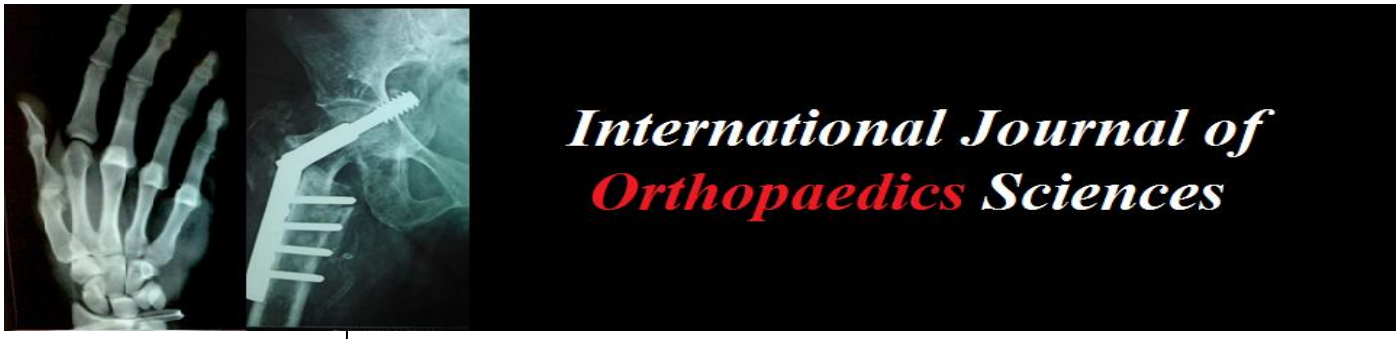

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How deep acetabular cup can be positioned from transverse acetabular ligament to have an ideal inclination?

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Abstract
Introduction: Acetabular component positing is the major deterministic step that defines the outcome following total hip replacement. Although various methods exist to measure and maintain cup inclination, intraoperative landmarks always guide to get the individual native inclination. This study aims to estimate the safe cup depth from the transverse acetabular ligament to get an ideal cup inclination.
Methodology: This is a prospective study conducted between 2017-2019. Patients who underwent uncemented total hip replacement for reasons other than hip dysplasia were included in the study. Modified Hardinge approach was used in all the cases. Archbold grading of TAL was done intra-operatively. The distance of the inferior rim of the cup to the TAL is measured and cup inclination is measured in post-operative radiograph with reference to the inter-teardrop line in anteroposterior radiograph of the hip. Correlation between cup depth and inclination is calculated by Spearman's correlation and regression curve analysis was used to analyze the results.
Results: We included 35 patients in our study and TAL was identified in all the cases and the mean radiological inclination achieved was 41.4º (SD=7.15) and the mean distance from TAL noted was 4.2 mm (SD=2.73). 85.7% of the cups were within the safe zone target of 30^0 to 50^0. There was a significant positive correlation between the cup depth and inclination angle ($r=0.93$, $p<0.05$) and regression analysis showed a safe distance limit of 8 mm from TAL maintains the cup within the safe zones of inclination by Lewinnek.
Conclusion: TAL can be reliably identified in all cases and can be used as a dependable intra-operative landmark for maintaining the cup inclination when the cup is positioned at a depth less than 6mm from the TAL. However, as the inclination is influenced by many factors, TAL alone cannot be used for determining the inclination of the acetabular component but can be used to guide the inclination along with other factors in play.

Keywords: Transverse acetabular ligament, cup inclination, total hip replacement, cup placement

Introduction
Acetabular component malposition in Total Hip Replacement (THR) may lead to adverse complications like impingement, accelerated wear, dislocation which required revision procedure [1, 2, 3, 4]. Hence component positioning takes a pivotal role in determining the outcome of the procedure. The 'safe zone' of Lewinnek [5] with an inclination of 40° (30° to 50°) and anteversion of 15° (5° to 15°), has become accepted as a reference for orientation of the acetabular component.
Surgeons depend on precise patient positioning to orient the acetabular component. However, this method cannot be ideal in all circumstances [6, 7]. Although computer-assisted component positioning gives accurate placement of components, feasibility and cost involved in the method prevent it from being useful for all cases of primary total hip replacement [8].
Beverland highlighted that if the component is positioned parallel to the TAL and psoas groove the patient-specific version and inclination can be restored [9]. Although a limit of 4mm has been established for reaming for the acetabulum in relation to the head size, maximum depth of the cup from the TAL beyond which safe zone of inclination target and center of the hip has not been detailed. Hence, we intend to assess the relationship between the

cup depth from the TAL and its implication on the inclination angle of the component in relation to the Lewinnek safe zones.

