The use of the transverse acetabular ligament in total hip replacement

AN ANALYSIS OF THE ORIENTATION OF THE TRIAL ACETABULAR COMPONENT USING A NAVIGATION SYSTEM

K. Fujita,
T. Kabata,
T. Maeda,
Y. Kajino,
S. Iwai,
K. Kuroda,
K. Hasegawa,
H. Tsuchiya

From Department of Orthopaedic Surgery, Graduate School of Medical Science, Kanazawa University, Kanazawa, Japan

It has recently been reported that the transverse acetabular ligament (TAL) is helpful in determining the position of the acetabular component in total hip replacement (THR). In this study we used a computer-assisted navigation system to determine whether the TAL is useful as a landmark in THR. The study was carried out in 121 consecutive patients undergoing primary THR (134 hips), including 67 dysplastic hips (50%). There were 26 men (29 hips) and 95 women (105 hips) with a mean age of 60.2 years (17 to 82) at the time of operation. After identification of the TAL, its anteversion was measured intra-operatively by aligning the inferomedial rim of the trial acetabular component with the TAL using computer-assisted navigation. The TAL was identified in 112 hips (83.6%). Intra-observer reproducibility in the measurement of anteversion of the TAL was high, but inter-observer reproducibility was moderate.

Each surgeon was able to align the trial component according to the target value of the angle of anteversion of the TAL, but it was clear that methods may differ among surgeons. Of the measurements of the angle of anteversion of the TAL, 5.4% (6 of 112 hips) were outliers from the safe zone.

In summary, we found that the TAL is useful as a landmark when implanting the acetabular component within the safe zone in almost all hips, and to prevent it being implanted in retroversion in all hips, including dysplastic hips. However, as anteversion of the TAL may be excessive in a few hips, it is advisable to pay attention to individual variations, particularly in those with severe posterior pelvic tilt.

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In total hip replacement (THR), accurate orientation of the acetabular component results in fewer dislocations, less impingement, reduced wear and improved survival.[1] The ‘safe zone’ of Lewinnek,[2] with abduction of 40° (30° to 50°) and anteversion of 15° (5° to 15°), has become accepted as a reference for orientation of the acetabular component, but introduction of the component within this safe zone does not always prevent dislocation. Some authors have recommended the use of the transverse acetabular ligament (TAL) (Fig. 1) to guide anteversion of the acetabular component.[3-5] However, this view has not been universally accepted.[6-8] The aim of this study was to use a computer-assisted navigation system to determine whether the TAL is actually useful as a landmark in THR.

Patients and Methods

Between January 2011 and January 2013, 121 consecutive patients (134 hips), excluding those who had previously undergone osteotomy, underwent primary THR using the posterolateral approach with the patient in the lateral decubitus position. There were 26 men (29 hips) and 95 women (105 hips) with a mean age of 60.2 years (17 to 82) at the time of operation. The pre-operative diagnosis included developmental dysplasia in 67 hips (50%), primary osteoarthritis in 32 (23.9%), osteonecrosis of the femoral head in 18 (13.4%), rheumatoid arthritis in seven (5.2%), femoroacetabular impingement in four (3.0%), subchondral insufficiency fracture in three (2.2%) and others in three (2.2%). The hips were divided into two groups: dysplastic (D) and non-dysplastic (N), according to the pre-operative diagnosis. All operations were performed by the senior author (TK) using a CT-based and surface registration-type navigation system (CT-based Hip, v1.0; Stryker Navigation, Freiburg, Germany). This was used intra-operatively to determine the orientation of the TAL. The acetabulum was reamed to the true floor. Soft tissue and osteophytes around the TAL were carefully removed with an electrosurgical knife and osteotome. The TAL was assessed and

■ K. Fujita, MD, Orthopaedic Surgeon
■ T. Kabata, MD, PhD, Orthopaedic Surgeon, Associate Professor
■ T. Maeda, MD, PhD, Clinical Lecturer, Associate Professor
■ Y. Kajino, MD, PhD, Orthopaedic Surgeon, Research Assistant Professor
■ S. Iwai, MD, Orthopaedic Surgeon
■ K. Kuroda, MD, Orthopaedic Surgeon
■ K. Hasegawa, MD, Orthopaedic Surgeon
■ H. Tsuchiya, MD, PhD, Orthopaedic Surgeon, Professor, Chairman
Kanazawa University, Department of Orthopaedic Surgery, Graduate School of Medical Science, 13-1 Takaramachi, Kanazawa, 920-8641, Japan.

