Risk Factors for Ligamentum Teres Tears

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Purpose: The purpose of this study was to examine the relationship between nontraumatic ligamentum teres (LT) tears and acetabular radiographic architecture. **Methods:** The inclusion criteria for this study were all patients who had anteroposterior pelvis radiographic views and had undergone arthroscopic examination of the LT. The exclusion criteria were Tonnis arthritic grade 3 and traumatic high-energy mechanisms of injury. Radiographic data were measured preoperatively on an anteroposterior pelvis view, including acetabular inclination (AI), lateral center edge (CE) angle, magnitude of cross-over sign, and ischial spine prominence. A Lateral Coverage Index (LCI) was defined as the center edge angle minus acetabular inclination. Hips were divided into 3 groups according to the LCI: (1) high: 34° and above; (2) medium: 19° to 33°; and (3) low: below 19°. **Results:** Of the 463 hips (430 patients) included in the study, 226 (49%) had a partial- or full-thickness LT tear. Patients with tears were significantly older than patients without tears ($P < .0001$), with average ages of 38 and 33 years, respectively. Radiographically, patients with tears had less acetabular retroversion, as reflected by lower ischial spine prominence values and lesser cross-over signs ($P = .01$ and .0005, respectively). Using the LCI, 115 hips (25%) were classified as high, 236 (50%) as medium, and 114 (25%) as low. Hips with low LCI were 1.74 times more likely to have LT tears than high LCI hips. **Conclusions:** This study found that the presence of LT tears was associated with acetabular bony morphology and age. LT tears were less frequent with high LCI and acetabular retroversion and less frequent in patients younger than 30 years. Further study is needed to establish whether there is a causal relationship between acetabular undercoverage and LT tears and whether LT tears may be a sign of microinstability of the hip. **Level of Evidence:** Level IV, therapeutic case series.

The ligamentum teres (LT), otherwise known as the round ligamentum of the femur, is a triangular band attaching the femoral head to the acetabulum. It is attached to either side of the acetabular notch by 2 bands and, at its apex, extends to the anterosuperior portion of the femoral head, merging with the fovea capitis femoris. The role of the LT has been debated since the 19th century, with proposed functions including that of a stabilizer, a fluid and force distributor in the acetabulum, and an embryonic remnant with no specific role in adults.[1-3] The LT has also been previously described as a possible transmitter of somatosensory signals that acts to help the hip avoid painful and excessive ranges of motion.[4] More recently, the LT in the hip has been thought to provide functions comparable to the anterior cruciate ligament in the knee.[5] With similar tensile strength, it has been proposed to provide some degree of stability in the hip, resisting dislocation and microinstability. Although the function of the LT has yet to be determined, its role as a possible source of hip pain following rupture has been more clearly elucidated.[6-13] Gray and Villar[10] first described LT tears as belonging to 1 of 3 groups: group 1, full-thickness rupture; group 2, partial-thickness tears; and group 3, degenerative tears. More recently, a new descriptive classification scheme has sorted LT tears into 3 groups: group 1, tears less than 50% thickness; group 2, tears greater than 50% but less than 100% thickness; and group 3, full-thickness tears.[14]

Although many previous publications have discussed the rupture of the LT in association with hip dislocation and previous hip conditions such as developmental dislocation of the hip, Legg-Calve-Perthes disease, or osteoarthritis, few have aimed to discuss nontraumatic rupture.[6,9-17] Furthermore, the possible relationships between nontraumatic or nondegenerative LT tears and bony morphology of the hip and acetabulum have not been reported.

The purpose of this study was to isolate and examine the relationship between nontraumatic LT tearing and

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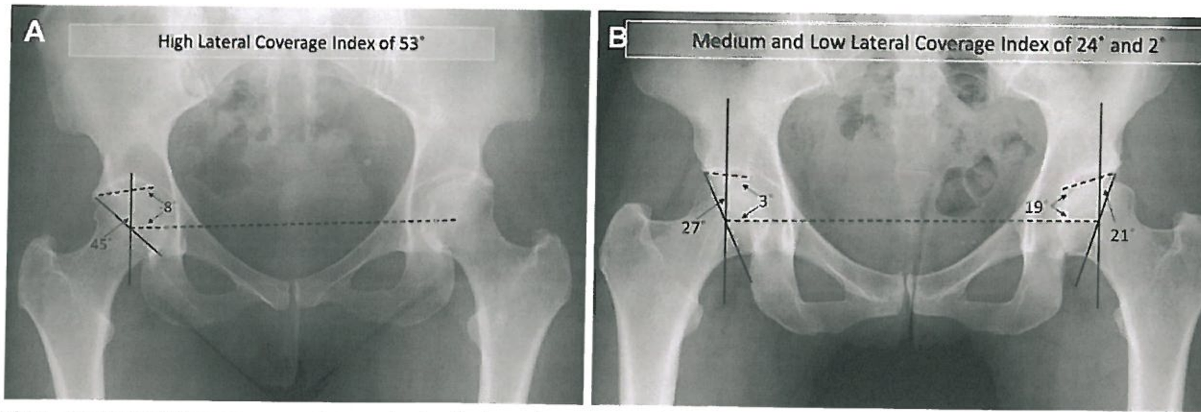


