Ten-Year Results of Medial Open-Wedge High Tibial Osteotomy and Chondral Resurfacing in Severe Medial Osteoarthritis and Varus Malalignment

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Background: High tibial osteotomy (HTO) is a widely used treatment option for medial osteoarthritis and varus malalignment, especially in young patients with early osteoarthritis. Limited outcome data are available for this procedure in severe osteoarthritis, and no long-term data are available using newer implants.

Purpose: To determine survivorship and functional results of medial open-wedge HTO combined with a chondral resurfacing (CR) procedure (abrasion plus microfracture) in severe medial osteoarthritis (Kellgren-Lawrence grade 3 and 4) and varus malalignment. Furthermore, factors that potentially influence the outcome were analyzed.

Study Design: Case series; Level of evidence, 4.

Methods: From September 2005 to December 2008, all cases of HTO (fixation with an angular-stable internal fixator) combined with CR were prospectively surveyed with regard to survival (Kaplan-Meier-method, not requiring arthroplasty) and functional outcome (subjective International Knee Documentation Committee [IKDC] score). Cartilage regeneration at the time of hardware removal, tibial bone varus angle (TBVA), pre- and postoperative mechanical medial proximal tibial angle (MPTA), and postoperative alignment were analyzed with regard to the result.

Results: Seventy-nine knees were included (73 patients; mean age 50.9 ± 7.6 years). The follow-up rate was 90% at 10.0 ± 1.2 years (range, 8.3-12.1 years). Pre- and postoperative mechanical tibiofemoral axis were 9.6° ± 3.0° of varus and 0.6° ± 2.7° of valgus, respectively. Survival rate was 81.7% (95% CI, 72.5%-90.9%) at 10 years. Subjective IKDC score significantly improved from 44±11 preoperatively to 70±13 at one, 66±15 at three, 66±15 at five, and 65±17 at ten years (P < .001 at any point of follow-up). Poor cartilage regeneration and low preoperative IKDC score (<40) were associated with decreased survival. High preoperative TBVA was associated with better and an overcorrected MPTA (>95°) with inferior functional outcome at final follow-up, respectively.

Conclusion: Even in cases of severe medial osteoarthritis and varus malalignment, HTO in combination with a CR procedure is a good to excellent treatment option. The role of the CR procedure remains unclear. Although good results are obtained with overcorrected MPTA, long-term functional outcome is inferior.

Keywords: osteotomy; HTO; arthritis; malalignment; microfracture; tibial geometry; joint line obliquity

Medial unicompartmental arthritis is a common problem, often facing young and active patients. Loss of the medial meniscus and varus deformities are strongly associated with its development and progression.21,36,46 Joint replacement, either unicompartmental, or total knee arthroplasty, has shown good results, especially for low-demand patients older than 60 years. But for young and high-demand patients, unacceptably high rates of revision have been reported.6 Joint-preserving procedures are generally preferable in these cases. Against this background, high tibial osteotomy (HTO) has become a widely accepted treatment option in medial osteoarthritis and varus malalignment.1,3,29,32,33,49 The biomechanical principle is to
redistribute weightbearing forces from the medial toward the lateral compartment by realignment of the mechanical axis. Lateral closing-wedge osteotomies were the standard approach for many years. In recent years, open-wedge techniques from the medial side have become more popular as they overcome some of the typical complications associated with lateral closed-wedge approaches, including injuries to the peroneal nerve, difficulties in precise deformity correction, and bone loss for arthroplasty in further course. There are a number of long-term follow-up studies on osteotomies around the knee; however, most report on lateral closed-wedge techniques. There are only a few studies available that focus on and exclusively include patients with severe osteoarthritis, as commonly osteotomies were seen as an ideal treatment for patients with early osteoarthritis. No long-term data are available for newer implants (angular-stable plates) and modern surgical techniques. Prognostic factors, such as demographic and radiologic parameters, are still being discussed; in particular, the value of additional chondral procedures is being debated. Recently, the relevance of joint line obliquity resulting from the correction, and especially the question to what extent it can be tolerated, came into focus.

Therefore, the purpose of this study was to determine survivorship and functional results of medial open-wedge HTO (angular-stable fixation) combined with a chondral resurfacing (CR) procedure (abrasion plus microfracture) in patients with severe medial osteoarthritis with full-thickness cartilage defects and varus malalignment. Furthermore, parameters that potentially influence the outcome were analyzed: age, sex, preoperative function (International Knee Documentation Committee [IKDC]), pre- and postoperative bony configuration of the tibia, degree of correction, and obtained cartilage regeneration.