Materials & Methods

This is a prospective study conducted between 2017-2019. All Patients who underwent uncemented total hip replacement for primary osteoarthritis of the hip or osteoarthritis secondary to inflammatory arthritis, osteonecrosis or femoral neck fracture were included in the study. Patients who had previously undergone surgery to the same hip (including osteotomy), osteoarthrosis secondary to dysplasias, and those with fixed pelvic obliquity were excluded from the study since they have altered anatomical landmarks which forms the basis of our study. All patients were subjected to radiographs of the pelvis with both hips – anteroposterior view. Pre-operative templating was done basically to evaluate for the center of rotation and limb length discrepancy.

Surgical technique

Modified Lateral Hardinge approach was used in all the cases in lateral decubitus position. After exposure to the acetabulum, the appearance of the transverse acetabular ligament (TAL) was graded according to the system described by Archbold [10] as shown in Table 1. Once identified, TAL is used as a guide serial reaming of the acetabulum by placing a reamer parallel to TAL. The final component was placed until a snug fit of the cup is achieved on impaction and the distance of the inferior rim of the cup to the TAL is measured as shown in Figure 1. Thus, TAL is used as a reference for acetabular depth and inclination.

Table 1: Showing the intra-operative classification of the TAL by Archbold [10]

Grade of TAL	Appearance of TAL during THR
1	Normal-quality TAL visible on exposure of the acetabulum
2	TAL covered by soft tissue, which needed to be cleared to expose the ligament
3	TAL covered by osteophytes, which have to be removed to expose the ligament
4	No ligament identified, even after adequate clearance of soft tissue or osteophytes

For all patients, third-generation un-cemented press-fit prosthesis with primary fixation stability was used. The articulation was metal-on-polyethylene in all cases. The patients were mobilized a day or two after surgery and were discharged when they were mobilizing independently. Radiological evaluation was done in the immediate post-operative period.

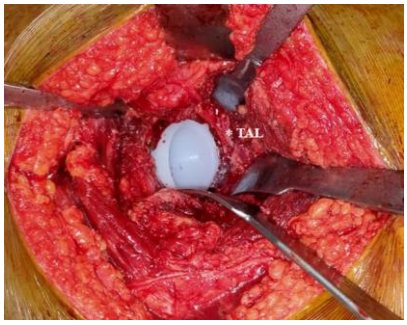

Fig 1: showing the method of measurement of the depth of the cup from TAL (Transverse Acetabular Ligament)

Cup inclination is measured in a post-operative radiograph focusing on public symphysis with reference to the inter-teardrop line as shown in Figure 2. Statistical analysis was performed using SPSS ver. 25.0 (SPSS Inc., Chicago, IL, USA). Correlation between cup depth and inclination is calculated by Spearman's correlation and regression curve analysis was used to analyze the results with a 95% confidence interval. A p-value < 0.05 was considered significant.

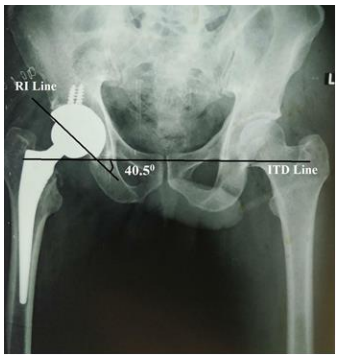

Fig 2: showing the measurement of Radiological Inclination angle between Radiological Inclination line (RI Line) and Inter Tear Drop Line (ITD Line)

Results

We included 35 patients in our study and TAL was identified in all the cases. Archbold grading of TAL was as shown in Table 1 with 18 hips in Grade I, 12 hips were of grade 2, grade 3 seen in 5 hips. In cases where TAL was covered by osteophytes, small diameter acetabular reamers were used to remove them to expose TAL. Additional secondary fixation devices were used for some patients.

The mean radiological inclination achieved was 41.4^{o} (SD=7.15) and the mean distance from TAL noted was 4.2 mm (SD=2.73). 85.7% of the cups were within the safe zone target of 30^0 to 50^0. At depth more than 6mm (n=5) intraoperatively inclination of the cup was more than 50^0 in all the cases. We had no complications and achieved stable hips with a good range of movements. The mean postoperative stay was 5.4 days.

There was a significant positive correlation between the cup depth and inclination angle by the Spearman correlation test ($r=0.93$, $p<0.05$). We plotted the depth of the cup measured as a distance from the inferior rim of the cup to the TAL and the post-operative inclination of the patient as a regression curve to estimate the safe range of the depth of the cup from the TAL which has 95% confidence interval and found that at

depth more than 6 mm, inclination went past the recommended safe zones as shown in Figure 3.

