Limb Alignment After Open-wedge High Tibial Osteotomy and Its Effect on the Clinical Outcome

HOSAM M. EL-AZAB, MD; MARIO MORGENSTERN, MD; PHILIP AHRENS, MD; TIBOR SCHUSTER, MSC; ANDREAS B. IMHOFF, MD; STEPHAN G.F. LORENZ, MD

The purpose of this study was to evaluate the accuracy of alignment after open-wedge high tibial osteotomy and its effect on the clinical outcome. A prospective case series of 56 consecutive patients underwent open-wedge high tibial osteotomy fixed with a TomoFix plate fixator (Synthes, West Chester, Pennsylvania). The correction angle was radiologically determined preoperatively and at 6 months postoperatively. The patients were clinically and radiologically examined preoperatively and at 3, 6, and 36 months postoperatively. The mechanical axis of 50 knees was corrected from an average of 5.7° varus to 1.3° valgus. Forty-three patients had an acceptable correction with Mikulicz line crossing the tibial plateau between 50% to 70% of the tibial plateau width measured from the medial border. Undercorrection (<50%, group II) and overcorrection (>70%, group III) were found in 4 and 3 patients, respectively. The mean Lysholm-Gillquist score at 36 months had improved in all groups, with a statistically lower value for group II.

Open-wedge high tibial osteotomy results in significant improvement of symptoms and function in all patients in the short term, even with under- and overcorrection of the osteotomy. Undercorrection was associated with a significantly lower clinical outcome in comparison to the accurate correction and overcorrection. Ligamentous laxity or soft tissue slackness of the knee can influence the overall correction after high tibial osteotomy and must be considered in preoperative planning. Patients with a high body mass index had inferior clinical results after open-wedge high tibial osteotomy.
HIGH Tibial Osteotomy is a reasonable treatment modality for unicompartmental medial osteoarthritis with varus deformity in young, active patients.\(^1,3\) It is a realignment procedure to transfer a weight-bearing load from an affected medial compartment to a relatively intact lateral compartment of the knee. It promotes symptom relief and potential healing of damaged cartilage,\(^2\) and it slows the progression of arthrosis in a knee with varus alignment.\(^3,6\)

Over- and undercorrection has been found by some authors to be associated with a poor clinical outcome.\(^6,8\) Therefore, it is important to achieve and maintain accurate correction of limb alignment until complete healing. Loss of correction after adequate preoperative planning may occur intra- or postoperatively; lack of fixation and instability are the main causes.\(^8-10\)

Postoperative optimal alignment following valgus-producing high tibial osteotomy is controversial. Optimal correction was defined to be 8° of anatomic valgus,\(^11\) between 3° and 6° of mechanical valgus,\(^3\) when the weight-bearing line passed through a point between 62% and 66%\(^12\) or 62.5%\(^6,13\) of the tibial plateau width.

With the introduction of the plate fixator for high tibial osteotomy in 2003,\(^14\) the open-wedge technique became more popular due to higher stability of the osteosynthesis and lower morbidity.\(^15,16\) Most previous studies describing the accuracy of correction used a closed-wedge technique,\(^15,17\) but few studies described this issue with the use of the open-wedge technique.\(^18,20\) To our knowledge, no study has described the accuracy of axis correction and its relation to clinical outcome using the TomoFix plate fixator (Synthes, West Chester, Pennsylvania). Therefore, the purpose of this study was to evaluate the accuracy of correction after open-wedge high tibial osteotomy using the TomoFix plate and the correlation between the correction in the frontal plane and the clinical outcome.

MATERIAL AND METHODS

From September 2006 to April 2007, a consecutive series of 56 patients with varus osteoarthritis underwent an open-wedge high tibial osteotomy fixed with a TomoFix plate. Four patients (7.1%) were lost to follow-up. Two patients (3.6%) were excluded. One patient suffered a fall on ice, resulting in breakage of the plate and displacement of the osteotomy 3 months postoperatively. A revision operation was performed successfully. The second patient reported pain in the whole body, gastrointestinal pain, swelling in multiple areas of the body, and sleep problems 6 months postoperatively. The diagnosis of fibromyalgia was made, which required intensive rheumatologic treatment, biasing the clinical outcome. The average follow-up period was 36±6.2 months (range, 30-46 months). Forty (80%) men and 10 (20%) women had an average age of 43 years (range, 24-58 years). Twenty-three (46%) right knees and 27 (54%) left knees were treated.

