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Flexion gap configuration in total knee arthroplasty following high tibial osteotomy

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Abstract Previous reports have described the potentially compromising effect of a high tibial osteotomy (HTO) on the results of a subsequent total knee arthroplasty (TKA). Although the reasons are not clear, some authors reported problems in soft-tissue balancing. In a prospective study, 22 patients with an average interval of 5.8 years after closed-wedge HTO were operated for TKA. All operations were performed with a CT-free navigation system, and measurements of the extension and flexion gap were assessed. The intraoperative data were compared to a control group of 100 consecutive computer-assisted TKA without previous osteotomy. In the study group, a highly significant shift towards a medial opening of the flexion gap between the posterior condylar line and the tibial resection (study group $0.4\pm 4.7^\circ$ medial opening versus control group $3.4\pm 3.3^\circ$ lateral opening, $p<0.001$) was observed. In the study group, 10/22 showed a medial opening of the flexion gap compared to 11/100 in the control group. Surgeons should be aware of difficulties in soft-tissue balance in TKA following HTO, especially for the flexion gap configuration and the axial rotation of the femoral component.

Rsum Plusieurs rapports ont dcrit l'effet potentiellement dfavorable d'une osttomie tibiale suprieure sur les rsultats d'une arthroplastie totale du genou secondaire. Bien que les raisons ne soient pas claires, quelques auteurs ont rapport des problmes dans l'quilibre des parties molles. Dans une tude prospective 22 malades ont eu une arthroplastie totale du genou avec un intervalle moyen de

5,8 ans aprs une osttomie tibiale. Toutes les oprations ont t excutes avec un systme de navigation sans scanner et l'intervalle en flexion et en extension a t mesur. Les donnes intraopratoires ont t compares un groupe tmoin de 100 arthroplasties totales du genou conscutives, sous contrle informatique, sans osttomie pralable. Dans le groupe d'tude a t constat une modification trs importante vers une ouverture mdiale de l'intervalle en flexion entre la ligne condylienne postrieure et la rsection tibiale (groupe d'tude $0,4\pm 4,7^\circ$ d'ouverture mdiale contre, dans le groupe tmoin, $3,4\pm 3,3^\circ$ d'ouverture latrale, $p<0.001$). Dans le groupe d'tude 10/22 ont montr une ouverture mdiale de l'intervalle en flexion compare 11/100 dans le groupe tmoin. Les chirurgiens doivent tre conscients de la difficult d'quilibrer les parties molles dans l'arthroplastie du genou aprs osttomie tibiale, surtout pour la configuration de l'intervalle en flexion et l'orientation axiale du composant fmoral.

Introduction

High tibial osteotomy (HTO) has proven to be successful for the treatment of unicompartmental osteoarthritis of the knee. The mid- to long-term results of HTO have been reported to provide symptomatic relief for approximately 10 years [1]. However, permanent pain relief is unlikely [20]. Thus, HTO generally buys time, but many of these patients eventually will need a total knee arthroplasty (TKA). Controversy exists as to whether or not HTO can have any deleterious effects on the outcome of a subsequent TKA. Several authors have compared the results of TKA in patients with and without a previous HTO, but these matched and comparative studies have had conflicting conclusions.

Recently, computer-assisted surgery has been introduced in TKA. These systems provide the opportunity to improve the accuracy of component orientation and restoration of the mechanical leg axis [3, 12, 17]. Using the computer-assisted technique, intraoperative angular

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and distance measurements have become available, with an accuracy of less than 1° or 1 mm [7]. It was the aim of the present study to evaluate the intraoperative data of alignment and gap configuration in TKA following a previous HTO in comparison to TKA without previous osteotomy.

Materials and methods

Within a prospective evaluation of 350 consecutive patients operated on for primary computer-assisted TKA, 22 patients were identified with a previous HTO on the treated leg (study group). All TKA were performed using the CT-free module of the Vector-Vision Navigation System (BrainLAB, Munich, Germany). In all cases, the intraoperative data of the flexion gap configuration were assessed using the navigation system. The intraoperative data of the study group were compared to a series of 100 consecutive TKAs without a previous HTO using the same operative technique (control group). The study was approved by the local ethics committee. Informed consent was obtained from each patient.

