Clinical and radiologic evaluation of medial epicondylar osteotomy for varus total knee arthroplasty

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Article info
Article history:
Received 27 February 2017
Received in revised form 9 October 2017
Accepted 2 November 2017

Keywords:
Arthroplasty
Knee
Medial epicondylar osteotomy
Medial release
Varus

Abstract

Background: In varus total knee arthroplasty (TKA), a pathologic contracture of the medial soft tissue should be released for ligament balancing. A medial epicondylar osteotomy has been performed as an alternative method for this. The purpose of this study was to demonstrate the clinical and radiologic results of medial epicondylar osteotomy for varus TKA, focusing on the union type of osteotomy site.

Methods: The study retrospectively evaluated 61 cases with a mean femorotibial angle of 10.4° varus and a mean flexion contracture angle of 8.5 ± 9.8°. Intraoperative medial and lateral gap difference in extension and 90° flexion was accepted at ≤ 2 mm. Clinical outcomes (Knee Society Scores, range of motion) and radiologic outcomes (coronal alignment and valgus stability) were compared between the two groups divided by the union type of osteotomy site (bony union or fibrous union).

Results: The clinical and radiologic outcomes were significantly improved at the latest follow-up. Bony union was achieved in 39 (63.9%) patients, whereas 22 patients showed fibrous union. There was no difference in the varus–valgus angle on the stress radiographs between the bony union and fibrous union group (1.6 ± 1.2° vs. 1.6 ± 0.8°, P < 0.916). The Knee Society Scores (knee, function), range of motion and radiographic alignment did not differ between the two groups.

Conclusion: Medial epicondylar osteotomy was a good option for gap balancing during TKA, as it provided satisfactory clinical and radiological results, regardless of union type of the osteotomy site.

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1. Introduction

The common goals of total knee arthroplasty (TKA) are to achieve the desired alignment in a relative and consistent way and to obtain functional stability with gap symmetry throughout the range of motion. Appropriate ligament balancing is necessary for the success of TKA and a crucial factor in preventing deleterious long-term effects, including instability, increased polyethylene wear, aseptic loosening, pain, and dysfunction [1–4].

In varus TKA, a pathologic contracture of the medial soft tissue should be released for ligament balancing. Every surgeon has his/her own surgical technique for performing a sequential medial release [5–10]. The superficial medial collateral ligament (MCL) is the structure of maximal and final correction during a medial release [8,11,12]. There are three components of the superficial
MCL for a medial release: femoral origin, midsubstance, and tibial insertion. Most surgeons perform a periosteal release of the superficial MCL on the tibial insertion; [13] however, an overzealous release of superficial MCL can cause detachment of the superficial MCL, which may lead to TKA instability such as medial joint opening and medial condylar lift-off [8,12,14]. Several surgeons have suggested superficial MCL release on the midsubstance by pie-crusting or multiple needle puncturing [5,6,15]. It can be debilitating if over-release or unpredictable tears of superficial MCL occur [16,17].

Engh introduced superficial MCL release with bone on the femoral origin and called it medial epicondylar osteotomy [18]. It can enable easy management of a knee with severe combined varus and flexion contracture deformity [11]. In spite of the theoretical advantage of medial epicondylar osteotomy, which can prevent unintended medial laxity during gap balancing, its clinical and radiological outcomes have not been thoroughly reported [11,19]. Furthermore, there is concern over nonunion or fibrous union of the bony wafer, which might affect TKA stability [11,20].

The purpose of the current study was to demonstrate the clinical and radiologic results of medial epicondylar osteotomy for varus TKA, focusing on the union type of osteotomy site. The hypotheses were as follows: (1) Medial epicondylar osteotomy for varus TKA would provide satisfactory clinical and radiologic outcomes, as well as stability after TKA over time; (2) The union type of bony wafer would not affect the clinical and radiologic results, including stability.