**METHODS**

From September 2005 to December 2008, a total of 73 patients (79 consecutive cases) underwent HTO in combination with a CR procedure at our institution. All met the following inclusion criteria and were enrolled in this study: medial knee pain, osteoarthritis grade 3 or 4 of the medial compartment on radiological assessment according to Kellgren and Lawrence, no anterior cruciate ligament insufficiency, malalignment with more than 4° of varus angulation between the tibial and femoral mechanical axis measured on a hip-to-ankle standing anterior-posterior radiograph, and full-thickness articular cartilage defects in the medial compartment as confirmed during arthroscopy according to the International Cartilage Research Society recommendations. Demographic data are presented in Table 1. All patients enrolled in this study gave their informed consent, and the study protocol was approved by the competent research ethics board. Preliminary 5-year results of parts of this study have been previously reported. Pre- and postoperative radiological evaluation consisted of weightbearing posterior-anterior (Rosenberg), standard lateral and axial views, and a hip-to-ankle standing anterior-posterior radiograph on a long cassette (Figure 1).

All patients were regularly contacted by telephone or postal questionnaire for evaluation of survivorship, defined as not requiring unicompartmental or total knee arthroplasty. All patients completed the self-administered IKDC subjective knee evaluation form preoperatively; after 1, 3, and 5 years; and at final follow-up. Hardware removal was performed 1 to 2 years after the index procedure, when the osteotomy was consolidated. This was combined with a diagnostic arthroscopy for evaluation of regenerated cartilage. The extent of filling of the former cartilage defect by stable regenerated cartilage was graded as “excellent” (100% defect filling), “good” (50%-100%), or “poor” (<50%) for further evaluation (Figure 2).

**Surgical Technique of Index Procedure**

Although today these procedures are performed without tourniquet, within the years of the study surgery was performed with inflated tourniquet. Arthroscopy was performed through anterior standard portals to exclude significant damage of the lateral compartment and to address intra-articular lesions as indicated. A standardized CR procedure was performed in all cases in the medial compartment in areas with exposed subchondral bone, consisting of the following steps: Unstable cartilage was removed with a curette to create stable borders, then abrasion with a bur was performed to remove the sclerotic layer, and finally microfracture was performed for further bone marrow stimulation. This was performed isolated on the femoral side in 20 cases (25.3%), isolated on the tibial side in 3 cases (3.8%), and on both the femoral and tibial side in 56 cases (70.9%). Then, a medial open-wedge osteotomy was performed in a biplanar fashion, as published by the AO knee expert group. The postoperative mechanical axis was planned for slight overcorrection of 0° to 3° of valgus. The angular-stable TomoFix implant (Synthes)

**TABLE 1**

| Demographic Data of the 79 Included Cases<sup>a</sup> |
|---|---|
| **Age, y** | 50.9 ± 7.6 (29.3-67.7) |
| **Sex** | |
| Male | 67 (84.8) |
| Female | 12 (15.2) |
| **Side** | |
| Left | 38 (48.1) |
| Right | 41 (51.9) |
| **BMI, kg/m²** | 27.1 ± 3.0 (21.5-35.0) |
| **Smoker** | 15 (19.0) |

<sup>a</sup>Data are presented as n (%) or mean ± SD (range). BMI, body mass index.
was used for fixation (Figure 4) in all cases. The vast majority of cases had undergone partial medial meniscus resection before (74 cases, 94%). Further resection was performed in 56 cases (71%). At the end of the procedure, the medial meniscus was intact in 1 case (1.3%), partially resected in 36 cases (45.6%), and subtotally resected in 42 cases (53.2%). Grading of cartilage damage in the other compartments is displayed in Table 2. In cases of grade 4 lesions of the trochlea, a CR was performed there as well.

An insufficient posterior cruciate ligament was present in 4 cases (5%), and a partial insufficiency was present in another 4 cases (5%). In 4 cases, the osteotomy gap was filled with autologous bone from the iliac crest; in all other cases, no filling of the gap was performed.

The postoperative rehabilitation protocol consisted of partial weightbearing (10-20 kg) for 8 weeks, with no restriction in range of motion, no brace, and the application of a continuous passive motion device (4-5 times per day for 30-45 minutes) for 8 weeks.