Patients younger than 60 years suffering from symptomatic medial unicompartmental varus osteoarthritis or medial local cartilage damage were included in this study. Exclusion criteria include severe osteoarthritis of the knee (Kellgren-Lawrence grade \(>\text{III})\),\(^21\) periarticular knee fractures, cruciate ligament insufficiency, patellofemoral complaints, and previous operations on the knee with arthrotomy. In addition to these selection criteria, the preosteotomy arthroscopy was considered, and meticulous intraoperative evaluation of the knee was also performed before osteotomy.

As a prospective study, all patients were examined preoperatively with medical history, visual analog scale (VAS), Lysholm-Gillquist score,\(^22\) and clinical examination of the knee. Preoperative radiologic examination included knee radiographs in 3 standard views and long-leg standing radiographs (Figure 1). Postoperatively, patients were followed up clinically at 3 (follow-up 1), 6 (follow-up 2), and an average of 36 (follow-up 3) months (range, 30-46 months). A long-leg standing radiograph was performed once again at follow-up 2 (Figure 1). Hardware was removed at an average of 13 months (range, 11-18 months postoperatively. For that reason, the patients were not evaluated at 12 months since the effect of metal removal may have an impact on the clinical results.\(^23\)

The planned correction was achieved when the weight-bearing line passed through a target point located at 62% of the tibial plateau width measured from the medial border of the tibial plateau.\(^6,12,13\) The suggested zone of an acceptable correction
was defined when the weight-bearing line passed between points at 70% and 50% of the tibial plateau width (group I).23

An undercorrection was defined when the weight-bearing line passed through a point medial to 50% of the tibial plateau width (group II), whereas an overcorrection was defined when the weight-bearing line passed through a point lateral to 70% of the tibial plateau width (group III). Furthermore, patients in group I were considered to also be in a best desired correction group (group BC) when the weight-bearing line passed through 62% of the tibial plateau width. In addition, the pure bony correction was evaluated separately on long-standing limb radiographs by subtraction of 2 measurements of the proximal medial tibial angle pre- and postoperatively (Figure 2). Body mass index (BMI) was measured and correlated with the frontal plane correction and Lysholm score.

Preoperative planning was performed for every patient according to the method of Miniaci et al on the long-leg standing radiographs (Figure 2).

Line I represents the old weight-bearing line of the limb extending from the center of the hip through the knee to the center of the ankle joint. Line Ia is the new mechanical axis of the limb, extending from the center of the hip passing through the Fujisawa point (62% of tibial plateau width) in the knee to the level of the ankle joint. Line II connects the osteotomy hinge point H with the center of the ankle joint. With the osteotomy hinge point H as the center, an angular arc is drawn from the center of the ankle to intersect line Ia. Line III connects the osteotomy hinge point H with the arc intersection of line Ia. The angle formed between line II and III is the correction wedge angle (α angle).

SURGICAL TECHNIQUE

A diagnostic arthroscopy of the knee joint was performed before surgical correction to verify the preoperative clinical and radiological findings. However, in no case was an osteotomy aborted due to the appearance of severe osteoarthritic changes on arthroscopy. Concomitantly, partial meniscectomy was performed in 26 patients (52%), microfracture in 3 patients (6%), and shaving and debridement in 4 patients (8%).

The procedure was performed with a medial intraligamentous open-wedge high tibial osteotomy in a biplanar fashion according to the technique published by the AO knee expert group (Figure 3).15,24,25 The new axis was set to the 62% valgus position, which was predetermined through the preoperative planning and confirmed intraoperatively under image intensifier. Control of the alignment was performed through visual inspection together with a cable extended over the whole limb from the center of the femoral head to the center of the ankle under fluoroscopic control. The osteotomy was fixed with a TomoFix plate, and the gap of the osteotomy was not filled with any graft material (Figure 4).

Postoperative Rehabilitation

Patients were mobilized on the first postoperative day. Partial weight bearing of 15 to 20 kg was allowed for 6 weeks. After radiological evaluation, the patients were mobilized.

Figure 2: Schematic drawing showing the planning for high tibial osteotomy according to Miniaci et al. Line II connects the osteotomy hinge point H with the center of the ankle joint. Line III connects the hinge point H with the arc intersection with line Ia. The angle of correction (angle α) is formed between line II and III. The proximal mechanical tibial angle (PMTA) is measured preoperatively and at 6 months postoperatively from the standing long-leg radiographs.