Fig 1. Radiographic measurement examples for the lateral coverage index (LCI). (A) Example of high LCI (53°) composed of CE angle of 45° and acetabular inclination of −8°. (B) Example of medium and low LCI on the right and left hip, respectively. On the right hip, CE angle of 27° and acetabular inclination of 3° yield LCI of 24°, whereas on the left hip, a CE angle of 21° and acetabular inclination of 19° yield a low LCI of 2°.

acetabular body architecture, as defined by measured radiographic angles. The hypothesis was that hips with less inherent acetabular bony coverage would be more prone to LT tears.

Methods

Patient Inclusion and Data Collection

Between April 2008 and February 2011, data were prospectively collected for all patients undergoing hip arthroscopic surgery at our institution. The inclusion criteria for this study were all who had anteroposterior (AP) pelvis radiographic views and had undergone arthroscopic examination of the LT. The exclusion criteria of this study were the following: revision arthroscopy, Tonnis grade 3, previous hip pathology (e.g., Legg-Calve-Perthes disease, slipped capital femoral epiphysis, acetabular fracture, avascular necrosis, dysplasia, and deep venous thrombosis), and hip injuries caused by high-energy mechanisms of injury. Objective data such as sex, age, height, weight, and body mass index (BMI) were collected. This study was approved by the institutional review board.

Physical Examination

A detailed physical examination was conducted and documented by the senior author and included passive range of motion (ROM) of the hip (flexion, abduction, internal rotation, and external rotation) and pain provocative tests (anterior, lateral, and posterior impingements tests).[18] Internal and external rotation were measured while the patient was in a supine position with both the hip and the knee flexed to 90°.

Radiographic Measurements

Radiographic views included an AP pelvic view, a cross-table lateral view, a Dunn view, and a false-profile view.[19,20] Measurements were made from these views including the Tonnis acetabular inclination (AI) angle using the method described by Jessel et al.,[21] the lateral center edge (CE) angle of Wiberg,[22] joint space at its lowest point,[23] Tonnis arthritis grade,[23] ischial prominence size in millimeters,[24] cross-over sign,[24-26] alpha angle (Dunn view),[27] and offset[28] in millimeters. All measurements were taken by the same orthopaedic surgeon (I.B.B.) using a Picture Archiving and Communication System (PACS) computer program. The cross-over sign size was quantified according to its percent from the acetabulum diameter; for instance, cross-over at the middle of the acetabulum was quantified as 50%.

Lateral Coverage Index Creation and Grouping

Both the CE angle and the acetabular inclination (AI) are descriptors of acetabular coverage, where hips with less coverage have lower CE angle and higher AI. Because both measurements apply to acetabular coverage, we sought to combine them into a single measurement. To meld the 2 into a single index reflective of lateral coverage, it was necessary to assign the CE angle a positive value and AI a negative value. This single value, previously presented as the Stability Index,[29] was renamed in this study as the Lateral Coverage Index (LCI), calculated as:

$$LCI = CE - AI$$

This formula was derived using the simplest possible relationship so that increasing LCI values represented higher CE and low AI, whereas low index represented low CE and high inclination (Fig 1).

To investigate the effect of increasing the LCI on LT tearing, it was necessary to split our population into incremental LCI groups. Patients were subsequently split into high, medium, and low LCI groups based on a histogram of the prevalence of various LCI values in the population (Fig 1). The lower 25th percentile was considered as low, the middle 50th percentile as medium, and the upper 25th percentile as high.

Imaging

Magnetic resonance imaging was obtained in all cases but 6 and was evaluated for the femoral alpha angle and femoral anteversion angle.[30,31] Magnetic resonance imaging examinations conducted at outside institutions were not included in this segment because of variations in measurement technique. Anteversion measurement was measured in computed tomography studies that were performed at our institution as well.

Acute Injury Determination

To eliminate patients with traumatic rupture of the LT, the operating surgeon asked all patients when and by what mechanism their hip pain began. Acute onset of pain was classified as positive if the patient noted a specific moment in time at which the pain began. Traumatic onset of pain was noted if the patient had a traumatic, high-energy event, which occurred in conjunction with the initial onset of hip pain before surgery (e.g., car accident, a fall from greater than 8 feet above the ground, crushing injuries by forklifts, high-speed skiing accidents). Traumatic patients were eliminated from the study.