2. Material and methods

2.1. Study design

From November 2004 to December 2012, 63 cases (of 909 cases of primary TKA, 6.9%) in 54 patients with primary TKA using medial epicondylar osteotomy and a minimum follow-up of two years were enrolled. Of the 63 cases, two were excluded due to lack of follow-up. Therefore, this study retrospectively reviewed 61 cases: 48 women (55 knees) and six men (six knees). The mean age was 72.4 years (range 53–87) and the mean BMI was 25.7 ± 4.2 kg/m² (range 15.8–36.8). The diagnoses were osteoarthritis in 54 cases, rheumatoid arthritis in two cases, osteonecrosis in two cases, traumatic arthritis in two cases, and Charcot arthropathy in one case. Posterior-stabilized fixed bearing TKAs were used in 48 cases (17 Advantim, 13 Vanguard, eight NexGen, eight PFC Sigma, and two Maxim) and mobile bearing TKAs in 13 cases (13 PFC Sigma RP-F). The mean follow-up period was 50.6 ± 29.8 months (range 24–116). This study was approved by the Institutional Review Board.

2.2. Surgical procedure and postoperative management

All TKAs were performed by two surgeons (BKJ, JAS) through the medial parapatellar approach and with the modified gap balancing technique [21]. The patient’s legs were manually pulled into neutral rotation to assess extent of varus and predict the extent of medial release [22]. After removal of osteophytes, menisci, and cruciate ligaments, the distal femur was cut perpendicular to the mechanical axis by preplanning, and the proximal tibia perpendicular to the anatomical axis. The intramedullary guide was used for the distal femur cut and the extramedullary guide was used for the proximal tibia cut in a standard fashion. The medial and lateral gaps were then measured in extension using two laminar spreaders. When the balanced gap in extension was tight, sequential medial release was performed as follows: (Step 1) release of the deep MCL; (Step 2) release of the posterior oblique ligament and/or semimembranous tendon; (Step 3) release of the posterior capsule; (Step 4) limited release of the superficial MCL ± medial epicondylar osteotomy [22]. This limited superficial MCL release procedure typically involves only proximal tibial attachment of the superficial MCL, which has been described by LaPrade et al., and the distal attachment is left mostly intact [23].

When the balanced extension gap was not achieved after limited superficial MCL release in the current study, a medial epicondylar osteotomy was performed as an additional component of step 4 of the medial release (Figure 1) [11]. Intraoperative medial and lateral gap differences in extension and 90° flexion were accepted at <2 mm. After medial epicondylar osteotomy was performed, the extension gap was measured again both laterally and medially using two calipers. On the medial side, a laminar

Figure 1. Medial epicondylar osteotomy with osteotome (A), and reattachment with non-absorbable sutures after component implantation (B).
spreader was tensioned until a rectangular extension gap was achieved. The bony wafer then typically moved distally to compensate the tight initial medial gap. In this position, the bony wafer was provisionally fixed using one or two #5 Ethibond (Ethicon, Somerville, New Jersey) non-absorbable sutures. Once gap symmetry in extension was obtained, two laminar spreaders were used with equal tension to measure the flexion gap in the 90° flexion position. To create a rectangular flexion gap, a line was drawn parallel to the resected proximal tibia, as the previously measured extension gap. Posterior condylar resection was performed primarily based on this parallel line, but the trans-epicondylar and posterior condylar axes were also checked to avoid extreme femoral external rotation or internal rotation in reference to the anatomical landmarks. The extension and flexion gaps were then measured using calipers in extension and 90° flexion.

After the gap balance was confirmed as acceptable, the bony wafer was secured to the medial femoral condyle with non-absorbable sutures (54 cases) or a 6.5-mm cancellous screw and washer (seven cases) in 90° flexion (Figure 1). One or two sutures were made into the anterodistal portion of the bony wafer, considering the vectors which tend to make the posterior and proximal displacement of the wafer. When using screw fixation, a 6.5-mm cancellous screw was fixated in the center of the wafer with the washer. After drilling the screw hole, the appropriate screw length was chosen using the depth gauge; the length was <30 mm in all cases. The screws did not interfere with the implanted posterior stabilized box in any cases. The fixation method was chosen as the suture technique in earlier consecutive series, while the screw technique has been used in recent cases. All the implants were fixed using cement after an acceptable gap balance was achieved. Postoperatively, range of motion exercises without a brace, and ambulation without crutches were permitted.

