1.13 |
| 3 (100% torn) | 5.50 ± 1.94 | 4.90 ± 1.43 | 5.43 ± 1.32 | 4.42 ± 1.03 |
| | $P < 0.0001$ | $P = 0.005$ | $P = 0.0015$ | $P = 0.006$ |
| *Villar class* | | | | |
| 0 (Not torn) | 5.09 ± 1.51 | 4.92 ± 1.24 | 5.24 ± 1.09 | 4.37 ± 0.93 |
| 1 (Full-thickness tear) | 5.11 ± 1.79 | 4.81 ± 1.28 | 5.29 ± 1.19 | 4.35 ± 0.98 |
| 2 (Partial-thickness tear) | 5.28 ± 1.69 | 5.00 ± 1.29 | 5.40 ± 1.19 | 4.43 ± 1.07 |
| 3 (Degenerative tear) | 5.62 ± 1.91 | 5.14 ± 1.51 | 5.54 ± 1.31 | 4.59 ± 1.09 |
| | $P < 0.0001$ | $P = 0.026$ | $P = 0.0002$ | $P = 0.003$ |

grade 2 (partial-thickness tears) and 24.5% had grade 3 (degenerative tears).

### Labral width

Table I displays the average labral size in all four quadrants for the different LT tear grades. PC Grade 2 LT tears had significantly larger labra on average in all four quadrants than grade 3, grade 1 and no tear; $P < 0.001$ in all quadrants. VC partial-thickness tears (grade 2) also had larger labra than full-thickness (grade 1) and no tear; However, degenerative tears (grade 3) had the largest labra in all four quadrants; $P < 0.01$ in all quadrants.

### Labral tears

Table II depicts average labral tear size and Seldes tear grading for each LT tear grade. PC Grade 3 LT tears had larger labral tears (95.69 ± 36.83°) than grade 2 (90.73 ± 38.14°), grade 1 (87.45 ± 40.00°) and no tear (76.55 ± 36.97°); $P < 0.0001$. Full-thickness (grade 3) LT tears had a significantly larger proportion of combined Seldes 1 and 2 tears (60%, $n = 54$) than in lesser LT tears grades (Grade 2: 48.28%, $n = 140$; Grade 1: 45.07%, $n = 192$; Grade 0: 36.76%, $n = 914$); $P = 0.0004$.

VC Degenerative tears had larger labral tears (99.71 ± 40.33°) than full-thickness (89.02 ± 38.23°), partial-thickness (76.18 ± 32.93°) and no tear (76.65 ± 36.99°); $P < 0.0001$. Full-thickness LT tears had a significantly larger proportion of combined Seldes 1 and 2 tears (56.45%) than in partial and no tear groups (Partial tear: 36.25%; No tear: 36.81%); $P < 0.0001$.

### Cartilage damage

Table III depicts average ALAD cartilage damage size and grading based on LT tear Percentile class. ALAD tears were larger in grade 3 (1.30 ± .61 cm) and grade 2 (1.30 ± 0.69 cm) than grade 1 (1.15 ± 0.62 cm) and no tear (1.08 ± 0.61 cm); $P < 0.0001$. Full-thickness LT tears (grade 3) were associated with a larger proportion of large cartilage flaps (ALAD 3) (33.33%, $n = 30$) and exposed bone (ALAD 4) (10.00%, $n = 9$), than grade 2 (ALAD 3: 31.38%, $n = 91$; ALAD 4: 7.24%, $n = 21$), grade 1 (ALAD 3: 27.63%, $n = 118$; ALAD 4: 5.85%, $n = 25$) and no tear (ALAD 3: 17.60%, $n = 161$; ALAD 4: 2.40%, $n = 22$); $P < 0.0001$ Table III).

Using VC, ALAD tears were larger in full-thickness LT tears (1.18 ± 0.55 cm) than partial-thickness tears (1.08 ± 0.53 cm), and also had higher proportions of large cartilage flaps and exposed bone; however degenerative LT tears were associated with the largest ALAD tears (1.34 ± 0.71 cm), and highest proportions of grades 3 and 4 ALAD tears; $P < 0.0001$.