**Statistical Analysis**

Data were obtained prospectively but analyzed retrospectively. Radiographs were analyzed retrospectively. The measured parameters were grouped for statistical evaluation. Statistical analysis was performed using IBM SPSS Statistics for Windows (version 24; IBM Corp). The survival curve is shown as a Kaplan-Meier plot. For comparison of survival rates, the log-rank test was used. For statistical evaluation of parametric data, a Student t test was used; for nonparametric data, the Mann-Whitney U test was used in unrelated samples; and the Wilcoxon signed-rank test was used in related samples. All reported P values are 2-tailed, with an alpha level <.05 considered significant. The intraclass correlation coefficient (ICC) was used to determine the interobserver reliability of radiographic measurements. An overall ICC for radiologic...
measurements of 0.999 (95% CI, 0.999-1.000) presents a very high reliability. Unless otherwise stated, descriptive results are demonstrated as mean ± SD (and range).

RESULTS

From a total of 79 cases, 4 patients died due to reasons unrelated to the procedure and 4 were lost in follow-up. The follow-up rate was 90% (71/79 cases), with a final follow-up at 10.0 ± 1.2 years (range, 8.3-12.1 years).

Survival

In Kaplan-Meier analysis, cumulative survival was 96.1% (95% CI, 91.8%-100.0%) at 5 years and 81.7% (95% CI,

TABLE 2
Cartilage Damage in Lateral and Patellofemoral Compartment at the Time of Index Surgery (International Cartilage Repair Society Classification)\(^a\)

<table>
<thead>
<tr>
<th>Cartilage Component</th>
<th>Grade 0</th>
<th>Grade 1</th>
<th>Grade 2</th>
<th>Grade 3</th>
<th>Grade 4</th>
</tr>
</thead>
<tbody>
<tr>
<td>Lateral femoral condyle</td>
<td>67 (84.8)</td>
<td>2 (2.5)</td>
<td>10 (12.6)</td>
<td>–</td>
<td>–</td>
</tr>
<tr>
<td>Lateral tibial plateau</td>
<td>72 (91.1)</td>
<td>3 (3.8)</td>
<td>4 (5.1)</td>
<td>–</td>
<td>–</td>
</tr>
<tr>
<td>Patella</td>
<td>34 (43.0)</td>
<td>7 (8.9)</td>
<td>32 (40.5)</td>
<td>5 (6.3)</td>
<td>1 (1.3)</td>
</tr>
<tr>
<td>Trochlea</td>
<td>32 (40.5)</td>
<td>3 (3.8)</td>
<td>20 (25.3)</td>
<td>14 (17.7)</td>
<td>10 (12.7)</td>
</tr>
</tbody>
</table>

\(^a\)Data are presented as n (%).

Figure 4. Postoperative radiographs with (A) consolidated osteotomy and (B) desired valgus correction of the same patient as shown in Figure 1.

Functional Outcome

Subjective IKDC score significantly improved from 44 ± 11 preoperatively to 70 ± 13 at 1 year, 66 ± 15 at 3 years, 66 ± 15 at 5 years, and 65 ± 17 at final follow-up at 10.0 ± 1.2 years (Figure 6). The difference from the preoperative value was significant at all points of follow-up (\(P < .001\)) and remained stable without significant decrease.
Influence of Clinical and Radiological Parameters

Measured radiologic parameters are presented in Table 4. Table 5 presents data on grouped demographic, clinical, and radiographic parameters, as well as their influence on survival and functional outcome at 1 year and at final follow-up. A low preoperative subjective IKDC score (below 40) and incomplete or no defect filling at arthroscopic reevaluation were associated with inferior survival but did not influence functional outcome (Figure 7). There was a tendency toward inferior survival in cases with undercorrection (defined as remaining varus) compared with accurately (0°-3° of valgus) and overcorrected (>3° of valgus) knees (P = .071). A higher preoperative TBVA (>6°) was associated with better functional results at final follow-up (Figure 8 and Table 5), and a postoperatively overcorrected MPTA (>95°) was associated with inferior functional results when compared with not overcorrected cases (Figures 9 and 10). However, these two did not influence survivorship.