Figure 2. Femorotibial angle (dotted line) and mechanical axis (solid line) using a whole lower extremity radiograph: pre-operatively (A) and at the latest follow-up (B).
2.3. Outcome measurement

Clinical and radiologic assessments were performed pre-operatively and at the latest follow-up. The clinical outcomes were evaluated using the Knee Society Scoring (KSS) system [24]. Active range of motion (ROM) was measured using a goniometer. Radiologic evaluations included the femorotibial angle and the mechanical axis using a whole lower extremity radiograph (Figure 2) [25]. Stability, including valgus angle, varus angle, and difference of varus–valgus angle, was measured on valgus and varus stress radiographs using Telos® (Telos, Weterstadt, Germany) in 20–30° flexion (Figure 3) [26]. At the latest follow-up, union was assessed by simple radiographs, including whole lower extremity radiograph, stress radiographs, and other radiographs (Figure 4). Bony union (Group 1) was defined as a bridging callus, and fibrous union; (Group 2) was defined as no or incomplete bridging callus of the osteotomy site. Group 1 and Group 2 were compared according to clinical outcomes, radiologic evaluations, and stability. The union type of the bony wafer was separately evaluated by two authors, and inter-observer agreement was 93% (57 of 61 cases). After a consensus meeting between two authors, final group designation was determined for comparison.

2.4. Statistical analysis

IBM SPSS Statistics version 19 (IBM Co., Armonk, NY, USA) was used for analysis of data. Wilcoxon signed ranks test ($P^1$) was used for comparison of clinical and radiologic results between pre-operative and the latest follow-up data. Mann–Whitney U test was performed for assessment of differences between Group 1 and Group 2 data ($P^2$). A $P$-value $<0.05$ was considered statistically significant.

3. Results

The patients who underwent TKA using medial epicondylar osteotomy showed good clinical and radiologic outcomes. In the clinical outcomes, the mean KSS knee score improved from $35.5 \pm 17.1$ points (range, 10–74) pre-operatively to $89.1 \pm 8.4$ points.
The mean KSS function score improved from 48.7 ± 16.0 points (range, 25–75) pre-operatively to 88.6 ± 8.0 points (range, 70–100) at the latest follow-up ($P_1 = 0.043$). In active ROM, the mean flexion contracture advanced from 8.5 ± 9.8° (range, 0–30) pre-operatively to 1.0 ± 2.3° (range, 0–10) at the latest follow-up ($P_1 < 0.001$), and mean further flexion was altered from 112.0 ± 21.8° (range, 30–140) pre-operatively to 118.9 ± 13.3° (range, 90–140) at the latest follow-up ($P_1 = 0.0264$). In the radiologic evaluations, the mean femorotibial angle was corrected from varus 10.4 ± 5.7° (range, 2.4–27.3) pre-operatively to valgus 5.5 ± 3.4° (range, 0.7–12.6) at the latest follow-up ($P_1 < 0.001$), and the mean mechanical axis was corrected from varus 16.7 ± 5.6° (range, 9.5–32.4) pre-operatively to varus 1.0 ± 4.1° (range, varus 7.9°–valgus 5.9°) at the latest follow-up ($P_1 < 0.001$). For stability, the mean valgus angle was 2.6 ± 1.0° (range, 1.0–4.3), and the mean varus angle was 3.8 ± 1.6° (range, 1.0–6.1) at the latest follow-up. The mean difference of varus–valgus angle on the stress radiographs was 1.6 ± 1.0° (range, 0–3.5).

According to the union type of the osteotomy site, there were 39 bony unions and 22 fibrous unions (Table 1). All bony unions were achieved by reattachment with cancellous screws and washers; however, 22 of 54 (40.7%) fibrous unions were observed in those with non-absorbable sutures. The clinical outcomes and radiologic results, except further flexion, were significantly improved in both groups at the latest follow-up. However, no significant difference was observed between the two groups. The mean difference of varus–valgus angle on the stress radiographs was 1.6 ± 1.2° (range 0–3.5) in Group 1 and 1.6 ± 0.8° (range, 0.4–2.5) in Group 2 ($P_2 = 0.916$). No irritation, tenderness, stiffness, instability, or loosening was observed in either group during follow-up.

