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Effects of Reduction Osteotomy on Gap Balancing During Total Knee Arthroplasty for Severe Varus Deformity

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ABSTRACT

This study aimed to assess the effects of down-sizing and lateralizing of the tibial component (reduction osteotomy) on gap balancing in TKA, and the clinical feasibility of an uncemented modular trabecular metal tibial tray in this technique. Reduction osteotomy was performed for 39 knees of 36 patients with knee OA with a mean tibiofemoral angle of 21° varus. In 20 knees, appropriate gap balance was achieved by release of the deep medial collateral ligament alone. Flexion gap imbalance could be reduced by approximately 1.7° and 2.8° for 4-mm osteotomy and 8-mm osteotomy, respectively. Within the first postoperative year, clinically-stable tibial component subsidence was observed in 9 knees, but it was not progressive, and the clinical results were excellent at a mean follow-up of 3.3 years.

Severe varus deformity with a tibiofemoral angle of 20° or more as measured on full-length weight-bearing radiographs necessitates extensive release of the medial structures to gain neutral limb alignment during total knee arthroplasty (TKA). Based on Insall's technique [1], progressive releases of the medial structures are performed until medial and lateral envelopes are equally balanced. This technique, however, faces a risk of overrelease and subsequent instability, ultimately resulting in the use of a thicker polyethylene insert or even a constrained-type prosthesis. Reduction osteotomy is known as a soft tissue-sparing technique for soft tissue balancing, and it is capable of reducing the amount of release required to balance the knee and of preventing overrelease of medial structures. Dixon et al [2] and Mullaji et al [3,4] proposed the effectiveness of down-sizing the tibial component in the case of knees with severe varus deformity. However, concrete evidence is lacking regarding how much degree of reduction osteotomy is needed to increase gap length or improve gap imbalance during TKA.

Biological fixation at the medial tibial plateau might be a potential drawback of reduction osteotomy, since removal of the underhanged bony margin at the medial tibial plateau may decrease bone quality around the tibial component, leading to premature loosening or subsidence of the component. In that case, use of an uncemented tibial component may further increase the risk of failure of biological fixation at the medial tibial plateau. Recently, a trabecular metal (tantalum) tibial component (Zimmer, Warsaw, IN, USA) has been developed and been clinically proven successful for rapid and safe biological fixation [5–8]. In this study, the beneficial effects of down-sizing of the tibial component on joint gap balancing were assessed, and the clinical feasibility of an uncemented modular trabecular metal tibial tray in this technique was evaluated.

Materials and Methods

Between January 2011 and June 2012, a consecutive series of 39 knees of 36 patients, who presented with an anatomical tibiofemoral angle of ≥15° varus based on full leg length radiograph and underwent primary TKA using a reduction osteotomy technique, were enrolled. The anatomical tibiofemoral angle was defined as the angle formed by the shaft axes of the femur and the tibia. This study received institutional review board approval to enroll the patients, who all provided their written, informed consent. All TKAs were performed by the first author. The demographic characteristics of the 36 patients enrolled are shown in Table 1. The mean anatomical tibiofemoral angle was 21 ± 9.8° (range: 15°–37°). The primary diagnoses were osteoarthritis in 35 knees and rheumatoid arthritis in 4 knees. Excluded were cases of knees with valgus deformity, revision TKA, and varus deformity due to residual extra-articular deformity after femoral or tibial shaft fracture.

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Table 1
Demographic Characteristics of the Enrolled Subjects.

Number of cases	36
Number of knees	39
Age (range)	69.8 ± 14.5[a]
Gender (male/female)	9/27
Body mass index (kg/m^2) [range]	25.3 ± 3.1 [21.6–30.9]
Primary diagnosis (OA/RA)	32/4
tibiofemoral angle (°)	21 ± 9.8 [range: 15–37][b]
KSS knee score	47.5 ± 12.5
KSS function score	48.1 ± 13.4
Length of down-sizing (ML/AP) [knees]	
4 mm/0 mm (size-4+ to 4 or size-5 to 4+)	5
4 mm/4 mm (size-4+ to 3)	5
4 mm/5 mm (size-4 to 2)	15
8 mm/4 mm (size-5 to 3)	4
8 mm/5 mm (size-4+ to 2)	9
8 mm/6 mm (size-4 to 1)	1

OA, osteoarthritis; RA, rheumatoid arthritis; ML, medial–lateral; AP, anterior-posterior.
[a] The values are given as the mean and standard deviation.
[b] The positive value means varus alignment.

The exclusion criteria did not include other patient variables such as patients' age and bone quality.