## DISCUSSION

Botser *et al.* [5] demonstrated clinically that damage to the ligamentum teres is associated with instability of the hip,

**Table II. Labral tear size and distribution of Seldes grading for each LT tear grade**

| | *Labral tear size (mean degrees ± SD)* | *Seldes grade* | | | |
|---|---|---|---|---|---|
| | | *0* | *1* | *2* | *1 and 2* |
| *Percentile class* | | | | | |
| 0 | 76.55 ± 36.97 | 0.55% | 34.14% | 28.56% | 36.76% |
| 1 | 87.45 ± 40.00 | 0.47% | 29.11% | 25.35% | 45.07% |
| 2 | 90.73 ± 38.14 | 0.00% | 28.28% | 23.45% | 48.28% |
| 3 | 95.69 ± 36.83 | 0.00% | 20.00% | 20.00% | 60.00% |
| | $P < 0.0001$ | $\chi^2$ $P = 0.0004$ | | | |
| *Villar class* | | | | | |
| 0 | 76.65 ± 36.99 | 0.55% | 34.07% | 28.57% | 36.81% |
| 1 | 89.02 ± 38.23 | 0.00% | 27.42% | 16.13% | 56.45% |
| 2 | 76.18 ± 32.93 | 0.63% | 35.31% | 27.81% | 36.25% |
| 3 | 99.71 ± 40.33 | 0.00% | 38.59% | 39.00% | 22.41% |
| | $P < 0.0001$ | $\chi^2$ $P < 0.0001$ | | | |

**Table III. Cartilage damage size and distribution of ALAD grading for each LT tear grade**

| | *ALAD tear size (mean cm ± SD)* | *ALAD grade* | | | | |
|---|---|---|---|---|---|---|
| | | *0* | *1* | *2* | *3* | *4* |
| *Percentile class* | | | | | | |
| 0 | 1.08 ± 0.61 | 18.03% | 38.14% | 23.83% | 17.60% | 2.40% |
| 1 | 1.15 ± 0.62 | 8.20% | 34.66% | 23.65% | 27.63% | 5.85% |
| 2 | 1.30 ± 0.69 | 6.55% | 24.14% | 30.69% | 31.38% | 7.24% |
| 3 | 1.30 ± 0.61 | 5.56% | 14.44% | 36.67% | 33.33% | 10.00% |
| | $P < 0.0001$ | $\chi^2$ $P < 0.0001$ | | | | |
| *Villar class* | | | | | | |
| 0 | 1.08 ± 0.61 | 18.11% | 38.09% | 23.82% | 17.56% | 2.41% |
| 1 | 1.18 ± 0.55 | 8.06% | 22.58% | 32.26% | 27.42% | 9.68% |
| 2 | 1.08 ± 0.53 | 10.25% | 37.58% | 25.16% | 25.16% | 1.86% |
| 3 | 1.34 ± 0.71 | 4.76% | 22.86% | 28.57% | 33.57% | 10.24% |
| | $P < 0.0001$ | $\chi^2$ $P < 0.0001$ | | | | |

while Martin *et al.* [16] demonstrated biomechanically the importance of the LT in hip stability. However, the data do not suggest which is the initial insult, damage to the LT or instability of the hip. More recently, our institution [6] demonstrated that acetabular undercoverage is associated with a higher incidence of ligamentum teres tears, while Gupta *et al.* [12] and Toft *et al.* [13] demonstrated that osseous acetabular undercoverage, as a surrogate for hip instability, is associated with developmentally larger labra. Using these previous findings, it would be logical to hypothesize that because both ligamentum teres tears and labral hypertrophy are associated with acetabular undercoverage in unstable hips, that there would be an association between ligamentum teres tears and labral hypertrophy. In our study, patients with partial-thickness tears of the ligamentum teres had significantly larger labra in all four quadrants than full-thickness tears, which rejects our hypothesis that larger LT tears are associated with larger labra. It is unlikely that hypertrophy of the labrum is an acquired response to instability, but instead developmentally larger labra stabilize the hip, which is protective of the ligamentum teres. Those without LT tears had significantly smaller labra in three out of four quadrants further supporting the multifactorial relationship of hip instability that includes acetabular labral width and bony acetabular coverage.

When looking at damage to the labrum, full-thickness tears of the LT had a larger area of damaged labrum than partial-thickness tears using both grading systems, which supports our second hypothesis. Moreover, full-thickness LT tears had a higher proportion of combined Seldes 1 and 2 tears than partial-thickness LT tears, suggesting more substantial damage to the labrum. This leads to two possible explanations: larger tears of the LT lead to greater hip instability and resulting damage to the labrum. Alternatively, developmentally larger labra may lead to more stable hips, which may cause less damage to the LT, and larger labra may be more resistant to damage.