Intraoperative Findings

The hip arthroscopies reported in this study were performed in a practice dedicated to hip arthroscopy and preservation. All were performed by the senior author (B.G.D.) in the modified supine position, using a minimum of 2 portals (anterolateral and mid-anterior).[32] The LT was examined routinely during all hip arthroscopies and a determination was made of whether a tear was present. If needed, internal and external rotation of the leg was performed to change the LT tension; also, an arthroscopic flexible probe was used for further examination of the ligament. LT tears were identified according to Gray and Villar's classification: class 1, complete rupture; class 2, partial-thickness tears; and class 3, degenerate tears.[10] Additionally, hips were classified according to a descriptive classification: group 1, a partial LT tear visualized to be of less than 50%; group 2, a partial LT tear of more than 50%; and group 3, a full-thickness LT tear.[14]

Other intraoperative data included concomitant labral tear size and location based on the hours on the acetabular clock face and the presence and location of acetabular cartilage lesions. The Acetabular Labrum Articular Disruption (ALAD) classification system was used to record chondral damage on the acetabular side (0, no damage; 1, cartilage softening; 2, carpet delamination; 3, cartilage flap; and 4, exposed bone).[33]

Surgical Procedures

LT tears were debrided using a radiofrequency device.[6,11] Bony pathology was corrected under fluoroscopic guidance. An acetabuloplasty was performed for pincer impingement, and a femoral osteoplasty was performed for cam impingement. Full-thickness articular cartilage damage was treated with debridement to create stable borders. Microfracture was performed using an awl according to Steadman's technique[34] in cases where exposed bone was present after the bony decompression.

Labral tears were treated with debridement or refixation. The decision on whether to debride or refixate the labrum in the setting of a labral tear depended on the stability of the labrum. Stable tears were debrided, whereas detached tears underwent refixation. Labral detachment followed with refixation was performed in the setting of pincer type femoroacetabular impingement (FAI) that required the rim to be trimmed (acetabuloplasty) greater than 3 mm.

Statistical Analysis

Correlations of 2 continuous variables were performed using the Pearson correlation coefficient test. Comparison of 2 continuous variables were performed with an

Table 1. Patient Demographics According to the Arthroscopic Findings of LT Tears

	Total	LT Tears Present	LT Tears Absent	*P*
No. of hips (patients)	463 (430)	226 (212)	237 (218)	
Age, yr (range)	35.52 (14–76)	37.93 (14–66)	33.22 (14–76)	.0001
Number of men (% of total)	181 (39.09%)	96 (42.48%)	85 (35.86%)	.1449
Number of right side hips (% right)	245 (52.92%)	126 (55.75%)	119 (50.21%)	.2325
Duration of symptoms, mo (range)	24.67 (0.75–240)	23.87 (1–168)	25.43 (0.75–240)	.6290
Workers' compensation (%)	48 (10.37%)	25 (11.06%)	23 (9.7%)	.6320
History of acute onset of pain (%)	134 (29%)	65 (28.89%)	69 (29.11%)	.9575
History of high-energy trauma (%)	0 (0%)	0 (0%)	0 (0%)	-
Patients with back pain (%)	98 (21.17%)	42 (18.58%)	56 (23.63%)	.1841
Revision surgery (%)	0 (0%)	0 (0%)	0 (0%)	-
Average weight, lb (range)	166.06 (100–300)	166.28 (100–300)	165.85 (100–300)	.9095
Average height, in (range)	67.72 (57–77)	68.03 (57–76)	67.52 (59–77)	.2765
Average BMI (kg/m^2) (range)	25.95 (16.23–51.01)	25.54 (16.23–43.85)	26.21 (17.22–51.01)	.3179

NOTE. The only significant difference was the average age of the patients, which was higher for patients with LT tears (see Fig 2).

