Technical note

One-stage computer-assisted total knee arthroplasty and tibial osteotomy

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1. Introduction

Mechanical axis alignment and ligament balancing are interdependent factors that are crucial to achieving good long-term outcomes of total knee arthroplasty (TKA) [1,2]. In patients with severe bone deformities, correcting the mechanical axis is technically demanding, most notably when the deformity is fixed and extra-articular [3]. Rajgopal et al. [3], Xiao-Gang et al. [4], and Koenig et al. [5] have stated that severe extra-articular deformities can usually be corrected during TKA by performing extensive ligament release, although a semi-constrained prosthesis may be required. In contrast, Zanone et al. [6], Madelaine et al. [7], and Lonner et al. [8] advocated combining the TKA with tibial osteotomy to correct the extra-articular bone deformity, thereby avoiding post-resection laxity, extensive ligament release, and the use of a semi-constrained prosthesis. However, combining TKA with tibial osteotomy is technically challenging and carries a risk of complications [7]. Two options are available: same-stage tibial osteotomy can be performed either before or after the TKA.

This article describes a one-stage computer-assisted technique for performing TKA followed by tibial osteotomy to obtain a mechanical axis of about 180° without extensive ligament balancing.

2. Technique

Pre-operative planning included measurement on a long-leg radiograph of the mechanical tibial, femoral, and femoro-tibial angles (Table 1). The reducibility of the deformity was assessed clinically. Amplification® (Amplitude, Valence, France) [1] was used for navigation. The prosthesis was the primary total knee implant SCORE® (Amplitude), characterised by a highly congruent rotating platform and an elongated tibial keel. The cementless versions of both the femoral and the tibial components were used (except in one patient, for the tibial component).

2.1. First step: implanting the total knee prosthesis

The procedure is performed with or without a tourniquet. An antero-medial approach is used, to allow the subsequent tibial osteotomy. A femoral rigid body is positioned through the incision in the metaphyseal position and a tibial rigid body transcutaneously in the diaphyseal position to avoid impeding the osteotomy. After arthrotomy and standard capsular release, the overall deformity and its degree of reducibility are assessed by a forced valgus or varus manoeuvre and measured using the navigation tool [9] (Fig. 1). The tibial cut is performed first, based on the
irreducible component of the deformity. For instance, if 10° of varus deformity persists during the forced manoeuvre, the tibial cut is angled 10° in varus (Fig. 2). Similarly, if the residual deformity is 9° of valgus, the tibial cut is angled 9° in valgus. In practice, the result is a cut parallel to the tibial joint surface, with no attempt to replicate an oblique joint space after the tibial osteotomy is performed. In the sagittal plane, the tibial slope is planned perpendicularly to the tibial mechanical axis. The femoral cuts are performed next, classically based on the ligament balance as assessed by the extension and flexion gaps measured using the navigation tool. No specific ligament release procedure is performed, and the global mechanical axis displayed by the navigation tool is not taken into account. The degree of femoral rotation is based on the ligament balance in flexion. The trial implants are then inserted. Fig. 3 shows an example, in which 10° of varus is allowed to persist.

2.2. Second step: corrective tibial osteotomy

The tibial osteotomy is performed to obtain an axis close to 180°, under guidance by the navigation tool and with an image amplifier. The staples used to close the osteotomy are positioned in order to avoid impeding the preparation of the tibial keel and the insertion of the final implants (Figs. 4 and 5).

2.3. Third step: insertion of the final implants

The final implants are then inserted. The elongated tibial keel bridges the tibial osteotomy. In the event of an opening-wedge osteotomy, autologous bone grafting is performed using fragments from the femoral resections. The two staples are left in place to enhance stability and put pressure on the autologous bone graft (Fig. 5). Stabilization using two staples was not required in either of the 2 cases of closing-wedge tibial osteotomy (Fig. 6).

3. Results

This technique was used in 8 patients, 5 females and 3 males with a mean age of 70 years (range, 56–85 years) and a mean body mass index of 27 (range, 21–46). Primary osteoarthritis was the reason for TKA in all 8 patients. Pre-operatively, 6 patients had varus deformity, ranging from 15° to 19°, and 2 had valgus deformity, of 10° and 18°, respectively. Closing-wedge and opening-wedge tibial osteotomy had been performed previously in 3 and 2 patients, respectively. The tibial osteotomy performed during TKA was opening-wedge in 6 of the 8 patients (Table 1). Patellar resurfacing was not performed. Rehabilitation therapy was started immediately, with no splinting. Contact weight bearing was allowed with two canes, for 2 months. All patients were re-evaluated by a surgeon, who determined the International Knee Society (IKS) score and obtained radiographs including antero-posterior, lateral, axial patellar, and long-leg views. Follow-up was 3 to 11 years.

