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Subtrochanteric Shortening in Total Hip Arthroplasty: Biomechanical Comparison of Four Techniques

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ABSTRACT

Safe reduction of the femoral head into the true acetabulum requires a certain amount of femoral shortening in patients with high dislocation of the hip. In subtrochanteric shortening applications, to reduce complications it is necessary to maintain a stable fixation at the osteotomy line. The purpose of this study is to investigate frequently used methods from a biomechanical point of view. Four osteotomy groups were created with composite femurs to investigate subtrochanteric osteotomies; transverse, oblique, z-subtrochanteric and double Chevron. All loading tests were carried out with two implant types both with and without strut graft and cable fixation. No single inherent feature increasing the stability of the investigated osteotomy types was found. Additionally graft application did not have a significant contribution to stability.

Currently cementless total hip arthroplasty is the most frequently chosen method for treatment of symptomatic patients with high dislocation of the hip [1,2]. Due to some reasons such as bone and soft tissue abnormalities and comparatively young average age, this group of patients is more liable to complications after total hip arthroplasty than the usual patient population [1–4].

To reduce complications such as acetabular and femoral component loosening, uncorrected Trendelenburg gait and dislocations due to relaxed abductor muscles as well as to correct high hip-joint reaction forces seen in high hip center procedures it is necessary to reproduce, as close as possible, normal or near-normal mechanics [1,3,5–8]. One of the most important steps in achieving this is to transfer the hip joint rotation center into the true acetabulum. The transfer of rotation center into the true acetabulum, requires a significant amount of distal displacement of the femur in patients with high dislocation of the hip. To maintain this safely, a certain amount of femoral shortening and of rotational correction is frequently required before implanting the femoral component and reducing the hip [4]. Without the shortening procedure, it is almost impossible to reduce the femoral head into the true acetabulum virtually in all patients. In addition, the neurovascular structures are at risk due to excessive tension [2].

Proximal, subtrocanteric and distal osteotomy methods are defined for femoral shortening and rotational correction [1,3,9]. Subtrochanteric osteotomy methods include frequently used types such as transverse subtrochanteric osteotomy, step-cut osteotomy, subtrochanteric z-osteotomy, subtrochanteric oblique osteotomy, and v-shape (double Chevron) osteotomy, as well as some unique osteotomy methods as defined by Togrul et al [1,2,10,11]. There are no objective data or decision making algorithms concerning the selection of osteotomy method in the literature and authors seem to be selecting their preferred method depending on their clinical experiences [1,2,12,13]. While some complications such as malunion or nonunion may be seen, possibly due to the failure of the femoral stem or aseptic loosening, the literature on subtrochanteric shortening methods reports satisfactory results in more than 80% of cases [5,14].

In subtrochanteric shortening applications to reduce complications such as malunion and nonunion it is necessary to maintain a stable fixation at the osteotomy line. Various studies examining femoral osteotomy types [15], different situations related to total hip arthroplasty [16,17], pelvic osteotomies [18], and periprostatic fractures and their fixation methods [19,20] from a biomechanical perspective are available. However, to our knowledge there is no study examining arthroplasty procedures together with subtrochanteric shortening and rotational correction osteotomy from a biomechanical perspective. Information on this topic is limited with clinical study results and author interpretations.

We hypothesized that the stability of the osteotomy would be higher with the z-subtrochanteric osteotomy model especially in

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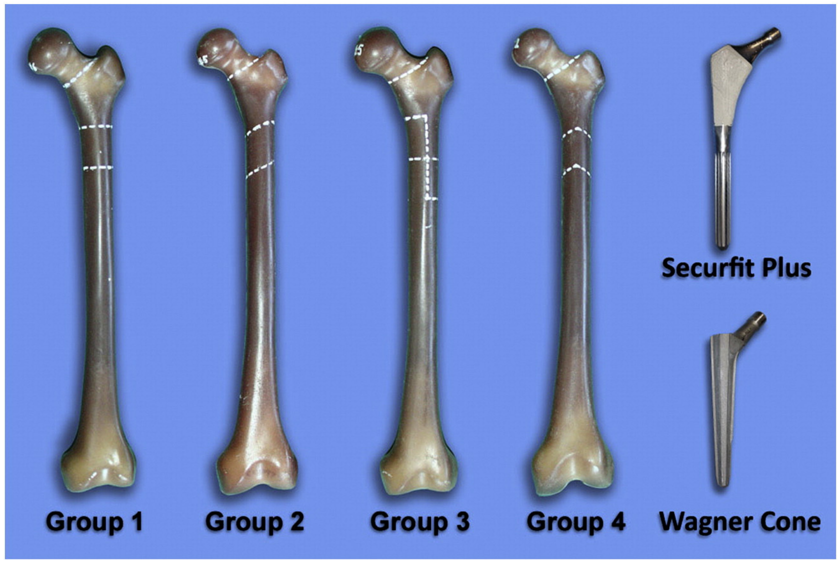

