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Progressive Femoral Varus Osteotomy and its Mechanical Implications : A Cadaver Study.

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Abstract

Background: Proximal femoral varus wedge osteotomy alters hip mechanics. Quantifying radiographic changes seen with increasing varus angulation can provide valuable information in the preoperative decision to determine the optimum degree of varus angulation.

Questions/Purposes: The purpose of this study is to measure the effect of varus angulation on radiographic indices such as femoral neck-shaft angle (NSA), acetabulo-trochlea distance (ATD), and femoral length. Finally, the mechanical implications of varus osteotomy will be considered, including changes in the hip's range of motion and its effect on gait.

Patients and Methods: Progressive varus osteotomies were performed on a cadaver femur in 15° wedges. AP radiographs were taken following each varus osteotomy and neck-shaft angle, articulotrochanteric distance, and femoral length were recorded.

Results: Preoperatively, the neck-shaft angle measured 132° and articulotrochanteric distance measured 20.4 mm. With each 1° wedge varus angulation, the mean reduction in neck-shaft angle was 0.448°, mean reduction in articulotrochanteric distance was 0.29 mm, and mean femoral shortening was 0.157 mm.

Conclusion: When determining the degree of varus angulation for a proximal femoral wedge varus osteotomy, it is important to consider abductor lurch, limb length discrepancy, and changes to the hip's range of motion, especially when varus angulation exceeds a neck-shaft angle of less than 110°.

Introduction

Proximal femoral varus osteotomy is a well-established treatment option to contain the femoral head within the acetabulum [8, 21]. Failure to contain the femoral head results in anatomic deformations, including coxa valga, femoral anteversion abnormalities, dysplastic hip, and hip instability [7, 9, 19-21, 24, 30, 33]. These anatomic changes lead to pain, sitting imbalance, and gait abnormalities.

Recommendations for the appropriate amount of varus angulation for any of the above conditions are not clearly established [4, 6, 10, 16, 17, 22, 36]. Insufficient varus angulation results in inadequate containment of the femoral head by the acetabulum, leading to recurrent subluxation. Excessive varus has some known consequences such as limb length discrepancy[2, 3, 13, 15], trochanteric over-riding [13, 28], abductor weakness, and subsequent Trendelenburg gait [36].

Radiographic indices such as neck-shaft angle (NSA) and articulotrochanteric distance (ATD) are used in pre-operative planning and post-operative radiological follow up of patients treated with varus osteotomy [5]. The amount of NSA, ATD and limb-length shortening that can be expected for increasing degrees of varus angulation would greatly assist in the preoperative planning process.

In this study we utilized a dry cadaveric pelvis and proximal femur with progressive varus to answer the following question: How does increasing varus angulation of the proximal femur affect NSA, ATD, and limb length?

Methods

This study was performed on a dry cadaveric adult pelvis and femur which had no evidence of proximal femoral deformity, acetabular dysplasia, severe degenerative disease, or secondary osseous changes.

Umbilical tape, serving as an artificial ligamentum teres, was secured to the femoral head with adhesive and threaded through a hole drilled through the center of the acetabulum. The skeletal pelvis was secured to a radiolucent structural support in the supine position with neutral pelvic inclination and pelvic rotation to either side. Neutral pelvic inclination was confirmed by aligning the tip of the coccyx 3 cm from the superior border of the symphysis. Four radio-opaque pin-heads were placed on the femur proximal and distal to area of the osteotomies to facilitate radiographic limb length measurements.

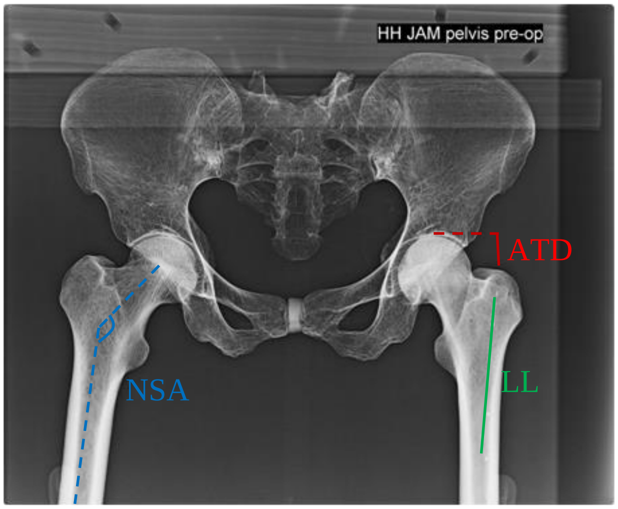


Figure 1: Articulotrchanteric distance (ATD), limb-length loss (LL), neck-shaft angle (NSA)

