Is transverse acetabular ligament an anatomical landmark to reliably orient the cup in primary total hip arthroplasty?

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KEYWORDS
Total hip replacement; Dislocation; Transverse acetabular ligament; Cup orientation

Summary
Introduction: Accurate positioning of the acetabular cup in primary total hip arthroplasty is critical to decrease the rate of dislocation. Inaccurate orientation of the cup is the most common error during this procedure. Target acetabular orientation is still controversial. An original study found a dislocation rate of 0.6\% when the cup was aligned with the transverse acetabular ligament (TAL).

Hypothesis: TAL is a patient-specific anatomical landmark and a tool for cup orientation.

Materials and methods: Eight cadaveric pelves (14 hips included for study) were harvested in toto at our research laboratory. Anatomical versions of the TAL, labrum and horns were measured in relation to the anterior pelvic plane. A navigator sensor and an optoelectronic device (Motion Analysis\textsuperscript{TM}) were used.

Results: Anatomical versions of the TAL, horns and labrum averaged 1.9\degree (range, \textendash8\degree to +13.3\degree), 3\degree (range, \textendash12.2\degree to 14\degree), and 26.3\degree (range, 17.4\degree to 41.8\degree), respectively.

Discussion: To our knowledge, this is the first study to report the orientation of the periacetabular soft-tissues. TAL anteversion was outside the safe zone described by Lewinnek, while labrum anteversion was within this safe-zone. We discuss the reference used, Lewinnek’s safe zone, and functional orientation of the implants. Lewinnek’s safe-zone does not seem to be valid. The TAL seems to be a specific reference for each patient but its reliability must still be confirmed as an adequate reference for positioning the cup in total hip arthroplasty.

Level of evidence: Level IV Prospective study.

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Introduction

Despite an increase in understanding of its causes and mechanisms, dislocation remains one of the main complications of primary total hip arthroplasty [1]. Three factors are involved: the surgeon (approach [2,3], experience [4,5], orientation of components [6–8]), the implants (ratio head/neck [2,9], anti-dislocation devices [10]) and the patient (age [3], sex, alcohol consumption [11], neurological history [12], history of surgery [13]). The position of the acetabular component is a central factor for preventing the risk of dislocation [14], as well as for limiting the risk of wear and loosening [15].

The orientation of the cup is defined by its inclination and version. Unlike inclination, which according to most authors should be approximately 45° [7,8,16,17] for optimal range of movement, implant stability and to limit wear, there is no consensus about how much anteverision is necessary for the cup. Murray [18] defined three types of cup anteverision: anatomical, operative and radiographic. Anteverision values are different depending on the plane of reference, and Murray has developed conversion nomograms for these three definitions. [18]. McKibbin [19] was the first to use the anterior pelvic plane (APP) (plane which passes through the two anterosuperior iliac spines and in the middle of the pubic tubercles) to measure acetabular anteverision. Lewinnek et al. [8] defined a “safe zone” defined from the APP (between 5 and 25° of radiographic anteversion) to reduce the rate of dislocation (1.5% vs 6%).

During surgery, the most important step is cup orientation, especially for young surgeons. The position on the operating table, dislocation of the native hip and the use of retractors all change pelvic, and thus acetabular version [20]. During traditional surgery, there are no reliable constants: table position (transverse axis), patient’s body (longitudinal axis). Computer assisted surgery has not solved this problem because except in cases of kinematic navigation, there is the problem of which reference to use for the subject in the decubitus position [21].

An original study in 2006 by Archbold et al. [22] reported a rate of dislocation of 0.6% (posterolateral approach, 28 mm heads) at a minimum of 8 months of follow-up if the cup component was placed parallel to the transverse acetabular ligament (TAL). The TAL is a fibrocartilaginous tissue, which unites the two horns of the acetabular notch. This ligament is usually found (99.7%) even in cases of severe osteoarthritis of the hip (after removing osteophytes) [22]. However, to our knowledge, there is no anatomical study which has evaluated the orientation of the transverse acetabular ligament and its variations.

We measured anatomical anteverision of the TAL in relation to the APP. We then compared these results to those of Lewinnek et al. [8] in order to discuss the reliability of using the TAL as an anatomical reference for positioning cups during primary total hip arthroplasty.