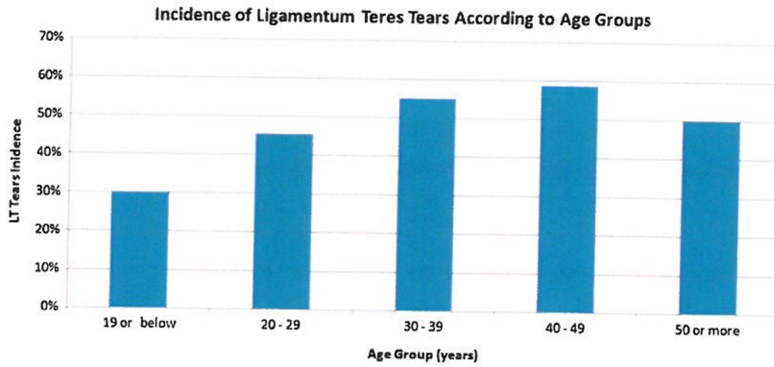


Fig 2. Incidence of LT tears according to age group. The lowest incidence of LT tears was found in patients younger than 20 years. Patients older than 30 years had a higher relative risk of 1.51 of having an LT tear.

unpaired 2-tailed Student *t*-test, and analysis of variance (ANOVA) was done for comparison of more than 2 continuous variables. Comparison of categorical values was performed using the χ-square test. Statistical analysis was performed using Microsoft Office Excel 2007 (Redmond, WA). Values of $\alpha < .05$ were considered statistically significant.

Fifty patients were randomly selected for remeasurement of their CE and AI angles by the same initial reader to obtain an intrarater intraclass correlation coefficient. Fifty patients were chosen because of similar studies in which intrarater reliability of radiographic measurements was determined using groups of 50 or fewer patients.[35-37] The intraclass correlation coefficient, used to determine intrarater reliability, was computed using Bartko's method for measuring a rater's self-consistency.[38,39]

Results

A total of 463 hips (430 patients) met the inclusion/exclusion criteria. The patient population was composed of 181 male participants and 282 female participants with a mean age of 35.5 years (range, 14 to 76 years) and an average BMI of 26 m^2/kg (range, 16.2 to 51.0) (Table 1).

LT Tear Determination

During hip arthroscopy, LT tears were identified in 226 (49%) patients, whereas 237 (51%) did not have an LT tear (Table 1). Of these tears, 106 were low-grade partial (tears of <50% of LT thickness), 104 were high-grade partial (tears >50% but less than full-thickness tears), and 16 were full-thickness tears.[14] According to the Gray and Villar classification, there were 12 full-thickness tears, 198 partial-thickness tears, and 16 degenerate tears (4 were full-thickness degenerate tears).[10]

Demographics

Hips with LT tears were not statistically different from hips without LT tears according to sex, affected side, or BMI ($P > .05$ for all). Patients with LT tears, however, were significantly older than were patients without LT tears ($P < .0001$), averaging 37.9 and 33.2, respectively (Table 1). To stratify the incidence of tears by age, we divided the patients into age groups (Fig 2). It was found that patients younger than 20 have the lowest incidence of LT tears and that the relative risk to have an LT tear was 1.51 higher for patients older than 30 years.

Physical Examination Findings

There was not a statistical difference between patients with and without LT tears with respect to any of the preoperative ROM examinations that were recorded or the pain provocative impingement tests (Table 2).

Radiographic Measurements

Lateral acetabular coverage, as reflected by the AI, CE angle, and LCI, was significantly higher for patients without LT tears ($P < .05$ for all). Patients without LT tears also had on average larger cross-over sign size and

Table 2. Physical Examination Findings of ROM and Provocative Impingement Tests Performed Preoperatively

	All Patients	LT Tears Present	LT Tears Absent	*P*
Internal rotation, ° (standard deviation)	22.66 (±15.66)	23.88 (±15.16)	21.5 (±16.06)	.10277
External rotation, ° (standard deviation)	50.6 (±15.3)	50.42 (±14.73)	50.76 (±15.85)	.81242
Abduction, ° (standard deviation)	45.29 (±11.24)	46.09 (±11.38)	44.51 (±11.08)	.13860
Flexion, ° (standard deviation)	118.01 (±16.94)	118.86 (±16.85)	117.19 (±17.03)	.29147
Positive anterior impingement (%)	429 (94.91%)	204 (94.01%)	225 (95.74%)	.40158
Positive lateral impingement (%)	240 (53.57%)	125 (58.14%)	115 (49.36%)	.06256
Positive posterior impingement (%)	143 (32.13%)	76 (35.51%)	67 (29%)	.14178
Positive internal hip click (%)	84 (18.71%)	37 (17.21%)	47 (20.09%)	.43499

Table 3. Labral Tears

	All Patients	LT Tears Present	LT Tears Absent	P
Total no. of labral tears (%)	444 (95.9%)	218 (96.46%)	226 (95.36%)	.55034
Most posterior tear (range)*	12.06 (7-15)	12.01 (7-15)	12.1 (9-15)	.41870
Most anterior tear (range)*	15.03 (12-17)	15.06 (13-17)	15.01 (12-17)	.38393
Average labral tear size, hr (range)	2.98 (0-10)	3.05 (0-10)	2.92 (0-6)	.31110
Labral tears spanning < 11 o'clock	33 (7.43%)	21 (9.63%)	12 (5.31%)	.00120
Labral tears spanning > 4 o'clock	11 (2.48%)	10 (4.59%)	1 (0.44%)	
Out of range	44 (9.91%)	31 (14.22%)	13 (5.75%)	

NOTE. Of the patients in the cohort, 95% had labral tears. The average tear size was 3 hours on the acetabular clock face and spanned from 12 o'clock posteriorly to 3 o'clock anteriorly. More than 90% of the labral tears were between 11 and 4 o'clock; however, the same was true for only 85% of the patients from the LT tear group.