The varus osteotomy was performed using an oscillating bone saw (Stryker system 6, Stryker Instruments, Kalamazoo, Michigan 49001) to make medial triangular closing wedge varus osteotomies in the intertrochanteric region. The femoral fragments were reattached with adhesive. Seven successive medial closing wedge varus osteotomies were performed in 15°

increments from 0°-105°. The 75° osteotomy images were excluded from analyses due to excessive hip flexion noted on biplanar radiographs.

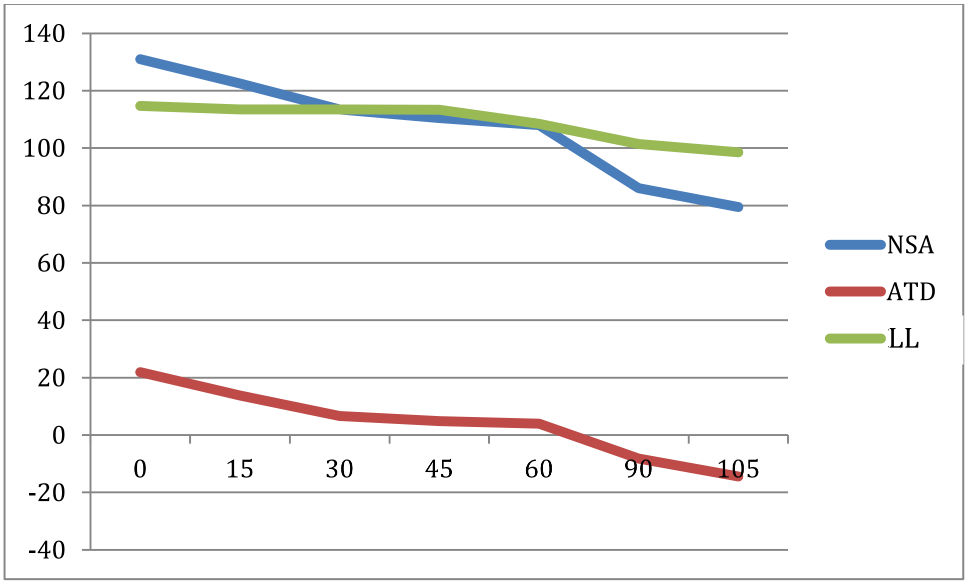
Biplanar anteroposterior (AP) pelvic radiographs were taken at baseline and following each progressive osteotomy. Computed tomography (CT, GE LightSpeed VCT, 64 slice) images of the immobilized pelvis were obtained at pre-osteotomy, with a 60° varus angulation, and 105° varus angulation. NSA was measured on Amicas PACS imaging software (Amicas Vision Server Software, v5.0, Amicas Inc., Brighton, MA, USA) by measuring the angle between a line drawn through the center of the femoral head and neck and a line drawn down the center of the femoral shaft [14]. ATD was measured on Amicas PACS imaging software by measuring the height difference between the tip of the greater trochanter and the most superior point of the femoral head [35]. Limb length loss was represented by the distance from the most proximal pin to the most distal pin on the femur (Fig 1). These measurements were performed by multiple observers and statistical analysis was performed to determined inter-observer reliability.

All statistical analysis was conducted using SPSS (version 12, SPSS Inc. Chicago, IL). Inter-observer reliability for each measure was assessed using intra-class correlation (ICC) analysis. ICC has a range between 0.0 and 1.0 with values closer to 1.0 representing stronger agreement. Because of the inherent differences in the nature of the tools that ICC can evaluate, there is no single scale that can be used to interpret acceptable levels of agreement for all ICC values, therefore levels of acceptability must change accordingly from study to study [26]. In this study we adopted Munro’s correlation strength categories (0.9 - 1.0 = “very high”; 0.7 - 0.89 = “high”; 0.5 - 0.69 = “moderate”; 0.26 - 0.49 = “low”; 0.0 - 0.25 = “little if any”) [25]. The two-way mixed model (absolute agreement) was utilized as the evaluators in this study were not randomly selected and were measuring identical radiographs.