Figure 3: Operative technique of open-wedge high tibial osteotomy. Successive osteotomes are introduced in the wedge gap (A). Maintenance of the wedge gap using the arthrodesis clamp (B). Measurement of wedge height using a wedge-shape instrument in the presence of arthrodesis clamp (C).
allowed to increase the weight-bearing load gradually by 15 to 20 kg every week to full weight bearing. During the early postoperative period, all patients received physiotherapy in the form of mobilization, continuous passive motion, and isometric exercises. The TomoFix plate fixator is a relatively large device that sometimes causes irritation over the stretched skin, which annoys many patients. Hardware removal was routinely performed approximately 12 months postoperatively (Figure 4).

Statistical Analysis

Statistical analyses were performed using the SPSS software package (version 17; SPSS Inc. Chicago, Illinois). Two-way analysis of covariance (ANCOVA) was conducted to assess differences in groups about the course of follow-up. Simple comparisons of means from 2 related measurements were performed by Student t test. Bivariate correlations of quantitative data were assessed using Spearman’s correlation coefficient (r). Descriptive results were displayed as a mean±standard deviation. All statistical tests were conducted 2-sided, and P<.05 was considered statistically significant.

RESULTS

Forty-three patients (86%) showed an acceptable correction according to our definition (group I). Undercorrection (group II) and overcorrection (group III) was found in 4 (8%) and 3 patients (6%), respectively (Tables 1, 2). The best defined correction was found in 29 patients (58%). Analysis of the pre- and postoperative axial alignment revealed an average lateral shift of the weight-bearing line of 34.2±12 mm (range, 12-61 mm).

After adjustment of the differences in baseline Lysholm score, there was a significant heterogeneity in Lysholm score level in different follow-up appointments between the groups (P=.017). The corresponding group differences in mean Lysholm score were: I vs II, 12.6±4.1 (P=.004); I vs III, 3.7±4.9 (P=.45); and II vs III, 8.9±6.0 (P=.15). Furthermore, there was a significant increase in Lysholm score within the groups (P<.05 for each trend test in each group), with statistically significant changes in the mean Lysholm score trend over time (Figure 5).

The mean postoperative Lysholm score for the total population at follow-up 3 was 85±14 points (range, 61-100) and classified as excellent, good, fair, and poor in 22 (44%), 17 (34%), 7 (14%), and 4 patients (8%), respectively. A test of Lysholm score trends over time revealed a significant improvement in the total study population (P<.01) (Figure 6). Furthermore, the number of patients with excellent and good Lysholm scores (80-100 points) increased from 22 (44%) at follow-up 1 to 34 (68%) at follow-up 2 and 39 (78%) at follow-up 3.

According to Lysholm score, the best clinical results (excellent and good) were found at follow-up 3 in groups I and BC (Table 3). At follow-up 3, forty-four patients (88%) reported a reduction of symptoms and functional improvement during activities of daily living. Twenty patients (40%) were very satisfied with the results, 22 (44%) were satisfied, 5 (10%) were partially satisfied, and 3 (6%) were not satisfied. Thirty-eight patients (76%) required no pain medication to perform sports and recreational activities, 10 (20%) required occasional pain medication, and 2 (4%) required regular pain medication. The VAS decreased significantly from 6.9±3.4 (range, 0-10) preoperatively to 2.3±3.5 (range, 0-10) at follow-up 3 (P<.01).

Mean α angle was 7.5°, closely similar to the mean bony correction of 7.1° (mean systematic deviation=0.38±0.1; P=.008) (Table 1).

Average BMI of all patients was 24.9±3.6 (range, 19-32). There was no significant correlation between BMI and the frontal plane axis correction (r=.111; P=.375), but there was an inverse mild correlation between BMI and Lysholm score at final follow-up, which was statistically significant (r=−.491; P=.003).

Apart from the abovementioned over- and undercorrection complications, 3 patients had relatively delayed healing of the osteotomy with consequent delayed plate removal (between 15-18 months postoperatively). These 3 patients belong to group I. However, no significant differences in the measured outcome of these patients were found when compared with the remaining patient cohort. One patient who was excluded from our series had a metal failure and secondary displacement of the osteotomy following knee trauma and was successfully revised.
DISCUSSION

The most important finding in this study is that an acceptable correction of the weight-bearing line was achieved in 86% of the patients. Under- or overcorrection of the weight-bearing line was found in 14% of the patients. There was a significant improvement of clinical outcome over time in the average patient cohort (Figure 6). However, the clinical outcome of the undercorrected group II was significantly lower than that of group I at follow-ups 2 and 3 (Table 2).