*The hours on the acetabular clock face in this table are presented in a military time style (i.e., 3 o'clock presented as 15) to have continuous numbering of the location.

larger ischial prominence ($P < .05$ for both). However, the anterior CE angle was not found to be significantly different between the 2 groups. Additionally, the femoral architecture, as presented by the alpha angle, offset, and femoral anteversion, was not found to be significantly different between the groups. Arthritic changes measured by the Tonnis arthritic grade were not significantly different as well.

The intraobserver reliability for CE and AI angles was measured through the intraclass correlation coefficient. The intraclass correlation coefficient was found to be .91 for AI and .79 for the CE angle.

Surgical Findings and Procedures

Acetabular labral tears (Table 3) were found in 95% of the cases. The average tear size was 2.98 hours on the acetabular clock face, with average span from 12 o'clock posteriorly to 3 o'clock anteriorly; this was not significantly different between the groups. Although 90% of the tears were found between 11 o'clock posteriorly and 4 o'clock anteriorly, significantly more patients had tears outside of that zone in the LT tears group ($P = .001$).

One patient had a radial tear that involved most of the labrum around the acetabulum spanning 10 hours. The acetabular cartilage was found to be significantly ($P = .049$) more disrupted on the LT tears group as well (Fig 3).

After diagnosis of an LT tear was made, the tears were debrided using a radiofrequency device. Reconstruction of the ligamentum was not performed. Overall, there was not a significant difference between the 2 groups in regard to the surgical procedures performed (Table 4).

The Classification System for LCI

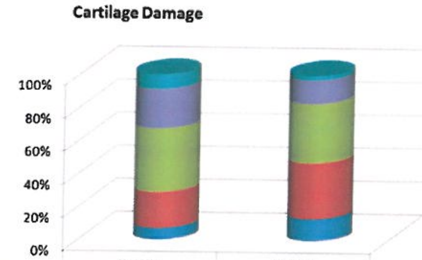
After classifying hips into the 3 LCI groups (low, high, and medium; Fig 4), 114 hips (25%) had a low LCI, 236 (50%) had a medium LCI, and 115 (25%) had a high LCI. A significant difference was found in the incidence of LT tears between the 3 groups ($P = .0004$). Among patients in the high LCI group, only 34.5% had an LT tear, whereas for the low LCI class, 60.0% had an LT tear. Hence, patients with low LCI measurements were 1.74 times more likely to have LT tears than were patients with high LCI values.

LT Tears Severity Analysis

Using a descriptive classification system to divide the ligamentum teres into 4 groups (no tear, low-grade partial thickness, high-grade partial thickness, and full thickness), analysis of variance was performed to validate the differences between the groups. Only 16 patients had a full LT tear, and in 4 of them the tear was degenerative; thus, because of the small group size, the full LT tear group was excluded from this analysis. In general, as the severity of the LT tear increased, the average age of the patients and the acetabular inclination increased, whereas the average CE angle, LCI, and cross-over sign values decreased (Table 5).

Discussion

Tears of the LT have been recognized as a cause of hip pain.[6-13] The function of the LT, however, has been debated in clinical literature since the 19th century.[2] Current studies have put forth that the LT plays little role



	Yes LTT	No LTT
4-Missing cartilage	8.90%	2.83%
3-Large flap of cartilage	23.97%	14.15%
2-Early peel of cartilage	38.36%	35.85%
1-Softening of the cartilage	21.92%	33.96%
0-None	6.85%	13.21%

Fig 3. The Acetabular Labrum Articular Disruption (ALAD) classification system was used to record chondral damage on the acetabular side. The group of patients with LT tears (LTT) had more disruption of the acetabular cartilage ($P = .049$).