Materials and methods

Materials

Eight fresh in toto cadaveric pelves (including sacroiliac joints, pubic ligaments, labrum and TAL) were harvested from the laboratory of anatomy in Lyon: three men and five women. The mean age was 82.5 ± 3.3 years (range 78–93). Only “normal” pelves were included in this study for a total of 14 acetabuli. Acetabuli with osteoarthritis of the hip, prior injury or hip surgery were excluded.

Once dissected and harvested, the fresh pelves were frozen until the experimental phase of the study. The pelves were thawed 24 hours before being studied to restore the texture to the TAL and the labrum.

Measurements were obtained with an optoelectronic system with passive markers called Motion Analysis® (Santa Rosa, California, USA). Six Eagle™ cameras (1.3 Mpx) were piloted by EVaRT 5.0™ software. An appropriate volume was chosen around the pelves. Static and dynamic calibrations were obtained. System errors were below 0.2 mm. The sampling frequency of the cameras was 100 Hz. A Butterworth filter was used (low pass, order 5, cut-off frequency 6 Hz) to correct the 3D path of the markers. Six markers (diameter 12 mm) were glued onto each pelvis with Loctite™ (Henkel, Marne-la-Vallée, France). Two were attached to the posterosuperior iliac spines (IPSIS-R) and (PSIS-L)-M, two to the anterosuperior iliac spines (ASIS-R and ASIS-L) and two to the pubic tubercles (PUB-L and PUB-R). The BrainLab™ tracking sensor and three markers were used to measure the different elements (Fig. 1). The exact dimensions were known (manufacturer’s specifications).

Methods

Both acetabuli were studied for each pelvis. It was important that the operator (the same orthopedic surgeon for all pelves) be careful to keep the tracking sensor in contact with the zone being studied. There were three consecutive acquisition sequences for each hip; TAL, horns and labrum. The entire TAL and labrum were palpated with the tracking sensor (for 5 and 10s, respectively).
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and the horns were tracked on their most prominent area.

EvaRT 5.0™ software calculated the 3D coordinates of the tracking markers at a main static reference point which was determined during calibration of the device. The Skeleton builder™ module integrated into the software was used to hierarchically define the objects being studied. In this way, it was possible to identify the position of an object in relation to another hierarchically superior object. The original position of the lowest object was provided by three coordinates and the orientation of this object was given by three angles.

An initial object was defined by its reference point created with the help of the markers ASIS-R, ASIS-L, PUB-R and PUB-L. The origin O was at the level of the pubis between the two markers PUB-R and PUB-L. The Y-axis was found between the origin O and the middle of ASIS-R and ASIS-L. The Z-axis was coplanar to the Y-axis, in the plane defined by PUB-R, PUB-L and ASIS-R and the Z-axis orientated towards the right. The X-axis was defined to create a direct orthonormal reference with Y and Z (with X towards the front). This reference was called the APP (Fig. 2). A second object was then defined at the level of the marker. The origin of this reference was the tip of the tracking sensor. Thanks to Skeleton™, the position of the origin of the tracking sensor was found directly in the reference APP.

Calculations and data analysis

The necessary data were obtained during the tracking phase. Once data were processed with EvaRT™, they were exported to format.htr. An Excel™ macro was then used to recover the 3D coordinates of the origin of the tracking device in the reference APP which was calculated over time using Skeleton™. Then by projecting these coordinates onto the XZ plane (transversal plane perpendicular to the APP), we calculated the anatomical anteversion of the TAL, the acetabular horns and the labrum. Anatomical anteversion was the anteversion measured in this transversal plane between the sagittal X-axis and the line corresponding to projection of the plane of interest (Fig. 3).

Results

This study included 14 acetabuli after excluding two hips that had former surgery. The anatomical version of the TAL was between $-8^\circ$ and $+13.3^\circ$ (mean = $1.9^\circ$) (Table 1). The anatomical version of the horns was between $-12.2^\circ$ and $+14^\circ$ (mean = $+3^\circ$) (Table 1). The anatomical version of the acetabular labrum was $+17^\circ \pm 41.8^\circ$ (mean = $+26.3^\circ$) (Table 1). Pelvis 1 and 5 presented with ligaments and horns

Table 1 Anatomical anteversions (in degrees) of the horns, TAL and labrum.