Surgical Techniques and Gap Measurement

The surgical techniques of TKA have been reported in detail previously [9]. Three-dimensional planning software (ATHENA®; Soft Cube, Osaka, Japan) was preoperatively used to determine the distal cut angle, rotational alignment, the proper size of the femoral component, and the cutting level and proper size of the tibial component. A posterior-stabilized (PS) prosthesis (NexGen® LPS-FLEX; Zimmer) was used in all 39 knees, and minimally-invasive technique was used through a mini-midvastus approach [9]. The tibial component used in all patients was a modular trabecular metal tibial tray (NexGen® TM tibial tray; Zimmer), which allowed replacement of the correct size of polyethylene insert. Before bone cuts of the femur and tibia, the deep medial collateral ligament (MCL) was released, which was just sufficient for removing osteophytes at the medial and posteromedial regions of the tibial plateau. All bone cuts were performed on the basis of a measured resection technique using intramedullary rods and low-profile cutting jigs. In all 39 knees, the optimal size of the tibial component was decided to be one or two sizes smaller than the size preoperatively determined on the three-dimensional planning software (Table 1). The degree of reduction osteotomy (4 mm for one size down or 8 mm for two sizes down) was decided based on the pre-existing gap imbalance and the sclerotic bone area of the medial tibial plateau at the time of operation. Reduction osteotomy along the medial aspect of the tibial surface was performed using the medial margin of the laterally-shifted tibial component as a reference (Supplementary Fig. 1). Before and after reduction osteotomy, an offset-type tensor [10–12] was fixed to the proximal tibia and fitted to the trial femoral component. A joint distraction force of 40 lb was routinely applied on the off-set tensor with a specific torque driver for which the accuracy was within ±3%, based on previous studies [12,13]. The reproducibility of the gap measurement using 40 lb of distraction force is reportedly optimal as it minimizes error resulting from creep elongation of soft tissues [12]. The component gap length (joint center gap) and gap imbalance (i.e. varus angle) were measured with the knee in 0°, 45°, 90°, and 135° of flexion (Supplementary Fig. 2). Regarding test–retest reliability of the offset-type tensor, correlation coefficients (r) for reliability were 0.92 for gap length and 0.91 for varus angle. If medial–lateral gap asymmetry remained after 4-mm osteotomy, such patients did not necessarily undergo 8-mm osteotomy. A major premise in the concept of reduction osteotomy is that the medial edge of the tibial tray should be placed on the sclerotic bone of the medial tibial plateau. If the tibial component is placed on the cancellous bone, premature component subsidence may occur. Following the gap measurement, step-by-step medial structure release was sequentially performed until the varus angle was reduced to 2° in 90° of knee flexion. Normally, the value of the varus angle measured with the femoral trial in place and the patello-femoral joint reduced increases with knee flexion angle, peaks at 90° of knee flexion, and then decreases [13]. The priority sequence of the medial structure release was semimembranosus tendon insertion, pes anserinus, and superficial MCL.

Statistical Analysis

Statistical analyses were performed using SPSS version 17.0 software (SPSS, Chicago, IL, USA). Comparisons of varus angle and gap length between pre-reduction and post-reduction osteotomy were conducted at each flexion angle of the knee using the paired Student's *t*-test. Statistical power for the paired Student's *t*-test was determined under each sample size and each effect size calculated.

Results

The beneficial effects of reduction osteotomy were evident on the analysis of joint gap kinematics. The sample size ($n = 39$) in this study allowed for a power of >80% to determine a significant difference in varus angle and gap length between pre-reduction and post-reduction osteotomy. Regardless of the magnitude of the reduction osteotomy performed, the varus angle was significantly decreased in all knee flexion angles (Fig. 1). The degree of varus angle reduction at knee flexion of 0°, 45°, 90°, and 135° was 0.7 ± 0.6°, 1.1 ± 1.0°, 1.7 ± 1.7°, and 1.8 ± 1.5°, respectively, following 4-mm of reduction osteotomy. Likewise, following 8-mm osteotomy, the decrement at each knee flexion angle was 0.9 ± 0.8°, 2.0 ± 1.8°, 2.8 ± 2.9°, and 1.5 ± 1.3°, respectively. The decrement of the varus angle and the increment of the gap length were larger at knee flexion of 45°, 90°, and 135° than at knee extension (Figs. 1 and 2). At 90° of knee flexion when the varus angle peaked, the varus angle reduction was 1.7° and 2.8° for 4-mm osteotomy and 8-mm osteotomy, respectively. Component gap length reached the maximum at 90° of knee flexion, and the value increased significantly only at 90° of knee flexion after reduction osteotomy (Fig. 2). The effect on gap length increment was relatively small at knee extension.

Additional medial structure release was not needed after reduction osteotomy in 20 of 39 knees. However, the remaining 19 knees needed additional step-by-step medial structure release to balance the joint gap appropriately. The final amount of medial structure release is shown in Table 2.

At a mean follow-up of 3.3 years (range 2.5–3.9 years), the final anatomical tibiofemoral angle was 5.9 ± 2.4° valgus (range 1.5°–8° valgus), and the KSS knee score and function score were improved to 91.8 and 78.3 points, respectively (Table 3). Of the 39 knees, subsidence of the tibial component, which is perceived as a potential early complication of a trabecular metal component [14], was found at final follow-up in 9 cases (≤2 mm in 7 and >2 mm in 2). However, no cases displayed further progression of subsidence more than 1 year postoperatively (Fig. 3).

Discussion

This study clearly demonstrated that reduction osteotomy increased component gap length and decreased the varus angle, which may reduce the risk of overrelease, as well as the amount of medial structure release. Medial–lateral soft tissue imbalance can be improved approximately 2° for 4-mm osteotomy and 3° for 8-mm osteotomy with the knee in 90° of flexion. In the setting of reduction osteotomy, a one or two-size smaller tibial component was used and shifted laterally to allow the underhanged posteromedial bone to be resected. Although size variation and size pitch of the tibial component depend on the