Table 4. Surgical Procedures Performed Arthroscopically

Procedure	Total (n = 463)	LT Tears Present (n = 226)	LT Tears Absent (n = 237)	P
Acetabuloplasty, n (%)	369 (79.7%)	168 (74.34%)	201 (84.81%)	.2070
Osteoplasty, n (%)	307 (66.31%)	147 (65.04%)	160 (67.51%)	.7446
Microfracture, n (%)	33 (7.13%)	21 (9.29%)	12 (5.06%)	.0884
Capsular closure or plication, n (%)	164 (35.42%)	86 (38.05%)	78 (32.91%)	.3528
Iliopsoas release, n (%)	110 (23.76%)	46 (20.35%)	64 (27%)	.1422
Labral repair, n (%)	300 (64.79%)	141 (62.39%)	159 (67.09%)	.5301

NOTE. No significant difference was found between patients with or without LT tears.

in stability of the hip joint, because it is possibly a mere embryonic remnant. Furthermore, in some hip preservation surgeries, such as open surgical dislocation, the LT is routinely resected.[40,41] Haviv and O'Donnell[11] showed significant pain relief and improvement in function after arthroscopic radiofrequency debridement of isolated LT ruptures. However, 5 of their 29 patients underwent a second arthroscopy, which showed retearing of the LT. All 5 underwent redebridement and capsular placation, which improved the symptoms. The importance of the LT as a stabilizer of the hip joint was also appreciated by Simpson et al.,[42] who recently reconstructed the LT in patients with LT tear and hip instability.

The purpose of the current study was to investigate an association between the acetabular architecture and LT tears. We hypothesized that a hip joint with less bony coverage would be more prone to LT tears. To isolate structural pathologies, patients with high-energy injuries that are known causes of LT tears[7,17] were excluded from the study. Similarly, because degenerative signs are known causes of LT tears,[10,14] patients with Tonnis grade 3 were also excluded. Ultimately, the most important findings of the present study were what exists between radiographic acetabular architecture, the patients' age, and nontraumatic LT tearing (Table 6).

According to our data, hips with LT tears had lower CE angles and higher AI angles (Table 7). Thus, the LCI was created, combining the effect of these 2 angles on LT tearing (Fig 1). This formula was designed so that higher LCI values would correspond to greater lateral acetabular coverage and lower inclination, and lower values would correspond to lower acetabular coverage and higher inclination. The patients were divided into 3 groups of LCI (low, medium, and high; Fig 4), supporting our hypothesis that decreased LCI values were associated with higher incidences of LT tearing, whereas higher LCI values were associated with lower incidences of LT tearing (Fig 5). Furthermore, the relative risk of having an LT tear was 1.74 times higher for patients with low LCI values than for patients with high LCI values (Fig 5).

An unexpected radiographic finding was acetabular retroversion, as reflected radiographically by the cross-over sign and ischial prominence values.[23,43-46] Those 2 values were inversely related to the presence of LT tears. The group of patients with LT tears had on average lower cross-over signs and lower ischial prominence values (Table 7).

Age was found to be a significant factor in tears of the LT. Patients with an LT tear were on average older than

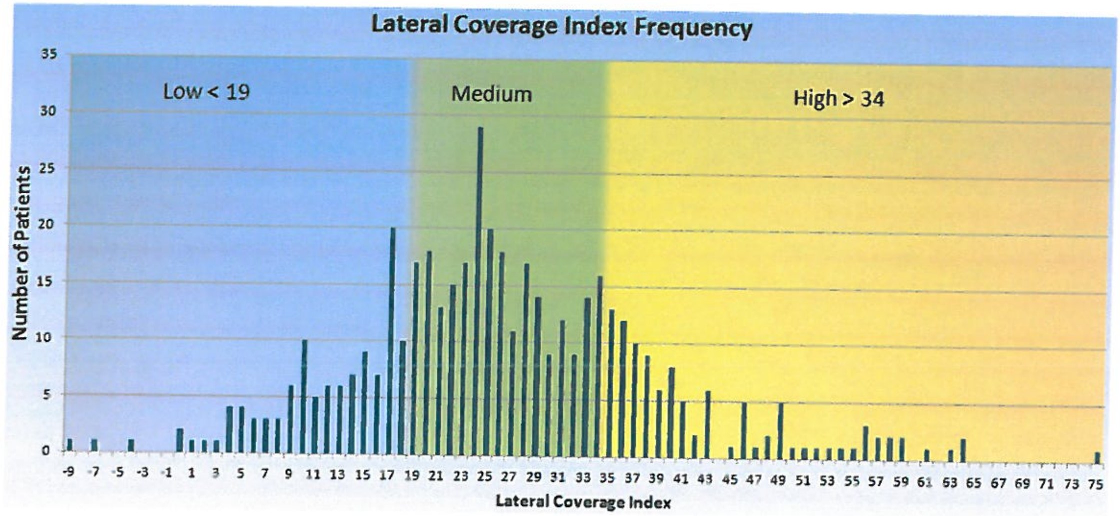


Fig 4. Histogram of the LCI incidence in the cohort and assignment to 3 groups: low, medium, and high. The lower 25th percentile was considered as low (blue); the middle 50th percentile was considered as medium (green), and the upper 25th percentile was considered as high (yellow). The groups consisted of 114, 236, and 115 patients, respectively.