<table>
<thead>
<tr>
<th>Pelvis</th>
<th>Side</th>
<th>Horns</th>
<th>TAL</th>
<th>Labrum</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Right</td>
<td>-10.4</td>
<td>-8.1</td>
<td>17.4</td>
</tr>
<tr>
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<td>Left</td>
<td>-5.1</td>
<td>-5.9</td>
<td>18.2</td>
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<td>4.2</td>
<td>3.3</td>
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</tr>
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<td>Left</td>
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</tr>
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</tr>
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<tr>
<td>8</td>
<td>Left</td>
<td>3.5</td>
<td>-4.5</td>
<td>22.5</td>
</tr>
</tbody>
</table>
with the greatest retroversion of approximately $-10^\circ$. There was anteversion in the labrum in all hips.

## Discussion

Since the study by Archbold et al. [22], the TAL has become an important reference for certain surgeons for hip arthroplasty. These authors identified a TAL in 99.7% of their interventions. The TAL has become one of the main anatomical references for positioning the cup both in traditional and computer-assisted surgery. Thus, this study was needed to confirm the reliability of this element as a reference point. To our knowledge, there are no other studies in the literature on the anatomical orientation of the "soft tissues" (transverse ligament, labrum) around the acetabulum. Moreover, most studies evaluating the orientation of total hip arthroscopy components are based on radiography whose parameters are not standardized.

### Anterior pelvic plane

We chose the APP because this is an "anatomical" plane which is used in most publications [7,23,24] and which has reference values determined by Lewinnek et al. [8]. We converted the radiographic anteversion values ($15 \pm 10^\circ$) into anatomical anteversion ($35 \pm 20^\circ$) using Murray’s conversion nomograms [18]. The APP was chosen despite the controversy about the functional notion of pelvic tilt. Pelvic version modifies acetabular orientation [25]. When pelvic version increases, acetabular anteversion decreases and vice versa. When standing, the anterior pelvic plan is not vertical because of this variation in pelvic version. Nevertheless, this is one of the only anatomical pelvic planes which is easily measured in vitro.

### Transverse acetabular ligament and the anterior pelvic plane

An MRI study by Archbold et al. [26] showed that mean anteversion (surgical anteversion) of a TAL-labrum plane was similar to that of the labrum in our study. (approximately 23°). On the other hand, our study does not support the use of a common TAL-labrum plane because we observed different anteversion for these two structures. A radiographic study by Pearce et al. [24] showed that the TAL was a reliable reference for aligning the cup in Lewinnek's safe zone. However, this study was based on non-standardized X-rays. Our study did not confirm these results, because orientation using the TAL with reference to the APP was not in Lewinnek’s safe zone.

### Lewinnek’s "safe zone"

Our study showed that orientation of the TAL (and the horns) was outside of (below) Lewinnek’s "safe zone". On the other hand, labral anteversion was found to be within this zone. Based on these results, in order to be within Lewinnek’s safe zone, the cup should have 30° of anteversion in relation to the TAL plane. Lewinnek et al. [8] analysed 113 X-rays with only nine patients with dislocation. These authors identified 1.5% of cases with dislocation in the ‘’safe zone’’ which is twice as many as the study by Archbold et al. [22] which used the TAL as a reference.

## Limits of our study

The limits of our study are the lack of power of our statistical tests. A study of variations scatterplot in TAL anteversion in a larger population would make it possible to draw conclusions about the intra-individual specificity of this reference. Our study only evaluated cup anteversion, and it is obvious that when trying to reduce dislocation, femoral stem anteversion, which is easier to evaluate during surgery, is complementary to that of the cup (notion of combined anteversion). [27]. Moreover, the tilt of the structures studied could result in variations in the projected anteversion. Finally, because this was an anatomical study, we did not take into account the lumbar-pelvic complex, whose balance affects the orientation of the acetabulum depending on the patient’s position (sitting, standing, lying down...).

## Conclusions

Our study showed that TAL anteversion was outside (below) Lewinnek’s safe zone. This standard should not be used to position cups between 5 and 25° in relation to the APP. Like Archbold et al. [22,26] and Biedermann et al. [7], we believe that cup orientation should be specific for each patient and not a universal standard as suggested by Lewinnek et al. [8]. Indeed, anteversion is not a static parameter but a specific dynamic value for each individual. Moreover, the APP varies significantly in relation to the vertical plan depending on the patient’s position (sitting, standing, lying down...) [29,30]. Lewinnek’s notion is static, standard and therefore incorrect. Anatomical anteversion of the TAL in the APP is approximately 0° ±10°. The TAL seems to be a specific reference for each patient but its reliability must still be confirmed as an adequate reference for positioning the cup in total hip arthroplasty.

## Conflict of interest statement

No conflict of interest.

## References


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