Correspondence should be sent to Dr T. Kabata; e-mail: tamonkabata@yahoo.co.jp

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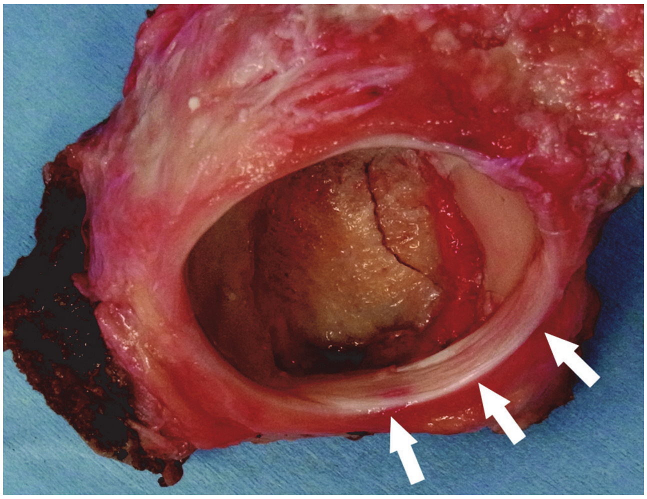

Fig. 1

Photograph showing the transverse acetabular ligament (TAL). It is short and transversely straddles the inferior limit of the bony acetabulum.

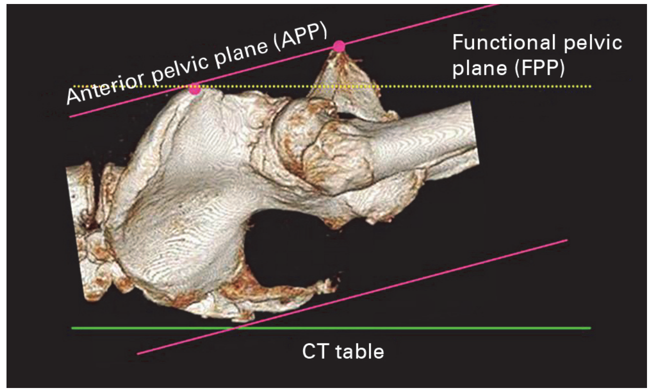

Fig. 3

CT reconstruction showing the anterior pelvic plane and functional pelvic plane in a patient with posterior pelvic tilt.

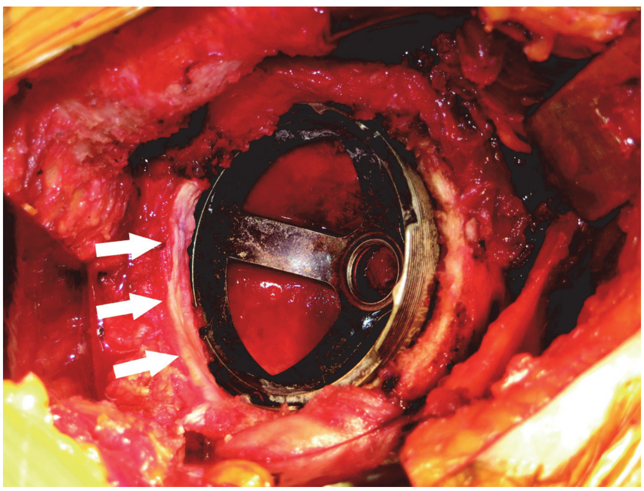

Fig. 2

Photograph showing alignment of the inferomedial rim of the acetabular trial with the transverse acetabular ligament.

classified according to the intra-operative classification system proposed by Archbold et al: grade 1 for normal-quality TAL visible on exposure of the acetabulum; grade 2 for a TAL covered by soft tissue; grade 3 for a TAL covered by osteophytes; and grade 4 when no ligament could be identified, even after clearance of soft tissue or osteophytes.[3] The anteversion of the TAL was then measured by aligning the inferomedial rim of the trial acetabular component with the TAL using computer-assisted navigation (Fig. 2).