DISCUSSION

The major findings of this study are good to excellent long-term results of HTO with CR in severe medial osteoarthritis and varus malalignment, with a survival rate of 81.7% after 10 years and a significant increase in subjective IKDC remaining constant over time. With regard to prognostic factors, the preoperative functional status and the metaphyseal varus inclination of the tibia should be considered. Extreme overcorrection of the MPTA should be avoided.

Several studies have investigated outcomes of valgus-producing ostotomies; however, long-term outcome data are mainly available from lateral closed-wedge ostotomies. In the largest series available, Hui et al22 reported a 10-year survival rate of 79% and a 15-year survival rate of 56% in a series of 455 cases. They reported a mean Oxford Knee Score of 40 (48 possible) in 272 cases 12 years after osteotomy, with cases that required further surgery excluded. Gstottner et al18 reported almost similar survival rates of 79.9% after 10 years and 65.5% after 15 years with closed-wedge techniques as well. Furthermore, a survival rate of 84.4% was reported for a 9- to 12-year follow-up in a meta-analysis (46 studies) by Spahn et al.47 Interestingly, Akizuki et al2 reported an exceptionally high 10-year survival rate of 97.6% after lateral closed-wedge osteotomy in a series of 132 patients of an Asian population.

Only a few midterm studies are available for newer implants and techniques.7,16,31,37 Bode et al2 reported a survival rate of 96% after 5 years using an analog surgical technique and the same implants as used in the present study. They found a significant increase in subjective IKDC and Lysholm score after 5 years. Floerkemeier et al16 reported an Oxford Knee Score of 43 after 3.6 years in a large series of 533 cases using the same implant.

There is a large heterogeneity in the literature with regard to additional cartilage-addressing procedures. The majority of studies did not perform any concomitant cartilage procedures. Sterrett et al50 reported on a group of 106 knees treated with combined opening-wedge HTO and microfracture in all cases. They found survival rates of 97% and 91% at 5 and 7 years, respectively, and a Lysholm score of 67 at 9 years. Kahlenberg et al26 recently published a review of HTO in combination with a variety of cartilage restoration techniques in 839 cases. A conversion rate to arthroplasty of 6.8% after a mean follow-up of 6.2 years was reported. Matsunaga et al35 found no difference in functional outcome, although cartilage regeneration was better in combined abrasion and HTO compared with HTO alone or HTO plus microfracture (closed-wedge technique). In contrast, Pascale et al39 found a higher subjective satisfaction among patients with additional microfracture compared with opening-wedge HTO alone after 5 years. In 135 cases undergoing revision arthroscopy at the time of hardware removal after opening-wedge HTO, Spahn et al46 found no correlation between cartilage regeneration and functional outcome. Harris et al20 reported a significantly higher survival rate at 5 years after combined procedures with cartilage repair than with HTO alone in a review of 69 studies of osteotomy alone or with biological reconstruction (including cartilage surgery, meniscus allograft transplantation). However, conclusions have to be drawn cautiously because of a variety of underlying pathologic conditions in this series.

Recently, some reports on cartilage regeneration after osteotomy without additional procedures have been published. Jung et al24 found cartilage regeneration in 92% of 159 cases after opening-wedge HTO without cartilage-addressing procedures. However, in most cases, only partial coverage was present, and there had been mainly lower grades of cartilage damage at the time of the index...
In a recently published series, Kim et al. reported on 104 cases undergoing opening-wedge HTO without additional procedures. They found improvements of cartilage lesions in 51.9% on the femoral condyle and 34.6% on the tibial plateau. In our study, good to excellent cartilage regeneration was found in 84.8% on the femoral and 78.4% on the tibial side, which appears superior to other reports. In our series, cases with complete defect

![Figure 7](image-url)  

**Figure 7.** Survivorship depending on (A) preoperative subjective International Knee Documentation Committee (IKDC) score and (B) on cartilage status at the time of hardware removal.