Table 5. Stratification According to LT Tear Severity

Group	N	Average Age (yr)	Average Acetabular Inclination (°)	Average CE Angle (°)	Average LCI (°)	Average Cross-over (%)
0: No tear	237	33.2	4.3	32.3	28.0	18.4
1-0: <50% Tear	106	34.6	4.3	30.1	25.7	14.7
2-50: <100% Tear	104	40.9	6.9	29.6	22.8	10.3
P		.0000	.0002	.0019	.0008	.0015

NOTE. Analysis of variance, according to the severity of LT tear grading, comparing average values of age, acetabular inclination, CE angle, LCI, and cross-over sign. As the severity of the LT tear increased, the average age of the patients and the AI increased, whereas the average CE angle, LCI, and cross-over sign values decreased. Sixteen patients with a full-thickness LT tear were excluded from this analysis because of the small group size and degenerative nature of the tear in 4 of them.

patients without a tear (Table 1). The calculated relative risk to have an LT tear was 1.51 higher for patients older than 30 years, whereas the incidence of tears was the lowest for patients younger than 20 years (Fig 2). However, when we stratified the radiographic findings according to the age groups, no significant differences were found.

Other factors were investigated in association with LT tears. Both groups, with and without LT tears, had symptoms on average for 2 years before surgery; about 29% of patients in both groups reported an acute onset of pain (Table 1). The physical examination data did not reveal any significant limitation in the ROM values of patients with LT tears. In some past studies, a reduced and painful ROM in internal rotation and extension was noted.[6,40,47,48] In our previous study, we reported comparable results to the current, with no loss of ROM in the LT tear group of patients.[14] The current data show that only the lateral impingement test approached statistical significance; however, with 10% difference, it is clinically insignificant (Table 2). LT tears are known to be related to degenerative changes, but there was no association with the Tonnis grade in the current cohort (Table 7).[10] Nonetheless, patients with an LT tear had significantly more cartilage damage (Fig 3), requiring more microfracture procedures (Table 5). Also, no relationship was found to the femur architecture, the alpha angle, and offset or the femoral anteversion (Table 7).

In the current cohort, 95% of the patients had labral tears (Table 3). However, no significant difference was found in relation to the labral tear sizes or location. Nonetheless, setting an arbitrary range between 11 o'clock posteriorly and 4 o'clock anteriorly revealed that more patients with LT tears have tears outside of these boundaries (Table 3). Another significant finding

Table 6. Factors Found to Be Associated With LT Tears

Related to LT Tears	Not Related to LT Tears
Age	Sex
Lateral CE angle	Tonnis grade
Acetabular inclination	Anterior CE angle
LCI	Alpha angle
Percentage of cross-over sign	Head–neck offset
Ischial prominence size	Femoral anteversion

was that patients with LT tears had more advanced acetabular chondral damage (Fig 5), leading to higher incidence of microfracture (Table 4). This combination of large labral tears, chondral damage, and LT tears may represent a destructive process in the joint that may be degenerative in nature or possible microinstability.

One concern regarding the study was reliability and repeatability of the measurements. The high intrarater intraclass correlation coefficients for both the CE and AI angles in this study (.79 and .91, respectively) indicated a low degree of variability between measurements of the same angle. Zingg et al.[49] conducted a study on 8 hips in which 3 raters measured the CE angle. This study yielded a high intraclass correlation coefficient (.97) for inter-rater reliability. Another larger study with 2 observers measured 20 different radiographic parameters twice in 39 hips and found intrarater coefficients values of .88 to .95 for the AI angle and .86 to .97 for the CE angle. Inter-rater reliability for AI and CE angles was found in this same report to be .45 for the AI and .73 for the CE angle.[35] Two other studies found intrarater coefficients for the CE angle to be .86 and .74.[50,51] This previous research, along with our high intrarater reliability coefficient values, validates the precision of the angle measurements that create the LCI measured herein.