We used the navigation system to measure the anteversion of the TAL on an anatomical frame of reference. The acetabular abduction angle was set to 45°. The screen was turned away from the surgeon's field of view during the measurements. Three measurements for each hip were independently performed by two surgeons chosen from among one expert (TK) and four non-experts (KF, YK, SI and KK). The first measurement was always made by the expert. The anterior pelvic plane (APP), defined by the bilateral anterior superior iliac spines and the pubic tubercle, was used as a reference plane for the pelvis. If this plane was tilted in the sagittal plane when the patient was lying in a supine position because of spinal or pelvic deformities, the anteroposterior axis was corrected during pre-operative templating[9]; in brief, the 'functional pelvic plane' (FPP) was used as a reference (Fig. 3).[10] In order to evaluate pelvic tilt, we measured the pelvic flexion angle (PFA), which is that between the anatomical plane of the pelvis, through both anterior superior iliac spines and the superior margin of the pubic symphysis, and the plane of the CT table with the patient supine.[11] We assigned a positive value to an anterior pelvic tilt and a negative value to a posterior tilt (Fig. 3). The angle of the trial acetabular component was described as that between the acetabular and the longitudinal axes, using the anatomical definition reported by Murray.[12]

We determined:

1) the proportion of hips in which the TAL was identified, and a subgroup analysis based on the pre-operative diagnosis was undertaken.

2) the individual reproducibility of the measurement of anteversion of the TAL.

3) the inter-reproducibility between the measurements made by two surgeons of the anteversion of the TAL; the mean value of the three measurements made by each surgeon was used; and

4) the value of the anteversion of the TAL in terms of its outlier rate from the safe zone; the mean value of all six measurements was used.

Considering that we assessed 'anatomical' anteversion and set the 'anatomical' abduction to 45° in this study, the

Table I. Rates of identification of the transverse acetabular ligament (TAL) and grade of TAL (Grade 1, TAL immediately visible; Grade 2, TAL covered by soft tissue; Grade 3, TAL covered by osteophytes; Grade 4, TAL not identified, even after adequate clearance)

	All (n = 134)	Dysplastic group (n = 67)	Non-dysplastic group (n = 67)	p-value
TAL identified (n, %)	112 (*83.6*)	52 (*77.6*)	60 (*89.6*)	0.05
TAL grade (n, %)				
Grade 1	57	26	31	
Grade 2	13	3	10	
Grade 3	42	23	19	
Not identified (grade 4) (n, %)	22	15	7	
Reason (n, %)				
Soft tissue	4	2	2	
Osteophyte	12	9	3	
Deformity	4	4	0	
Unknown	2	0	2	

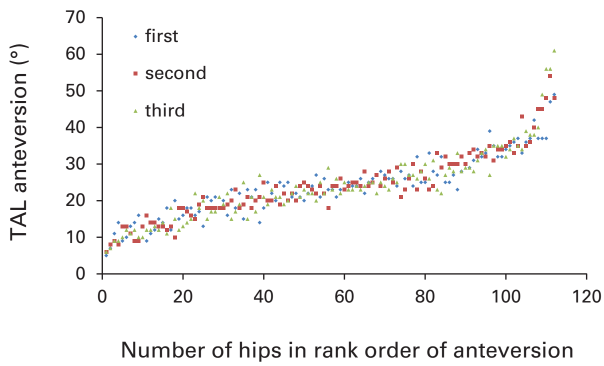

Fig. 4

Graph showing anteversion of the transverse acetabular ligament (TAL) measured by an expert (ICC (1.1) = 0.887, 95% CI 0.848 to 0.916).

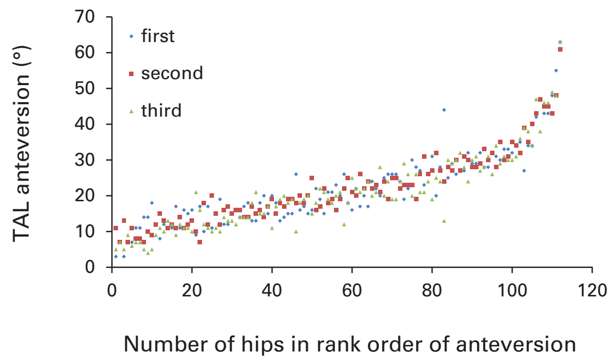

Fig. 5

Graph showing anteversion of the transverse acetabular ligament (TAL) measured by a non-expert. (ICC (1.1) = 0.876, 95% CI 0.828 to 0.905).

safe zone with anteversion of 5° to 25° described in radiographic definitions should be converted to anteversion of 7° to 37° in the anatomical definition.[12] In addition, a multivariable analysis of gender, age, pre-operative diagnosis and the PFA was performed to examine the risk factors for outliers from the safe zone.