### TABLE 5  
**Influence of Different Factors on Survival and Functional Outcome at 1-Year and Final Follow-up**

<table>
<thead>
<tr>
<th>Factor and Category</th>
<th>No. of Cases</th>
<th>Survival at 10 Years</th>
<th>Subjective IKDC at 1 Year</th>
<th>Subjective IKDC at Final Follow-up</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Survival, %</td>
<td>95% CI</td>
<td>Score</td>
</tr>
<tr>
<td>Demographic factors</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Age, y</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>&lt;50</td>
<td>36</td>
<td>87.5</td>
<td>76.1-98.9</td>
<td>72</td>
</tr>
<tr>
<td>≥50</td>
<td>43</td>
<td>76.9</td>
<td>63.4-90.4</td>
<td>69</td>
</tr>
<tr>
<td>Sex</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Male</td>
<td>67</td>
<td>78.4</td>
<td>67.8-89.0</td>
<td>70</td>
</tr>
<tr>
<td>Female</td>
<td>12</td>
<td>85.7</td>
<td>59.8-100.0</td>
<td>71</td>
</tr>
<tr>
<td>Preoperative function</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Subjective IKDC&lt;40</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>&lt;40</td>
<td>30</td>
<td>68.0</td>
<td>50.6-85.4</td>
<td>67</td>
</tr>
<tr>
<td>≥40</td>
<td>49</td>
<td>90.6</td>
<td>81.8-99.4</td>
<td>73</td>
</tr>
<tr>
<td>Bony configuration</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Preoperative TBVA, deg</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>&lt;6</td>
<td>43</td>
<td>82.2</td>
<td>70.2-94.2</td>
<td>69</td>
</tr>
<tr>
<td>≥6</td>
<td>36</td>
<td>81.1</td>
<td>67.2-95.0</td>
<td>72</td>
</tr>
<tr>
<td>&lt;9</td>
<td>67</td>
<td>79.9</td>
<td>69.7-90.1</td>
<td>69</td>
</tr>
<tr>
<td>≥9</td>
<td>12</td>
<td>91.7</td>
<td>76.0-100.0</td>
<td>78</td>
</tr>
<tr>
<td>Preoperative MPTA, deg</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>&lt;85</td>
<td>41</td>
<td>89.0</td>
<td>78.8-99.2</td>
<td>71</td>
</tr>
<tr>
<td>≥85</td>
<td>38</td>
<td>74.5</td>
<td>60.0-89.0</td>
<td>69</td>
</tr>
<tr>
<td>Postoperative MPTA, deg</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>&lt;95</td>
<td>64</td>
<td>80.1</td>
<td>67.8-92.4</td>
<td>71</td>
</tr>
<tr>
<td>≥95</td>
<td>15</td>
<td>83.0</td>
<td>70.3-95.7</td>
<td>67</td>
</tr>
<tr>
<td>Undercorrection, deg</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Remaining varus</td>
<td>19</td>
<td>74.6</td>
<td>59.1-90.1</td>
<td>71</td>
</tr>
<tr>
<td>0-3 of valg</td>
<td>51</td>
<td>87.5</td>
<td>77.3-100.0</td>
<td>70</td>
</tr>
<tr>
<td>Cartilage regeneration</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Complete (100%) coverage</td>
<td>28</td>
<td>90.3</td>
<td>77.0-100.0</td>
<td>72</td>
</tr>
<tr>
<td>Incomplete or no coverage</td>
<td>41</td>
<td>76.2</td>
<td>62.7-89.7</td>
<td>70</td>
</tr>
</tbody>
</table>

IKDC International Knee Documentation Committee; MPTA, mechanical medial proximal tibial angle; TBVA, tibial bone varus angle.

*See Figure 7.*
filling showed significantly better survival; however, it cannot be differentiated if these cases responded better to the combined procedure per se or if better cartilage regeneration actually leads to better survival. Finally, the role of cartilage-addressing procedures remains unclear.

In summary, our study results are consistent with the results published in the literature. HTO has often been proposed as an ideal treatment in early osteoarthritis, and it is known that higher degrees of osteoarthritis are accompanied by inferior results. However, our results of HTO exclusively in cases of severe osteoarthritis demonstrate that excellent results can also be obtained in these cases. Therefore, the degree of medial osteoarthritis should not be a limiting factor or contraindication for this procedure. Within recent years, there has been good evidence that arthroplasty after osteotomy is associated with excellent results despite being technically demanding. Thus, by postponing primary arthroplasty even in severe osteoarthritis, osteotomies can improve the unsolved problem of impending multiple revision arthroplasties, especially in younger patients.

A number of factors that potentially influence the results have been discussed, including age, sex, body mass index, status of the anterior cruciate ligament, cause of osteoarthritis, preoperative knee function, and preoperative scores. In our study, age and sex did not influence the overall result. A low preoperative IKDC score (below 40) was associated with significantly inferior survival. This is in line with the findings of Bonasia et al., who found an excellent preoperative Knee Society score to be significantly related to a good outcome.