Additionally, a high incidence (49%) of LT tearing was found within our cohort. Previous studies have typically reported varied, yet low, incidence rates of LT tears ranging from 4% to 17%,[6,52,53] whereas other studies reported a much higher rate of LT tears (51% to 65%)[14,54] among hip arthroscopy patients. This higher rate of LT tearing is most likely caused by an increased use of hip arthroscopy and subsequent awareness of LT tearing. Some of the tears were low-grade partial-thickness tears, which may not have been considered pathologic in prior studies.[14]

One of the strengths of the present study is its large population size of patients with LT tear data and radiographic measurements. Additionally, the measurement of all radiographs by the same reader provides a degree of consistency between patients. The current study was unique because it aimed to isolate association of LT tears and acetabular bony architecture. To our knowledge, there is no other study currently published, which

Table 7. Radiographic Findings

	All Patients	LT Tears Present	LT Tears Absent	*P*
Acetabular inclination	4.84 (±5.66)	5.41 (±5.77)	4.29 (±5.52)	.03231
CE angle	31.15 (±7.55)	29.93 (±7.47)	32.32 (±7.46)	.00061
LCI	26.98 (±12.08)	24.51 (±12.32)	28.04 (±11.84)	.00184
Percent of cross-over	15.38% (±17.39%)	12.32% (±16.12%)	18.41% (±18.11%)	.00051
Ischial prominence	5.08 (±5.33)	4.43 (±5.08)	5.71 (±5.5)	.01041
Anterior CE angle	31.63 (±10.2)	31.28 (±11.19)	32.21 (±8.36)	.51333
Alpha angle (Dunn view)	67.22 (±15.75)	67.73 (±16.69)	66.72 (±14.82)	.49186
Offset (mm)	4.61 (±2.83)	4.58 (±2.81)	4.65 (±2.86)	.78474
Tonnis arthritic grade				
0	65.15%	66.22%	64.14%	.8566
1	25.76%	25.33%	26.16%	
2	9.09%	8.44%	9.70%	
Magnetic resonance imaging: femoral anteversion	8.45 (±8.81)	8.74 (±8.51)	8.2 (±9.07)	.62185
Computed tomography: femoral anteversion	15.52 (±9.26)	15.81 (±9.83)	15.29 (±8.81)	.68457

NOTE. Significant difference in the acetabular architecture was found between patients with and without LT tears. Patients with LT tears were significantly less covered laterally as indicated by the higher acetabular inclination, lower CE angle, and lower LCI (CE minus acetabular inclincation). The ischial prominence size and the percentage of the cross-over sign, which were both lower for patients with LT tears, indicate lower acetabular retroversion. However, the anterior coverage, as presented by the anterior CE angle, was found insignificantly different. Also, the femoral head–neck architecture was insignificantly different.

supports this relationship between radiographic measurements of acetabular architecture and LT tearing.

The primary limitation of this study was that only 1 surgeon classified LT tears during surgery and that there was no evaluation of intraobserver or interobserver reliability of the presence of LT tears in hips. Because the grading of the LT tears by both classification systems depends on direct arthroscopic evaluation by the surgeon, intraobserver and interobserver reproducibility could not be tested. Similarly, an interobserver reliability could not be found for radiographic measurements because only 1 surgeon conducted measurements of the CE and AI angles. Another limitation of this study was that LT pathology was not completely isolated; 95% of the hips in this study had concomitant labral tearing. Last, power analysis was not performed as there was no precedent study that was thought to be appropriate to predict expected differences in the angles measured.

Overall, this study did not prove causation of LT tears but rather showed an association of LT tears to age and acetabular bony morphology. One theory to explain this association would be that insufficient acetabular coverage might compromise the structural stability of the joint, and perhaps even compromise labral seal. At present, it is not known whether LT tears cause instability, or instability causes LT tears. However, if there is indeed an association between LT tears and instability, then the finding of LT tear in the absence of other causes could be considered an indication to minimize acetabular rim trimming and perhaps to perform anterior capsular tightening, as recommended by Haviv and O'Donnell.[11]

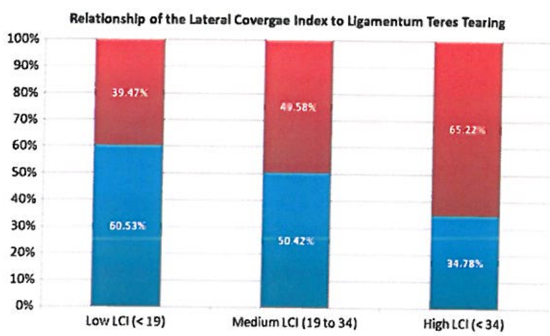


Fig 5. Percentage of patients with and without LT tears (LTT) within the 3 LCI groups. The difference between the groups was found to be significant at $P = .0004$. Patients with a low index value were 1.74 times more likely to have an LT tear than were patients with a high index value.

Conclusions

This study found that the presence of LT tears was associated with acetabular bony morphology and age. LT tears were less frequent in patients with a high LCI and acetabular retroversion and in patients younger than 30 years. Further study is needed to establish whether there is a causal relationship between acetabular undercoverage and LT tears and whether LT tears may be a sign of microinstability of the hip.

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