The study group consisted on 14 women and eight men who all received a previous high tibial closed-wedge osteotomy. The average interval between the osteotomy and the TKA was 5.8 (range 2–11) years. The mean age at TKA was 63.8 (range 49–82) years. The mean preoperative deviation from a neutral leg axis was 4.0° (range 11° varus to 9° valgus).

In the control group, 68 women and 32 men were evaluated. The mean age was 68.8 (range 51–86) years, and the mean preoperative deviation from a neutral leg axis was 7.6° (range 18° varus to 20° valgus).

Surgical technique

The navigation system (VectorVision, BrainLAB) is based on an optical tracking unit, which detects reflecting marker spheres attached to the bone and instruments by an infrared camera system. After performing a standard medial parapatellar approach for TKA, two reference arrays with passive marker spheres were rigidly attached to the femoral and the tibial bone. Specific landmarks, which are necessary for navigation, were digitized at the beginning of the operation.

In all patients, the proximal tibial and the distal femoral resections were performed as primary surgical steps perpendicular to a neutral leg axis using the navigation system. Afterward, if necessary, ligament release was performed to achieve a rectangular extension gap. The sequence of soft-tissue release was made in a standard way, as described by Colizza et al. [6]. The steps of ligament release were monitored by the navigation system using a tensor device that provided similar tension to the medial and lateral knee compartment with two independent, calibrated springs (BalAnswer, DePuy, Inc., Warsaw, IN, USA, Fig. 1). A spring force of 100 N was used to

assess the extension and flexion gap. Gap sizes and deviation of the leg axis were displayed by the navigation system.

After creating a rectangular extension gap and thereby a neutral leg axis in extension, the knee was brought to 90° flexion. Again, the tensor was placed between the tibial plane and the posterior condyles. At this stage, data on the configuration of the flexion gap concerning gap size and angle between tibial resection and posterior condylar line were stored to the navigation system and were available for further data analysis. Thereby, the optimal femoral component orientation resulting in a symmetric, balanced, flexion gap was determined by the navigation system.

In all cases, PFC Sigma implants (DePuy, Inc.) were inserted. All operations were performed by one team with experience in computer-assisted TKA. Statistical analysis was performed to identify differences between the groups using the unpaired t test, with a $p < 0.05$ considered to be significant.

Results

Extension gap configuration

For the intraoperative evaluation of the extension gap, after performing an appropriate release, a symmetric, balanced, configuration within a range of $\pm 3^\circ$ was documented for all cases of the study 22 of 22) and control (100 of 100) groups using the calibrated tensor device (Fig. 1). No differences between the groups were identified ($p > 0.05$).

Flexion gap configuration

In the study group, the intraoperative evaluation showed a mean *medial* opening of the flexion gap between the

Fig. 1 Tensor device, BalAnswer (DePuy, Inc.): similar tension on the medial and lateral knee compartment is provided with two independent, calibrated springs. The spring force can be adjusted continuously between 0 N and 135 N.

Fig. 2 Flexion gap balance of study and control groups using the tensor device. Negative values represent medial opening and positive values represent lateral opening of the flexion gap in degrees.

posterior condylar line and the tibial resection of $0.4 \pm 4.7^\circ$ (range 9° medial opening to 8° lateral opening). In the control group, a mean *lateral* opening of the flexion gap of $3.4 \pm 3.3^\circ$ (range 7° medial opening to 10° lateral opening) was observed (Fig. 2). The difference was highly significant ($p < 0.001$).

In the study group, ten cases showed a medial opening of the flexion gap. In the control group, this was seen in 11 cases only. In the study group, nine cases showed a lateral opening between 0° and 6° . This was observed in 68 cases in the control group. Three cases in the study group and 21 in the control group had a lateral opening of the flexion gap of more than 6° (Table 1).