There is increasing interest in the bony configuration of deformities and its influence on outcome and the strategy of correction. The ideal degree of correction has been extensively investigated in the past decades, with recommendations from neutral up to extreme valgus corrections. In recent years, individual approaches to the degree of correction based on the underlying condition and the extent of cartilage damage have been proposed. Generally, undercorrection is known to be associated with inferior results, which is in line with our findings. It has been proposed that tibial correction in preexisting tibial varus deformity leads to superior results when compared with extra-tibial or intra-articular
varus deformity.\textsuperscript{33} The TBVA was proposed as a good measurement of a metaphyseal varus deformity of the tibia.\textsuperscript{9} A high TBVA was previously reported to be associated with superior results after HTO.\textsuperscript{37} This is in line with our findings of significantly better outcome at long-term follow-up when the TBVA was 6\textdegree{} to 9\textdegree{} or even greater. In contrast, van Raaij et al\textsuperscript{53} found that proximal tibial varus inclination had no influence on survival. It has to be acknowledged that the TBVA might be difficult to measure (lowest ICC of all radiographic parameters in our study: 0.866) and that good results can also be obtained in the absence of a distinct TBVA.

Recently, the joint line obliquity came more into focus because deformity correction might lead to new iatrogenic deformities, and it has been speculated that excessive medial/lateral slope might lead to transverse shearing forces between the femur and tibia.\textsuperscript{4} Tibial overcorrection can result from overcorrection per se, the compensation of medial joint space narrowing, inadequately addressed lateral laxity, or the presence of femoral or combined deformities. A resulting iatrogenic deformity might not be of importance only for osteotomy results but also for possible prosthetic joint replacement in the future with regard to bone loss (more of relevance in lateral closed-wedge than in medial open-wedge osteotomies), difficulties in ligament balancing, and the risk of substantial joint line obliquity after total knee arthroplasty, which is associated with inferior results.\textsuperscript{44}

To overcome the problem of potential iatrogenic deformities, the concept of individual correction at the site of deformity and the concept of double-level osteotomies were introduced, especially for cases of large and combined deformities. Babis et al\textsuperscript{50} reported on a series of 29 cases of double osteotomies with a mean 13.9\textdegree{} varus malalignment preoperatively. Excellent functional results and a high survival rate of 96\% after 8 years have been reported. The authors proposed a joint line obliquity of 0\textdegree{} ± 4\textdegree{} to be acceptable. An older study defined 10\textdegree{} of joint line obliquity to be tolerable, but there is no evidence for these limits.\textsuperscript{41,411} Saragglia et al\textsuperscript{52} reported on 42 cases of navigation-assisted double-level osteotomies with a mean follow-up of 3.8 years without any conversions to arthroplasty up to that point. Lee et al\textsuperscript{30} investigated changes of joint line orientation and bony tibial configuration in valgus osteotomies. In their series of 50 cases, they found that a mean increase of the MPTA of 9\textdegree{} resulted in a joint line obliquity relative to the ground of only 4.1\textdegree{}. They showed that this was partially compensated by a changed orientation of the ankle joint line. Therefore, overcorrection might result in minor relevant changes of joint geometry than it might appear at first sight.

However, so far no threshold has been defined as to what extent an overcorrection of the MPTA after tibial osteotomy can be accepted, and no comparative studies between single- and double-level osteotomies are available. Our data show that functional long-term outcome decreases in cases of MPTA greater than 95\textdegree{}, but up to 10 years, there was no difference in the rate of conversion to arthroplasty, and obtained results are overall satisfying. Therefore, a certain degree of overcorrection is surely acceptable. Indications for double-level osteotomies in these cases still need to be clearly defined.

Limitations

There are some limitations of this study that certainly have to be considered: First, there is neither a control group with nonoperative treatment for evaluation as to what extent arthroplasty could be postponed nor a control group treated with osteotomy alone without CR to evaluate the effect of the performed cartilage-addressing procedure. Furthermore, arthroscopic evaluation between 1 and 2 years can present only short-term outcomes and was not performed in all cases.

CONCLUSION

Even in cases of severe medial osteoarthritis and varus malalignment, HTO in combination with a CR procedure is an excellent treatment option with regard to functional results and survival without arthroplasty. The role of the CR procedure remains unclear. Even with overcorrected MPTA, good results can be obtained; however, functional results at long-term follow-up are inferior.

REFERENCES