Figure 2 showing the regression linear and quadratic plot with a 95% confidence interval range showing that safe zone of inclination of 30^0 to 50^0 can be achieved at depth of the cup within 8 mm and perfect inclination of 45^0 could be achieved at depth of 5.9 mm (SD=0.6) from TAL. With increasing depth of the placement of the cup, there is a tendency for the cup to be inclined more vertical to the horizontal reference resulting in the placement of the cup out of the safe zone of Lewinneck.

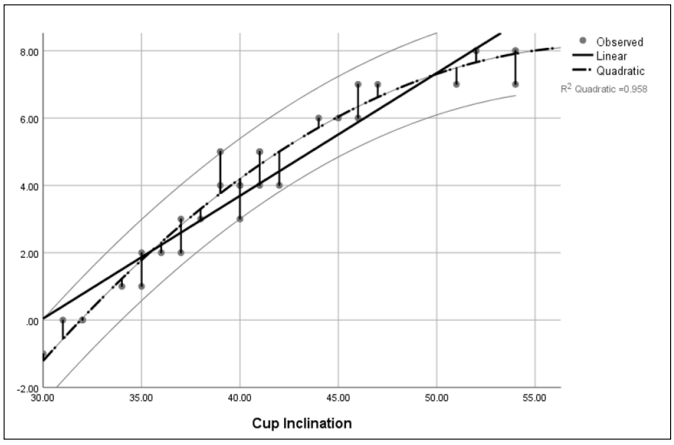

Fig 3: Regression analysis curve with a 95% confidence interval plot.

Discussion

TAL remains one of the anatomical landmarks of cup alignment which is independent of the patient positioning. [11] Archbold *et al* in 2006 [10] introduced the use of the TAL as a patient-specific reference point in determining the correct acetabular cup anteversion. With a large sample size (1000 cases), the TAL was easily identified in most cases (997 cases) and a very low rate of dislocation (0.6%) was seen. Importantly, limitations of this technique were recognized i.e. severe dysplasia or following pelvic trauma – both of which have been excluded in this study. They identified Grade 1 TAL in 490 cases, Grade 2 in 351 cases, 156 cases had grade 3 TAL while TAL could not be identified in 3 cases (Grade 4). In our study, TAL was identified in all cases. 14 cases were grade 1, 7 cases grade 2, and 5 cases had grade 3, which is in agreement with the incidence of TAL in their study.

According to Beverland, [9] in the normal hip the TAL and labrum extend beyond the equator of the femoral head and therefore, if the definitive acetabular component is positioned such that it is cradled by and just deep to the plane of the TAL and labrum, and is no more than 4 mm larger than the original femoral head, the center of the hip should be restored.

Recent studies support the use of transverse acetabular ligament in determining the anteversion of the acetabular component [11, 12, 13]. In the normal hip the TAL and labrum extend beyond the equator of the femoral head, and therefore if the definitive acetabular component is placed such that it is cradled by and just deep to the plane of the TAL and the labrum, the center of the hip should be restored. [9] Literature studying the use of TAL as a guide in acetabular component placement has mostly produced favorable outcomes in their cases, except for few studies [14] that do not validate the use of TAL to cause significant improvements.

Beverland [9] described three major determinants of post-operative radiological inclination which are the operative inclination which is the angle between the acetabular axis and the floor of the operating theatre; operative anteversion which increases post-operative inclination and position of the pelvis. Hence these factors must be kept in mind while aiming to achieve perfect acetabular cup inclination.

One of the few studies which were critical about the use of TAL was by Epstein *et al*, 2011 [14]; comparing the use of the TAL for positioning the acetabular cup with conventional freehand methods. They compared anteversion and abduction angles using TAL and freehand technique. They identified TAL in only 47% of 64 hips in a prospective series of patients who underwent primary THA. They concluded that the TAL was not regularly identifiable and that its use as a reference aid for correct acetabular cup anteversion was no more accurate than a conventional freehand technique. However, the study includes significant methodological flaws – the two surgeons had contrasting experiences in their ability to identify the TAL; one surgeon had far fewer outliers than the other and the use of Woo and Morrey technique of measuring anteversion which has been proven to have poor reliability in the measurement of radiological anteversion. Therefore, its conclusions must be taken with caution.

Our study has some limitations. Studies with large sample size are needed to further validate the results of our study. Identification of the TAL involves inter-observer variability which needs to be taken into account. Although TAL has been used for traditionally utilized for achieving patient-specific version, with our study, we recommend limiting the depth of the cup within 8mm of TAL ensures inclination within the safe zone with a 95% confidence interval.

Conclusion

TAL can be reliably identified in all cases and can be used as a dependable intra-operative landmark for maintaining the cup inclination when the cup is positioned at a depth less than 8 mm from the TAL. However, as the inclination is influenced by many factors, TAL alone cannot be used for determining the inclination of the acetabular component but can be used to guide the inclination along with other factors in play.

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