One reason for undercorrection despite meticulous preoperative planning and intraoperative measures may be ligamentous slackness and neglection of the weight-bearing effect on the mechanical axis of the lower limb.12 During the operation, the patients lay supine and knee ligaments were relaxed, whereas the long-leg radiograph was performed in a full weight-bearing standing position. Another explanation may be an increased medial muscle cocontraction postoperatively or increased tension of the long adductor muscle and the hamstrings as a result of their irritation by the plate.28,29

Although the mean bony correction was nearly similar to the preoperatively determined mean α angle (7.1° and 7.5°, respectively) (Table 1), inaccurate correction was detected in 14% of cases, which underlines the effect of soft tissue slackness or laxity on the measurement of mechanical axis. This difference between bony and overall correction should be considered during measurement of the weight-bearing line.

Preoperative planning is an important task. The presence of ligamentous laxity or rotation of the limb during standing radiographs could be a source of error. Adequate intraoperative technique is mandatory to achieve an accurate correction together with intraoperative assessment of the weight-bearing line. Many techniques were described to assess the limb alignment intraoperatively, such as visual inspection, cable method, grid board, or navigation system.26,27 However, all of these methods ignore the effect of weight bearing and ligamentous laxity on the mechanical axis of the lower limb.

Table 1
Analysis of Examined Parameters

<table>
<thead>
<tr>
<th>Variable</th>
<th>Mean±SD</th>
<th>Minimum</th>
<th>Maximum</th>
</tr>
</thead>
<tbody>
<tr>
<td>Preoperative mechanical axis, deg⁺</td>
<td>5.7±2.48</td>
<td>1.0</td>
<td>10.0</td>
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<tr>
<td>α angle</td>
<td>7.5±2.53</td>
<td>4.0</td>
<td>12.0</td>
</tr>
<tr>
<td>Bony correction</td>
<td>7.1±2.4</td>
<td>3</td>
<td>12</td>
</tr>
<tr>
<td>Postoperative mechanical axis, deg⁻</td>
<td>−1.3±2.07</td>
<td>−6.0</td>
<td>3.0</td>
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<tr>
<td>WBL</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Preoperative, %</td>
<td>27±11.2</td>
<td>−6</td>
<td>44</td>
</tr>
<tr>
<td>Postoperative, %</td>
<td>57±8.0</td>
<td>37</td>
<td>73</td>
</tr>
<tr>
<td>Lysholm score</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Postoperative</td>
<td>59±19.5</td>
<td>19</td>
<td>90</td>
</tr>
<tr>
<td>Follow-up 1</td>
<td>69±15.6</td>
<td>44</td>
<td>100</td>
</tr>
<tr>
<td>Follow-up 2</td>
<td>83±16.7</td>
<td>61</td>
<td>100</td>
</tr>
<tr>
<td>Follow-up 3</td>
<td>85±14.0</td>
<td>61</td>
<td>100</td>
</tr>
<tr>
<td>BMI</td>
<td>24±2.4</td>
<td>19</td>
<td>33</td>
</tr>
</tbody>
</table>

Abbreviations: BMI, body mass index; deg, degrees; SD, standard deviation; WBL, weight-bearing line.⁺+, varus; −, valgus.