Fig. 1. Femoral implants (Type 1: Secur-Fit Plus and Type 2: Wagner-Cone) and four osteotomy types (Transverse (Group 1), Oblique (Group 2), Z-subtrochanteric (Group 3) and Double Chevron (Group 4).) All osteotomy lines were marked and osteotomies were made along these lines.

rotational tests followed by double chevron, oblique and transverse osteotomies respectively. We also hypothesized that proximal and distal locking type implant would have higher stiffness values and also strut graft and cable fixation would enhance the stability with higher stiffness values. The aim of this study is to investigate total hip arthroplasty together with subtrochanteric shortening osteotomy in surgical treatment of patients with high hip dislocation from a biomechanical point of view.

Materials and Methods

Four osteotomy types were chosen to investigate subtrochanteric osteotomies; namely transverse (Group 1), oblique (Group 2), z-subtrochanteric (Group 3) and double Chevron (Group 4). For osteotomy applications in each group, 7 fourth generation composite femurs (Sawbones, item no: 3403 medium–left) were used.

In each group a segmental resection to create 4 cm shortening was completed. All osteotomy lines were marked precisely by a white marker using a digital Vernier caliper and osteotomies were made along these lines (Fig. 1).

In transverse shortening osteotomy the proximal cut was applied at the distal edge of the trochanter minor and the distal osteotomy is completed by a parallel transverse cut 4 cm distal from the proximal cut. In oblique shortening osteotomy the proximal cut was started at the medial part and 1 cm from the distal edge of the trochanter minor, the oblique cut was at a 30° caudocranial angle from medial to the lateral. The distal oblique osteotomy was made by a parallel cut 4 cm distally. Z-subtrochanteric shortening osteotomy was applied as a half transverse cut from medial to the mid-point of the anterior and posterior cortexes, passing through the distal edge of the lesser trochanter. A full transverse cut 4 cm distal from the proximal cut was made and then a lateral half transverse cut was done 4 cm from the full transverse cut. Later these cuts were joined by a longitudinal cut along the center line in the sagittal plane to complete the z-subtrochanteric osteotomy. Double Chevron shortening osteotomies were completed as described by Becker and Gustilo [10]; the peak of the osteotomy was 3 cm distal from the trochanter minor with lateral and medial ends 1 cm distal from the peak point. Distal osteotomy was applied identically 4 cm distally.

To research the effects of various design types of prostheses, two different cementless femoral implant types were chosen. The first is a press-fit structured proximal and distal locking prosthesis (Type 1: Stryker Secur-Fit Plus Max, No: 9/13). The hydroxyapatite treated proximal design of the implant enhances the implant friction fit and augments the load transfer capabilities while enhancing proximal press-fit and increasing rotational and axial stability. The distal part has a cylindrical, bullet-tipped and slotted (tri-slot) design with flutes which improves distal locking especially in anomalous canal geometries (Fig. 1). This implant is used with distal reaming and proximal rasping and it shows well proximal and distal press-fit locking properties. The second is a straight–conic structured prosthesis (Type 2: Zimmer Wagner-Cone, No: 21/135°), especially appropriate for cementless applications with deformities in the proximal femoral region and considered to have more proximal locking features. The stem has a 5° taper with a circular cross-section. This implant is used with reaming of entire contact surface and has eight longitudinal ribs with relatively sharp ridges (Fig. 1). These ridges engage the femoral cortex and enhance the rotational stability and osteointegration. To prevent sliding between the 28 mm stainless steel femoral head and loading plate of the test device during axial loading tests, a cementless acetabular component (with polyethylene insert) secured inside a block was positioned in between (Fig. 2).

For strut graft applications, two 20 × 70 mm strut grafts were prepared from composite femur material. The grafts were contoured to the femur precisely for each sample using a power tool with an abrasive disc. In experiments with graft applications, two strut grafts, two steel 2.0 mm cables and two sleeves were used for each test sample. The cables were placed within 1 cm of the proximal and distal edges of the grafts. A double-sided tensioner was used to tighten the cables to the maximum available limit (150 lb) and the sleeves were crimped.

During load testing to fix the composite femur material in defined positions within the test area of the universal test device, a modular pedestal of aluminium alloy was produced. This pedestal was designed to fix the composite femur material from both intramedullary and extramedullary sides (Fig. 2). Axial loading was applied in single leg stance position (12° adduction and 8° flexion). Torsional loading was applied in horizontal position with the femoral neck parallel to the horizontal plane. And lateral bending was applied in horizontal position with femoral neck perpendicular (femoral head in upward orientation) to the horizontal plane. Axial load was 2500 N, torsional load was 200 N and lateral bending load was 250 N. To