Statistical analysis. Statistical analysis was performed using SPSS (PASW Statistics Base v19; SPSS Inc., Chicago, Illinois). Fisher's exact probability test was used to assess the differences in the TAL-identified rate and the outlier rate between the two subgroups. A two-sided Mann–Whitney U test was used to assess the differences in TAL anteversion and pelvic tilt between the two subgroups. The intra-class correlation coefficient (ICC) with 95% confidence intervals (CI) was used to assess individual observer reproducibility. Pearson's correlation coefficient was used to assess inter-observer reproducibility. Multivariable logistic regression analysis was used to assess the risk of outliers. Data were expressed as mean and standard deviation (SD). The level of significance was set at $p < 0.05$. A power analysis was calculated for both our study and a previous study,[13] which served as a control group. In our study, using the TAL, we assumed that the outlier rate from the safe zone of anteversion of the TAL would be 10%. In the previous study, which used a conventional technique, the outlier rate from the safe zone was 27.8%. The statistical power was set as power = $1 - \beta$ = 80%, and sensitivity as α = 5% to detect significant ($p < 0.05$) differences in outlier risk. The power analysis consequently set the required number of hips as 75 per group. The study had ethical approval.

Results

The TAL was identified in 112 hips (83.5%); 52 of the 67 hips (77.6%) in group D and 60 of the 67 hips (89.6%) in group N (Table I). Large osteophytes and synovial proliferation in the inferior acetabulum, and severe deformity due to congenital dislocation or previous arthrodesis, made it difficult to identify the TAL in every hip. Individual observer surgeon reproducibility in the measurement of anteversion of the TAL was high for both the expert (ICC (1.1) = 0.887, [95%CI 0.848 to 0.916]) (Fig. 4) and the non-expert surgeons (ICC (1.1) = 0.876, [95%CI 0.828 to 0.905]) (Fig. 5). There was a moderate correlation between the measurements of TAL anteversion made by two observers ($r = 0.658$, $p < 0.001$) (Fig. 6). The mean difference in

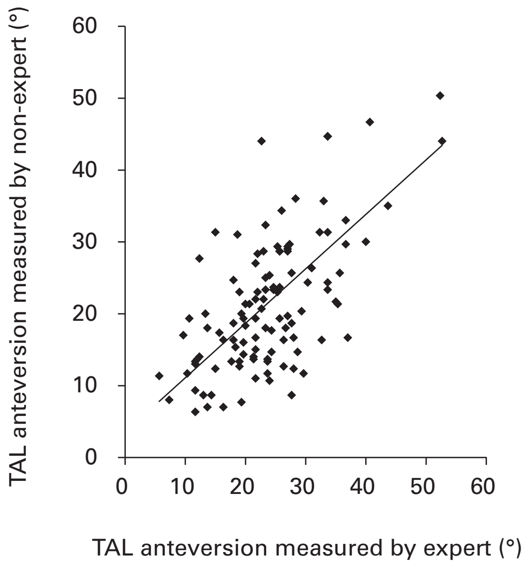

Fig. 6

Graph showing the correlation of the measurement of anteversion of the transverse acetabular ligament (TAL) by non-expert and expert surgeons (r = 0.658).