Table 2
Relation Between Lysholm Score and WBL at Different Time Points

<table>
<thead>
<tr>
<th>WBL, %</th>
<th>Lysholm Score</th>
<th>Mean±SD</th>
<th>Minimum</th>
<th>Maximum</th>
</tr>
</thead>
<tbody>
<tr>
<td>Group I</td>
<td>50-70</td>
<td>61.8±19.1</td>
<td>29</td>
<td>96</td>
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<tr>
<td>Group II</td>
<td>&lt;50</td>
<td>50.8±8.3</td>
<td>44</td>
<td>62</td>
</tr>
<tr>
<td>Group III</td>
<td>&gt;70</td>
<td>36±17.5</td>
<td>19</td>
<td>54</td>
</tr>
<tr>
<td>Group BC</td>
<td>57-67</td>
<td>62±16.2</td>
<td>34</td>
<td>96</td>
</tr>
<tr>
<td>Follow-up 1</td>
<td>50-70</td>
<td>68.4±17.1</td>
<td>44</td>
<td>100</td>
</tr>
<tr>
<td>Group II</td>
<td>&lt;50</td>
<td>63.8±15.3</td>
<td>44</td>
<td>79</td>
</tr>
<tr>
<td>Group III</td>
<td>&gt;70</td>
<td>61.2±17.2</td>
<td>49</td>
<td>81</td>
</tr>
<tr>
<td>Group BC</td>
<td>57-67</td>
<td>69±15.8</td>
<td>45</td>
<td>89</td>
</tr>
<tr>
<td>Follow-up 2</td>
<td>50-70</td>
<td>84.8±10.5</td>
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<td>100</td>
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<tr>
<td>Group II</td>
<td>&lt;50</td>
<td>64.8±10.7</td>
<td>61</td>
<td>75</td>
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<tr>
<td>Group III</td>
<td>&gt;70</td>
<td>81.3±3.1</td>
<td>78</td>
<td>84</td>
</tr>
<tr>
<td>Group BC</td>
<td>57-67</td>
<td>86±9.2</td>
<td>70</td>
<td>100</td>
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<tr>
<td>Follow-up 3</td>
<td>50-70</td>
<td>88.2±13.3</td>
<td>66</td>
<td>100</td>
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<tr>
<td>Group II</td>
<td>&lt;50</td>
<td>65.5±15.3</td>
<td>61</td>
<td>79</td>
</tr>
<tr>
<td>Group III</td>
<td>&gt;70</td>
<td>86±6.1</td>
<td>79</td>
<td>90</td>
</tr>
<tr>
<td>Group BC</td>
<td>57-67</td>
<td>89.2±10.3</td>
<td>77</td>
<td>100</td>
</tr>
</tbody>
</table>

Abbreviations: BC, best correction group; BMI, body mass index; SD, standard deviation; WBL, weight-bearing line.
According to long-term early studies reporting the effect of high tibial osteotomy, under- or overcorrection is frequently associated with inferior clinical results.\textsuperscript{7,8,13} Undercorrection results in a recurrence of varus deformity and is associated with persistence or recurrence of symptoms.\textsuperscript{3,30} Overcorrection can lead to a poor cosmetic result, persistent pain, tilting of the joint line, and considerable loss of bone in case of closed wedge technique, a situation which is often difficult to treat with another osteotomy or an arthroplasty.\textsuperscript{18,31}

The improvement in groups II and III (under- and overcorrection) might be explained with changes in biomechanics and kinematics of the knee with release or decrease of the mechanical pressure on the symptomatic medial compartment,\textsuperscript{32} lowering of the intraosseous venous pressure, and improvement of blood supply of the knee.\textsuperscript{33}

Our result concerning postoperative correction was better than that of Marti et al,\textsuperscript{19} who found the best acceptable correction (weight-bearing line between 57\%-67\%) in 50\% of their patients (58\% in our series). Although our radiological results were slightly inferior to those of Niemeyer et al,\textsuperscript{23} who found an acceptable correction (weight-bearing line between 50\%-70\%) in 90\% of their patients (86\% in our series), the mean Lysholm score in our series at final follow-up was superior (85 vs 78 points).

We found no significant correlation between BMI and the degree of correction in the frontal plane. However, we found a mild inverse correlation between BMI and Lysholm score at follow-up, which means a deterioration of the clinical results with elevated BMI. This result is similar to Spahn et al,\textsuperscript{34} who found a negative correlation between the clinical results and BMI. They suggested that high BMI could be implicated as a reason for loss of correction after weight bearing. This explanation can be accepted with closed-wedge or open-wedge high tibial osteotomy with conventional noninterlocking plates due to further collapse of the osteotomy. Since interlocking plate fixators were used in this series, no collapse should be expected.\textsuperscript{15,35} However, due to the lack of immediate postoperative long-leg radiographs, this study cannot prove this thesis. In our opinion, worsening of the clinical results with increased BMI correlates to elevated biomechanical loads on the knee joint cartilage and the resulting progress of osteoarthrosis rather than loss of correction of osteotomy.

Considered a limitation of our study, the follow-up time was relatively short. Long-term follow-up evaluation is mandatory to determine the outcome of open-wedge high tibial osteotomy under the use of an interlocking fixation device.
CONCLUSION

Open-wedge high tibial osteotomy results in significant improvement of symptoms and function in all patients in the short term, even with under- and overcorrection of the osteotomy. Undercorrection was associated with a significantly lower clinical outcome in comparison to accurate correction and overcorrection. Ligamentous laxity or soft tissue slackness of the knee can influence the overall correction after high tibial osteotomy and must be considered in preoperative planning. Patients with a high BMI had inferior clinical results after open-wedge high tibial osteotomy.

REFERENCES