Table 1

<table>
<thead>
<tr>
<th></th>
<th>Group 1 (bony union)</th>
<th>Group 2 (fibrous union)</th>
<th>$P_2$</th>
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<tbody>
<tr>
<td>Number of cases</td>
<td>39</td>
<td>22</td>
<td>0.952</td>
</tr>
<tr>
<td>Age</td>
<td>72.5 ± 8.9 years</td>
<td>72.3 ± 10.4 years</td>
<td>0.629</td>
</tr>
<tr>
<td>Sex (male:female)</td>
<td>4:35</td>
<td>2:20</td>
<td>0.095</td>
</tr>
<tr>
<td>BMI</td>
<td>25.2 ± 4.3 kg/m²</td>
<td>26.7 ± 3.8 kg/m²</td>
<td>0.053</td>
</tr>
<tr>
<td>Implant (fixed:mobile)</td>
<td>31:8</td>
<td>17:5</td>
<td>0.542</td>
</tr>
<tr>
<td>KSS knee score (pre-op/latest FU)</td>
<td>36.5 ± 15.9/90.1 ± 6.6 ($P_1 = 0.018$)</td>
<td>34.3 ± 19.1/87.0 ± 12.0 ($P_1 = 0.011$)</td>
<td>0.217/0.223$^*$</td>
</tr>
<tr>
<td>KSS function score (pre-op/latest FU)</td>
<td>48.6 ± 18.7/88.8 ± 8.2 ($P_1 = 0.018$)</td>
<td>48.8 ± 11.7/88.0 ± 8.4 ($P_1 = 0.010$)</td>
<td>0.919/0.780$^*$</td>
</tr>
<tr>
<td>Flexion contracture (pre-op/latest FU)</td>
<td>9.0 ± 9.2/0.9 ± 1.9° ($P_1 &lt; 0.001$)</td>
<td>7.5 ± 11.0/1.3 ± 2.8° ($P_1 = 0.011$)</td>
<td>0.196/0.275$^*$</td>
</tr>
<tr>
<td>Further flexion (pre-op/latest FU)</td>
<td>113.5 ± 20.0/117.2 ± 13.7° ($P_1 = 0.646$)</td>
<td>109.4 ± 25.8/121.1 ± 13.0° ($P_1 = 0.283$)</td>
<td>0.461/0.345$^*$</td>
</tr>
<tr>
<td>Femorotibial angle (pre-op/latest FU)</td>
<td>Varus 8.3 ± 5.5°/valgus 5.0 ± 3.3° ($P_1 &lt; 0.001$)</td>
<td>Varus 11.2 ± 7.3°/valgus 6.3 ± 3.5° ($P_1 &lt; 0.001$)</td>
<td>0.140/0.182$^*$</td>
</tr>
<tr>
<td>Mechanical axis (pre-op/latest FU)</td>
<td>Varus 14.7 ± 5.6°/varus 1.2 ± 4.4° ($P_1 &lt; 0.001$)</td>
<td>Varus 18.0 ± 6.8°/varus 0.6 ± 3.4° ($P_1 &lt; 0.001$)</td>
<td>0.053/0.288$^*$</td>
</tr>
<tr>
<td>Difference of varus–valgus angle (latest FU)</td>
<td>1.6 ± 1.2°</td>
<td>1.6 ± 0.8°</td>
<td>0.916</td>
</tr>
</tbody>
</table>

$P_1$, $P$-value between pre-operative and latest follow-up data.

$P_2$, $P$-value between Group 1 and 2 data.

BMI, body mass index; Pre-op, pre-operative; FU, follow-up.

$^*$ $P$-values of pre-operative/postoperative data comparison between the Group 1 and 2.