The average of the measurements of the two evaluators was utilized for linear regression analysis to evaluate the relationship between varus and NSA, ATD, and LL.

Results:

Linear Regression analysis demonstrated a decrease in NSA, ATD and limb length (LL) with increasing intervals of varus angulation (Table 1). Based on the R^2, 97.69% of variation in NSA is explained by a change in varus and for each additional 1˚ increase in varus, NSA decreases by 0.477˚ (F = 199.821, df=5, $p < 0.001$), 96.6% of variation in ATD is explained by a change in varus and each additional 1˚ increase in varus, ATD decreases by 0.315˚ (F = 143.988, df=5, $p < 0.001$), 89.8% of variation in LL is explained by a change in varus and for each additional 1˚ increase in varus, LL decreases by 0.162˚ (F = 43.885, df=5, p = 0.001).



The inter-observer ICC results of measurements were: NSA 0.991 (95% confidence interval (CI) 0.952-0.998, p<0.001), ATD 0.988 (95% CI 0.943-0.998, p<0.001) and LL 0.97 (95% CI 0.069-0.996, p<0.001). Inter-observer reliability was evaluated using Interclass Correlation Coefficient and all measures were found to be in excellent agreement

Discussion:

Selection of the appropriate amount of varus angulation involves striking a balance between creating enough varus to contain the femoral head and creating so much varus that the changes in hip biomechanics become intolerable, eventually leading to osteoarthritis. The purpose of this paper is to quantify changes in radiographic indices like NSA, ATD, and limb length loss with increasing varus angulation.

This study has some limitations. This study used a single dry human adult cadaver pelvis and femur. This limitation was addressed by selecting a cadaver with no gross deformities or morphological abnormalities that may affect the results. This may be another limitation as femoral varus osteotomies are an intervention performed on patients with conditions such as cerebral palsy, Legg-Calve-Perthes Disease, or hip dysplasia. Furthermore, our adult cadaver hip had a preoperative NSA of 132°, which was closer to the average NSA of an adolescent hip at 135° than it is to the average NSA of an adult hip at 125°.[12, 30, 34] Also, femoral limb length discrepancy as described by Sabharwal should be measured from the top of the femoral head to the distal end of the medial femoral condyle.[27] This limitation was addressed by fixing radio-opaque markers to the femur on either side of the osteotomy site and focusing on changes in LL, ATD, and NSA instead of the absolute values of the radiographic indices. Finally, the cadaveric pelvis model does not account for the remodeling potential in adolescent patients. [11, 18, 32] Some groups have accounted for remodeling by recommending a post-operative NSA that varies with the age of the patient. [4, 22] This remodeling potential may influence the range of optimum varus angulation in an adolescent patient compared to our cadaveric pelvis model.

As varus angulation increases, NSA, ATD, and limb length decrease linearly. The study demonstrated that the apparent NSA decreased by 0.448° for every 1° of varus osteotomy. The reason why NSA does not change with varus angulation in a 1:1 ratio may be due to the affect femoral version has on apparent NSA in biplanar radiographs.[19, 20, 29, 30].

The amount by which ATD was found to decrease with varus angulation is consistent with what has been previously reported by other groups. [2, 28] With increasing varus angulation, the greater trochanter elevates and ATD declines, resulting in a shortening of the moment arm of the hip abductors. The shortening of this moment arm is responsible for causing abductor weakness and Trendelenburg gait. Other groups have reported ways to mitigate trochanteric prominence, abductor weakness, and Trendelenburg gait by performing a varus osteotomy with trochanteric arrest (apophysiodesis) and trochanteric transfer or distalization [1, 36]. Others recommend a transtrochanteric curved varus osteotomy [3, 13].

There is a wide range of reported values for femoral length shortening with varus angulation.[1, 3, 23] Limp has been found to be associated with a mean limb length discrepancy of 15.5 mm, whereas those without a limp had a limb length discrepancy of less than 11.9 mm.[13] Limb shortening can be reduced by performing a curved transtrochanteric varus osteotomy[3, 13, 15, 31] and in pediatric patients by utilizing other techniques like contra-lateral epiphisiodesis.

In this study we demonstrated that progressive varus osteotomy alters the morphology of the proximal femur. Additionally, we have provided a correlation of amount of varus osteotomy to change in radiographic parameters ATD, NSA, and limb length loss which should help with surgical planning in patients requiring femoral varus osteotomy.

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