Table II. The angle of anteversion of the transverse acetabular ligament (TAL) (PFA, pelvic flexion angle)

	All (n = 112)	Dysplastic group (n = 52)	Non-dysplastic group (n = 60)	p-value
Mean TAL anteversion (°) (SD; range)	22.7 (8.5; 7.7 to 54.7)	21.1 (6.9; 7.7 to 39.3)	24.1 (9.4; 10.3 to 54.7)	0.14
Outlier rate (n, %)	6 (*5.4*)	1 (*1.9*)	5 (*8.3*)	0.14
Mean (SD) PFA (°)	3.1 *(6.3)*	4.9 *(5.1)*	1.5 *(6.9)*	0.02

Table III. Multivariate analysis of the risk factors for outliers from the safe zone (PFA, pelvic flexion angle)

Factors	Within safe zone (n = 106)	Outside safe zone (n = 6)	Adjusted OR (95% CI)	p-value
Gender (n, %)	25 (*23.6*)	0 (*0*)	23436764 (-)	1.00
Mean (SD) age (yrs)	59.4 (0.7)	72.5 (5.1)	1.185 (0.984 to 1.427)	0.07
Dysplasia (n, %)	51 (*48.1*)	1 (*16.7*)	0.401 (0.016 to 10.299)	0.58
Mean (SD) PFA (°)	3.6 (5.5)	-6.5 (11.8)	0.852 (0.737 to 0.984)	0.03

the values obtained by two surgeons was 6.4° (SD 5.0; 0.3° to 21.3°), and there was a difference of > 10° in 27 of 112 hips (24.1%). The mean anteversion of the TAL in all hips was 22.7° (SD 8.5; 7.7° to 54.7°), for group D, 21.1° (SD 6.9; 7.7° to 39.3°) and for group N, 24.1° (SD 9.4; 10.3° to 54.7°) (Table II). The rate of outliers from the safe zone in all hips was six (5.4%), in group D it was one of 52 hips (1.9%) and in group N it was five of 60 hips (8.3%). The significant risk factor for outliers from the safe zone was posterior pelvic tilt, not a pre-operative diagnosis of dysplasia (Table III).

Discussion

Instability and dislocation are leading causes of revision in primary THR, which one source has estimated as accounting for 22.5% of revisions.[14] Accurate orientation of the acetabular component during the initial THR reduces the incidence of revision.[1]

For each hip there should be a unique, optimal anteversion for the acetabular component. Lewinnek et al[2] defined the 'safe zone'. Archbold et al[3] however, subsequently reported that TAL-guided positioning of the acetabular component results in a rate of dislocation of only 0.6%, and recommended its use, as have other authors.[4,5] However, the situation required more investigation in Japan, where there are high rates of developmental hip dysplasia.[15] Abe et al[8] reported that anteversion of the TAL is more variable in dysplastic hips, and therefore is not a reliable guide in such patients. It has not yet been established that patient-specific target zones defined by anatomical landmarks such as the TAL can improve the rate of dislocation and impingement after THR.

When we used the TAL as a guide a number of problems arose, such as certainty as to its identification, as well as the accuracy of the method and its applicability to dysplastic hips.

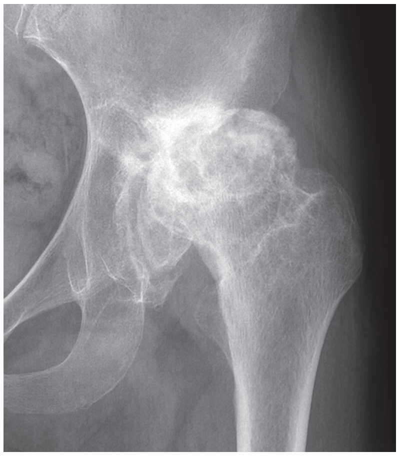

Fig. 7

Radiograph of the hip of a 64-year-old female patient with developmental dysplasia of the hip. The transverse acetabular ligament could not be identified owing to severe osteophytosis.

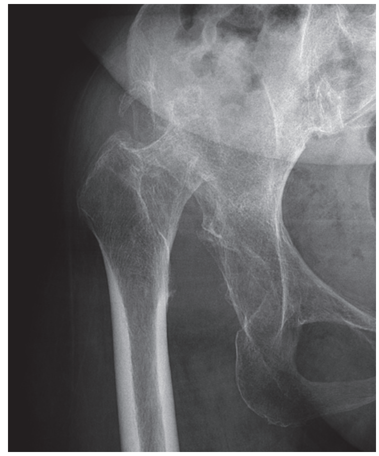

Fig. 8

Radiographs of the hip of a 76-year-old female patient with congenital dislocation of the hip. The transverse acetabular ligament could not be identified owing to severe deformity.