$^*$ Data are given as mean ± standard deviation.
4. Discussion

One goal of TKA is to obtain symmetric and balanced flexion and extension gaps. This study evaluated the usefulness of medial epicondylar osteotomy as an alternative technique for ligament balancing for varus TKA. The results of this study support the hypothesis that medial epicondylar osteotomy provides satisfactory clinical and radiologic outcomes, including stability for varus TKA. In addition, the union type of bony wafer did not affect the clinical and radiologic results.

Varus deformity of the knee is very common in Asians. Therefore, a meticulous and sequential medial release is essential for achieving proper gap balancing [5–10]. Through sequential medial release, as described above, appropriate gap balancing with ≤2-mm gap difference was achieved by the following steps: deep MCL release; posterior oblique ligament and/or semimembranous tendon release; posterior capsule release; and limited superficial MCL release ± medial epicondylar osteotomy [22]. During medial release for varus TKA, release of the superficial MCL provides the greatest effect in changing the medial gap among the structures of medial soft tissue [8,12,27]. For that, care in performing superficial MCL release should be taken to prevent severe instability.

There are three methods for superficial MCL release. One is release of the superficial MCL on the tibial insertion, as described by Insall [13]. This method is simple, popular, and familiar to orthopedic surgeons working with varus TKA. However, it has the potential for overzealous release or detachment of the superficial MCL, resulting in occurrence of a Grade 3 superficial MCL tear [8,11,12]. Conservative treatment of Grade 1 or 2 superficial MCL tears has been found to result in successful healing, although some residual medial laxity is common; such treatment of a Grade 3 superficial MCL tear has shown much worse outcomes [28]. Iatrogenic superficial MCL injury in TKA can be different from a superficial MCL tear of a normal knee. Several surgeons have reported that detachment of the superficial MCL on the tibial insertion does not affect the clinical outcomes of TKA and has no instability [7,29,30]. However, a previous study reported that medial instability could not be completely removed by detachment of the superficial MCL on the tibial insertion [31]. To date, it is not precisely known how medial laxity can affect the long-term results of TKA. No matter how it can affect the clinical outcomes of TKA, it is believed that overzealous release or detachment of the superficial MCL should be avoided.

Another method is release of the superficial MCL on the midsubstance [5,6,15]. Multiple needle puncturing and pie-crusting technique are effective, safe, and minimally invasive techniques for gradual correction [5,6,15]. These techniques can provide a medial release of ≤6–8 mm [15]; however, they can cause Grade 1 or Grade 2 superficial MCL tears. When Grade 3 superficial MCL tears occur, management of this serious problem is both critical and difficult [16,17]. Bellemans reported that a thicker insert was required in one case and more constrained implants were required in two cases to manage over release of the superficial MCL [16]. In particular, Lee and Lotke emphasized that unconstrained posterior cruciate-substituting TKA had higher failure rates than a constrained prosthesis in the iatrogenic super

MCL [16]. In this study, several knees with relatively mild varus deformity required medial epicondylar osteotomy for ligament balancing. This may be explained by a severe flexion contracture with mild varus deformity or a severe pathological contracture of the medial soft tissue owing to sedentary lifestyles such as sitting on the floor in Asians.