All patients were re-evaluated at least 3 years after the procedure. Knee manipulation under general anaesthesia was required 45 days post-operatively in 1 patient. Another patient experienced deep vein thrombosis. Full weight bearing was achieved.
**Fig. 2.** Use of the navigation tool to plan the tibial cut at 10° of varus, thus correcting the residual 10° of valgus during passive forced varus.

**Fig. 3.** HKA angle measurement after insertion of the trial implants: persistence of 10° of varus.
Fig. 4. Medial opening-wedge corrective tibial osteotomy under guidance by fluoroscopy (a) and by the navigation tool (b). The final HKA angle is 180°.

Fig. 5. Final result after navigated TKA and medial opening-wedge tibial osteotomy.

by all patients after 2 months. The mean knee and function IKS scores were 91 and 87, respectively. Mean flexion was 110° (range, 90–130) and the mean HKA angle was 180° (range, 176°–181°). The patella was aligned in all 8 patients. There were no cases of rotational ligament instability, inadequate implant fixation, or specific complications of osteotomy (fracture, non-union, discomfort, or hardware breakage).

4. Discussion

Same-stage TKA and tibial osteotomy is regarded as technically challenging [4,7,8]. A navigation tool benefits both reliability and reproducibility by determining the optimal orientation of the cuts – most notably at the tibia (the site of the deformities in our population) – according to the irreducible component of the
deformity during reduction manoeuvres. Thus, the size of the bone wedge can be planned, and correction of the HKA angle by the osteotomy after insertion of the trial implants can be monitored in real time.

Navigation has been proven to increase the accuracy and reproducibility of TKA [10–15], thereby improving long-term implant survival [2]. Navigated TKA combined with tibial osteotomy has been recommended by Rhee et al. [16] for patients with severe extra-articular deformities and by Catani et al. [17] for those with extra-articular mal-union. Of our 8 patients, 5 had a history of tibial osteotomy, which had caused metaphyseal mal-union. Correcting the deformity within the prosthesis via extensive soft-tissue release can raise technical challenges and can induce instability requiring the use of a semi-constrained prosthesis. Achieving correction by an osteotomy within the deformity, without damaging the ligaments, therefore holds appeal as a more rational and conservative strategy.

Nevertheless, navigating complex surgical procedures requires thorough familiarity with the software, which can be achieved only by using the navigation tool routinely for all primary arthroplasties, particularly in simple cases. This strategy is followed in our department. Navigation should not be reserved for complex cases.

The surgical sequence described here consists in inserting the trial TKA implants then performing the tibial osteotomy, which is maintained by two staples, and inserting the final implants, including a tibial implant equipped with a long keel. Madelaine et al. [7], in contrast, have advocated performing the tibial osteotomy before the TKA. However, bone healing was delayed in their population and they consequently recommended rigid internal plate fixation. Furthermore, with their sequence, concern about loading and compromising the primary osteotomy may impede a reliable evaluation of ligament balance.

In contrast, starting by preparing the TKA allows ligament balancing in flexion and extension within the intact ligament envelope, without considering the mechanical axis or having to protect the tibial osteotomy. Furthermore, rigid internal fixation is unnecessary. Stability is ensured by the long tibial keel, two staples to maintain the osteotomy, and autologous bone grafting if opening-wedge osteotomy was performed. Thus, immediate weight bearing can be allowed. However, as a precaution, our patients were asked to use two canes to minimise weight bearing. Complete bone healing was achieved consistently. Tibial plate fixation requires a more extensive approach, with detachment of the medial ligament plane, and also increases the risk of specific complications (plate breakage, delayed healing, and discomfort due to the hardware located under the skin). The use of a long tibial keel precludes adjustment of the tibial slope, but this is probably a smaller disadvantage compared to those associated with tibial plate fixation. The recommended keel length is 100 mm. In our study, of the 2 patients with the poorest outcomes, 1 received a 75 mm keel and the other no keel (material unavailable in the operating theatre), which may have contributed to loss of angle correction in the coronal plane. In our patients, tibial slope was planned perpendicularly to the tibial mechanical axis, both because the tibial implant had 4◦ of slope within the insert and to avoid impeding the implantation of the long tibial keel. Tibial slope measurement by the navigation tool after the tibial osteotomy was not feasible in our patients but would be possible with the currently available software. We assessed tibial slope clinically based on absence of extension lag before and after the tibial osteotomy.

5. Conclusion

The technique described herein produced satisfactory clinical and radiographic outcomes. For patients with severe, irreducible bone deformities, we recommend the use of a navigation tool for performing an accurate tibial osteotomy in combination with primary TKA. We advocate performing the TKA first then correcting the mechanical axis by a tibial osteotomy, to avoid extensive soft-tissue release or the use of a semi-constrained prosthesis.
Disclosure of interest

SD, OT, and FC receive royalties from Amplitude.

References