With respect to the proportion of hips in which the TAL could be identified, Archbold et al[3] reported 99.7% (997 of 1000 hips), whereas Epstein et al[6] reported 47% (30 of 64 hips) and Miyoshi et al[16] 81.6% (93 of 114 hips). In our study, we were able to identify it in 83.6% of hips (112 of 134), 77.6% in group D (52 of 67) and 89.6% in group N (60 of 67). In dysplastic hips the proportion in which the TAL could be found was thus markedly reduced. Where the TAL was not identified, group D had more hips with osteophyte formation and severe deformity. Thus we considered this to be the reason why it is likely to be damaged during exposure in dysplastic hips with long-standing problems, as there are often extensive inferior osteophytes (Fig. 7) and the TAL sometimes becomes ossified. Additionally, group D contained some severely deformed hips and the true acetabulum could not be identified intra-operatively (Fig. 8). In addition, with extensive synovial proliferation, which was found in some hips in both groups, the TAL might be destroyed in the attempt to expose it.

With respect to the reproducibility of this method, Kalteis et al[4] reported that there was only moderate intra- and inter-observer agreement with regard to the alignment of the acetabular trial using the TAL and the posterior labrum. In our study, individual observer reproducibility was high and each surgeon was able to align the trial accurately according to the anteversion of the TAL. However, inter-observer reproducibility was only moderate, and in 24.1% of the hips there was a > 10° difference between the two surgeons. Thus, clearly, the alignment of the trial component using this method can differ considerably among surgeons. These differences might be due to poor exposure of the TAL or the fact that it is short and thickened, making it difficult to identify appropriately.

It is difficult to be certain that anteversion of the TAL will reflect acetabular anteversion ideally in all hips. It has been reported, even using the APP reference, that anteversion of the TAL is not affected by pelvic tilt, which suggests there are large individual variations in anteversion of the TAL[4,17] Kalteis et al,[4] Epstein et al[6] and Archbold et al[17] reported outlier rates from Lewinnek's 'safe zone'[2] of 13%, 41% and 43%, respectively. In our study, the anteversion of the TAL varied widely, but only 5.4% of the measurements of anteversion were outliers from the safe zone.

In each hip the angle of anteversion of the TAL with the APP reference has a specific value regardless of alterations in pelvic tilt. However, if the pelvic tilt changes, it does so with the FPP reference. It can be calculated that, if pelvic tilt increases by 10° posteriorly, anteversion of 20° and inclination of 40° will alter radiological anteversion to 28° and inclination to 43°. Thus, anteversion of the TAL with the FPP reference is heavily dependent on pelvic tilt. In our study, the posterior pelvic tilt was a statistically significant risk factor for outliers. Where severe posterior pelvic tilt is present the angle of anteversion of the TAL may be excessive.

Although Abe et al[8] suggested that anteversion of the TAL is larger and more variable and not a reliable guide in dysplastic hips, we found the opposite, that anteversion of the TAL was not larger, it was less variable, and had a lower outlier rate in dysplastic hips than in other hips. We found that as the pelvic tilt was significantly more anterior in dysplastic hips, anteversion of the TAL was unlikely to be excessive. The pre-operative diagnosis of dysplasia was not a risk factor for outliers.

A limitation of our study is the fact that we set the abduction to 45° at the outset when measuring anteversion of the TAL. Previous studies[3,4,7,17] assessed the plane as defined by the TAL and the posterior labrum.

This may be why this study had a lower rate of outliers than previous studies.[4,17] In addition, we only measured the alignment of the trial acetabular component in relation to the TAL, not the alignment of the implanted component. In practical terms, even if the surgeon aligns the component with the TAL before impaction, the implanted component may have a changed orientation.

In conclusion, we were able to identify the TAL in many hips and use it to determine anteversion of the acetabular component in THR. Each surgeon was able to align the component according to the target for anteversion of the TAL. It is useful as a landmark for the orientation of the acetabular component within the safe zone in almost all hips and to prevent implanting the component in retroversion in all hips, including dysplastic hips. However, as anteversion of the TAL may be excessive in a few hips, attention must be paid to individual variations, particularly in patients with severe posterior pelvic tilt.

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