Full-thickness LT tears and high-grade partial-thickness LT tears (grade 2) had similar sized ALAD cartilage defects; both had significantly larger chondral defects than low-grade partial-thickness LT tears (grade 1) and intact LTs. However, full-thickness LT tears were associated with a higher proportion of higher-grade chondral damage (ALAD 2–4) than less severe tears. By definition, VC degenerative LT tears are associated with OA and thus were associated with more severe ALAD and Seldes tear size and grades. This data suggests damage to the ligamentum teres may be an indicator of hip instability and overall articular health.

A recent study by O'Donnell and Arora proposes a new classification for LT pathology based on joint hypermobility as well as the presence of synovitis [17], addressing weaknesses previously identified in both the Villar and Percentile classifications [18]. We believe this classification system to be promising, however, because our study was prospectively collected and retrospectively reviewed we are unable to incorporate this classification system into our analysis; future studies may benefit from additional comparisons between classification systems.

Kaya *et al.* [8] previously demonstrated that ligamentum teres tears are associated with higher-grade cartilage defects of the acetabular cartilage. The grading system they used was a non-specific chondral grading system (International Cartilage Repair Society) and they only defined the LT as intact or damaged; in our study we use the hip-specific ALAD system and stratify based on severity of LT tear.

The strengths of our study include the prospective nature of our data collection and the large sample size. One of the weaknesses of this study was that labral measurements with a 5-mm tipped probe may lead to measurement inaccuracies, particularly when reporting to the nearest whole number; for statistical purposes average widths were reported to one one-hundredth of a millimeter, though such precision is unrealistic clinically. At our institution inter-rater reliability using such methods when performed independently has been shown to be fair to good [12]. Other institutions have demonstrated that 5-mm probes provide measurements of shoulder and knee pathology similar to open measurements, and are more accurate than MRI or ultrasound [19, 20]; the accuracy of such measurements decreases with smaller measurements and surgeon inexperience [20]. In addition, the potential for selection bias in using only symptomatic patients requiring surgical intervention may lead to confounding of intraoperative findings by other etiologies such as femoroacetabular impingement (FAI). Future studies should be performed to incorporate other aspects of FAI, such as Cam or Pincer deformity and to determine long-term outcomes of patients with tears of the ligamentum teres and if they have differences in rates of revision or conversion to total hip arthroplasty. Furthermore, as hip instability has been correlated with both acetabular labral width and bony acetabular undercoverage, future investigation should include both intraoperative labral width and measurements of bony architecture using imaging.

## CONCLUSIONS

Pathology of the ligamentum teres was associated with hypertrophic labra and increased damage to the labrum and cartilage of the hip. While high-grade partially torn ligamentum teres were associated with larger labra, full-thickness LT tears were associated with more damage to the acetabular labrum and articular cartilage. Moreover, smaller labra were associated with these full-thickness tears, suggesting that the native and pathological conditions of the labrum and ligamentum teres are directly involved in the integrity of one another and essential in maintaining stability of the hip; ultimately, causality between joint instability and intra-articular pathology cannot be determined, but the condition of the ligamentum teres demonstrated an association with labral and acetabular cartilage injury and should be evaluated when considering hip preservation surgery.

## FUNDING

This study was performed at the American Hip Institute. This study was approved by the Institutional Review Board (IRB ID: 5276)

## CONFLICT OF INTEREST STATEMENT

Dr. Domb is a board member for American Orthopedic Foundation, American Hip Foundation, AANA Learning Center Committee, Hinsdale Hospital Foundation, and Arthroscopy Journal; Consulting Fees from Adventist Hinsdale Hospital, Amplitude, Arthrex, MAKO, Medacta, Pacira Pharmaceuticals, and Stryker; Educational funding from Arthrex, Breg, and Medwest; Food and Beverage from Arthrex, Ceterix Orthopaedics, DePuy Syntheses Sales, DJO Global, FUJIFILM SonoSite, Linvatec, MAKO Surgical Corporation, Medacta, Pacira Pharmaceuticals, Stryker, and Zimmer Biomet Holdings; Ownership Interests in Hinsdale Orthopedic Associates, American Hip Institute, SCD#3, North Shore Surgical Suites, Munster Specialty Surgery Center; Research support from Arthrex, ATI, Kaufman Foundation, Medacta, Pacira Pharmaceuticals, and Stryker; Royalties from Arthrex, DJO Global, MAKO Surgical Corporation, Stryker, and Orthomerica; Speaking fees from Arthrex and Pacira Pharmaceuticals; Travel and lodging from Arthrex, Medacta, and Stryker.

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Dr. Trenga has no conflicts to declare

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