In a recent cadaveric biomechanical study, Mihalko et al. reported that medial epicondylar osteotomy laxity increased at 60° and 90° flexion compared with that of standard MCL release [38]. They insisted that medial epicondylar osteotomy caused flexion instability, and suture repair could not stabilize the osteotomy, so a more constrained prosthesis might be required [38]. However, this study had several limitations. (1) They might have committed generalization fallacy. They asserted that the standard medial release was biomechanically better than the medial epicondylar osteotomy and their clinical series found satisfactory exposure and corrected ligament balancing in all cases through standard MCL release. In the current study, the rate of performing medial epicondylar osteotomy was 6.9% (63 of 909 cases). A previous study reported that the rate of medial epicondylar osteotomy was 3.8% (11 of 290 cases) [31]. This indicates that the application of this technique is limited for several varus TKAs. Even if standard MCL release is performed, occurrences of 3.5% (six of 173 cases) for superficial MCL detachment or 15 cases with superficial MCL detachment over 8.5 years have been reported [5,9]. Therefore, comparison of the medial epicondylar osteotomy and standard MCL release without detachment might be unreasonable. (2) This was a time zero study and a biomechanical study does not reflect all clinical situations. This study was not reflective of the adductor tension to stabilize the bony wafer. The most important criticism of this study is that the comparison between healed medial epicondylar osteotomy and well-balanced MCL release without detachment was unfair. If healing of the bony wafer occurred, bony healing would have been faster and better than soft tissue healing. (3) They used normal human cadaver knees, posterior cruciate-retaining implants, and #2 Dexon. Normal human cadaver knees have a mild deformity so they do not require extensive medial release and can use posterior cruciate-retaining implants. However, knees requiring medial epicondylar osteotomy have
severe combined varus and flexion contracture deformities or severe pathological contractures of the medial soft tissue. Those knees require extensive medial release with limited use of posterior cruciate-retaining implants. In that study, they sutured the bony wafer using #2 Dexon, and it is believed that #2 Dexon is an absorbable suture that is biomechanically weaker than non-absorbable sutures.

The current series showed 63.9% bony union of the osteotomy site, which is higher than those of the Engh and Ammeen's study (54%) [11]. The current study found that all cases fixed with cancellous screws and washers showed bony union, while substantial fibrous union occurred in cases with sutures. The fixation method was one of the important differences between previous studies and the current study, suggesting that more secure fixation leads to bony union of the bony wafer. Therefore, recently, cancellous screws and washers have been used for fixation of the bony wafer because a more secure fixation device might offer a better chance of achieving solid bony union. However, occurrence of fibrous unions has not caused problems such as instability, pain, and tenderness. Similar to the current study, Orban et al. reported good clinical results with medial epicondylar osteotomy and reattachment of the bony wafer, although all the cases showed fibrous union [20]. These findings suggest that concern over nonunion or fibrous union may not be a serious problem from a clinical point of view, although bone union needs to be enhanced after medial epicondylar osteotomy.

The current study had several limitations. First, it did not include a control group, and a small number of enrolled cases can limit the power value of a study. However, cases requiring medial epicondylar osteotomy were rare, with 63 of 909 cases (6.9%) over eight years. Second, it used limited superficial MCL release before determining the necessity of medial epicondylar osteotomy. Engh et al. proposed medial epicondylar osteotomy to avoid complete release of superficial MCL, and the superficial MCL was kept intact [11]. Although the current study used limited superficial MCL release, the technique typically involved only proximal tibial detachment of the superficial MCL, while the distal, main bony attachment was mostly intact, which was described by LaPrade et al. [23]. Complete superficial MCL release means detachment of both the proximal and distal attachments. Therefore, it is believed that the medial epicondylar osteotomy technique is not fundamentally different from those of previous reports. Third, stress radiographs in 20–30° flexion were only obtained. Mihalko et al. pointed out the instability of medial epicondylar osteotomy at 60° and 90° flexion compared with standard MCL release [38]. However, the current study did not observe, by physical examination, instability at 90° flexion in all cases with medial epicondylar osteotomy, but there was no way of objectively evaluating instability at 90° flexion postoperatively. Further, laxity at 30° of knee flexion mainly represents the status of the collateral ligaments [34]. Fourth, the follow-up period might have been too short to present any complications due to instability. Longer-term follow-up is recommended for further investigations.

5. Conclusions
In conclusion, medial epicondylar osteotomy provided satisfactory clinical and radiological results without instability for varus TKA at a mean follow-up of 4.2 years. In addition, the clinical and radiologic results, including stability, were similar, regardless of the type of union. Medial epicondylar osteotomy is considered to be a useful alternative technique for ligament balancing.

Conflict of interest
None of the other authors (JAS, YGN, JYK, BKL) have relevant conflicts of interest to declare.

Acknowledgments
This research did not receive any specific grant from funding agencies in the public, commercial, or not-for-profit sectors. This study was performed at Gachon University Gil Medical Center.

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