Discussion

The issue of whether a previous HTO has any potential adverse effect on a subsequent total knee replacement remains a matter of controversy. Some authors report inferior results in patients who have undergone a previous HTO [8, 13, 16, 20] while other authors report no inferior results of TKA following a HTO [2, 4, 10, 11, 14, 18, 19]. Meding et al. [11] presented the results after bilateral TKA in 39 patients (with and without a previous HTO). In that study, no significant functional differences between the bilateral cases were found after 6.5-year follow-up. Staeheli et al. [18] reviewed 35 patients with TKA after a previous HTO (average follow-up 44 months). They

Fig. 3 Information given by the navigation system: the surgeon is aware of the relation of different axes for femoral component rotation before determining the final position of the anterior and posterior cut.

found good-to-excellent results in 89% of the knees and concluded that the previous HTO had no deleterious effect on the subsequent total knee replacement. However, Windsor et al. [20] analyzed the outcome of 45 patients with a total knee replacement after HTO and an average follow-up of nearly 5 years. Although they found good-to-excellent results in 80% of patients, the authors concluded that the results of total knee replacement after HTO are comparable with those after revision surgery and inferior to those after primary total knee replacement. Katz et al. [8] compared the results of TKA in 21 patients who had had a previous HTO with those in a matched group of 21 patients without a previous osteotomy. After an average follow-up of less than 3 years, only 81% of those patients with a previous HTO showed good or excellent results compared with 100% of those with no previous HTO. Mont et al. [13] compared the results of TKA in a matched group of 73 knees each with and without a previous osteotomy. After an average follow-up of 6 years, only 64% of the knees that had a previous osteotomy had a good-to-excellent result compared to 89% of those without a previous HTO. Parvizi et al. [16] found that the overall functional outcome based on the Knee Society Score and the radiographic outcome was inferior in patients who have had a previous proximal tibial osteotomy.

Further, in several studies, problems in soft-tissue balancing and remaining instability in TKA following HTO were reported. Different authors [5, 9] recognized

Table 1 Flexion gap configuration of study group and control groups between posterior condylar line and tibial resection plane

Flexion gap	Medial opening $<0^\circ$ (%)	Lateral opening $0-6^\circ$ (%)	Lateral opening $>6^\circ$ (%)
Study group (n=22)	45	41	14
Control group (n=100)	11	68	21

the possible need for a lateral ligamentous balancing, especially in knees with severe overcorrection after a HTO. Parvizi et al. [16] found a considerable number of patients with residual instability. Prior to TKA, more than one third of the knees exhibited instability in the coronal plane. Although the instability was corrected in most cases, there were still a fair number of knees with clinical evidence of instability following arthroplasty. Similar results have been reported by Staeheli [18] who found an increased rate of residual instability in patients managed with TKA after HTO.

To our best knowledge, the present study is the first that evaluates the flexion gap stability and configuration in patients with TKA after HTO. For both groups, we identified a certain variation of flexion gap configuration after creating a symmetric extension gap with a standardized release technique. This variation of flexion gap configuration is in agreement with the data reported in literature that demonstrate a certain variation of lateral opening of the flexion gap in primary TKA series [15, 21]. Compared to the control group, and also compared to literature data [15, 21], the study group showed a highly significant shift toward a *medial* opening of the flexion gap of nearly 4°. Possible reasons for these findings might be a preoperative patella baja, periarticular scarring, preoperative malalignment because of undercorrection or overcorrection, proximal tibial bone deficiency, and retained hardware, all of which are reported to contribute to the technical difficulty of obtaining optimal soft-tissue balancing in TKA after an HTO [16, 20].

These findings imply several conclusions: surgeons should be aware of difficulties in obtaining a correct soft-tissue balance in these cases, not only for the extension gap (coronal plane), but also for the flexion gap configuration and the axial femoral component orientation.

The results of the present study cannot answer the question whether the potential risk of flexion gap instability or femoral component malrotation might be responsible for a reduced clinical outcome, as reported in other clinical series [8, 13, 16, 20]. Nevertheless, it is evident that the surgeon has to be aware of potential problems in the flexion gap balancing in these cases. Furthermore, the so-called gap technique in combination with a navigation system seems to be very useful in the surgical treatment of these patients. By that, the surgeon is aware of the specific situation of the flexion gap configuration during surgery, and the decision of axial femoral component orientation can be made based on precise information compared to both the ligament situation and the bony landmarks (posterior condylar axis, epicondylar axis, whiteside-line) (Fig. 3). Using a fixed external rotation (e.g., 3° external to the posterior condylar line) of the femoral component should be avoided, and gap stability should be assessed carefully.

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