

Accuracy of the second metatarsal as a landmark for the extramedullary tibial cutting guide in total knee arthroplasty

Tadashi Tsukeoka · Yoshikazu Tsuneizumi ·
Tae Hyun Lee

Received: 6 January 2014 / Accepted: 18 August 2014 / Published online: 27 August 2014
© European Society of Sports Traumatology, Knee Surgery, Arthroscopy (ESSKA) 2014

Abstract

Purpose The purpose of this study was to evaluate the accuracy of the second metatarsal (MT2) as a landmark for proximal tibial cutting in total knee arthroplasty (TKA). It was hypothesized that the accuracy of the MT2 is not high, especially in rheumatoid arthritis (RA) patients whose foot joints are apt to be involved.

Methods Computer simulation studies on 48 RA knees and 45 osteoarthritis (OA) knees were performed. The deviations from the mechanical axis (MA) of the tibia when the guide rod was pointed toward the base of the MT2 or the distal part of the MT2 were measured.

Results The mean deviation from MA was $0.8^\circ \pm 2.1^\circ$ valgus (range 8.1° – 6.3° valgus) and $1.2^\circ \pm 2.9^\circ$ valgus (range 11.6° – 7.9° valgus) at the base of the MT2, and at the distal part of the MT2, respectively. The outlier rate when using the base of the MT2 was lower than when using the distal part of the MT2 (12.9 vs 32.3 %, $p = 0.0032$). The outlier rate was equivalent in OA and RA patients (n.s.). However, foot involvement in RA patients demonstrated a trend toward significance (base of MT2 $p = 0.078$, distal part of MT2 $p = 0.068$).

Conclusions The major clinical relevance was to raise caution about using the MT2. Surgeons should aim toward the base of the MT2, but avoid using it in RA patients with foot involvement. The accuracy of the MT2 is not high and it should be used only to supplement other landmarks.

Level of evidence II.

Keywords Total knee arthroplasty · Second metatarsal · Extramedullary cutting guide · Alignment

Introduction

The correct alignment of the implant components has been cited as the one of the most important aspects of a successful knee arthroplasty [2, 9, 12]. Although numerous bone and soft tissue landmarks have been advocated [5, 6, 15–17], it is difficult to align an extramedullary guide to the mechanical axis (MA) of the tibia [8, 10, 14]. The same is true for patient-specific positioning guides and it is recommended to perform the alignment check using anatomical landmarks before making the cuts [4, 14].

The second metatarsal (MT2) is a well-known distal landmark for the extramedullary tibial cutting guide in total knee arthroplasty (TKA). Most of the manufacturers' instruction manuals recommend that the alignment rod through the tibial cutting block should point to the MT2 when an extramedullary alignment check is performed. However, to our knowledge, there is no study on the accuracy of predicting proximal tibial cutting using the MT2 as a distal landmark for the extramedullary guide in TKA in RA patients or in osteoarthritis (OA) patients.

Because any rotational foot abnormality would affect the accuracy of the MT2 as a landmark for tibial cutting, it was hypothesized that the accuracy of the MT2 is not high, especially in RA patients whose foot joints are apt to be involved.

This study was conducted to answer the following questions. (1) How often do outliers occur when MT2 is used as a distal landmark for the extramedullary tibial cutting guide in TKA? (2) Is the accuracy of the predicted tibial cutting using MT2 as a landmark in RA patients inferior to that in OA patients? (3) Is the accuracy of the predicted tibial cutting affected by foot involvement in RA patients?

T. Tsukeoka (✉) · Y. Tsuneizumi · T. H. Lee
Department of Orthopaedic Surgery, Chiba Rehabilitation Center,
1-45-2 Hondacho, Midori-ku, Chiba 266-0005, Japan
e-mail: mddd940@ybb.ne.jp

Materials and methods

This computer simulation study involved a total of 93 knees: 45 knees in 39 consecutive female patients with OA and 48 knees in 34 consecutive female patients with RA. All patients with OA or RA who were candidates for primary TKA were considered for inclusion in this study. Exclusion criteria included evidence of trauma, infection, tumor, or any congenital disorder. The demographic data of the patients are shown in Table 1. For computed tomography (CT) scans, the patient was placed in the supine position on a table and the knee was extended while the ankle was maintained at 0° of flexion with a leg holder. Preoperative high-resolution CT scans of all the affected lower limbs, including the whole tibia and foot, were performed as a standard exam for TKA preoperative planning using a 16-detector CT unit (Toshiba Medical, Japan) in the helical mode in a 512 × 512 matrix, and setting slice thickness at 1 mm. Three-dimensional (3D) CT-based preoperative TKA planning software (ZedKnee® LEXI Co., Ltd., Tokyo, Japan) was used to determine the

tibial MA and perform the measurements. The tibial MA was defined as a straight line from the center of the appropriately sized tibial component without posterior slope to the center of the distal tibial plafond [17]. The AP axis of the tibia was defined as a straight line connecting the mid-posterior cruciate ligament (PCL) attachment with the medial edge of the patellar tendon attachment (Akagi line [1]).

For RA patients, the Larsen grades [11] were applied to each of the five joints related to the MT2 axis (i.e., ankle, subtalar, talonavicular, navicular–second cuneiform and second cuneiform–second metatarsal joints) using reconstructed CT images. Foot involvement was defined as a foot that had a Larsen grade 3 or a high-grade arthritic change in at least one of these five joints.

Two simulations were performed using the virtual extramedullary cutting guide, which was 8 cm long between the proximal fixation spike and the rod. The rotational alignment of the guide was the Akagi line and the rod was pointed toward (1) the base of the MT2 and (2) the distal part of the MT2 (Fig. 1). The spike of the extramedullary guide was affixed to the point of the plateau on the line that passed through the center of the keel and parallel to the component axis (Fig. 1a, b). The angle between the projected lines of the MA of the tibia and the longitudinal axis of the tibial cutting guide in the plane perpendicular to the Akagi line and the MA of the tibia was measured (Fig. 1c, d). A positive value indicated varus of the predicted tibial alignment. Preoperative TKA planning automatically measures the angle by dotting the reference points on reconstruction CT images (Fig. 2). To measure the test–retest reliability, each set of measurements was repeated on 20 randomly selected subjects with 6 months intervening. The outliers were defined as deviations >3° from the MA of the tibia [12]. The accuracy of the predicted tibial

Table 1 Demographic data of the patient groups

	RA	OA	<i>p</i> value
Patients (knees)	34 (48)	39 (45)	
Age (years) (SD)	64.1 (8.9)	74.2 (5.8)	<0.001
Height (cm) (SD)	153.3 (7.3)	150.5 (5.7)	0.049
Weight (kg) (SD)	56.1 (13.6)	56.7 (11.0)	n.s.
BMI (kg/m ²) (SD)	23.9 (5.4)	24.9 (4.2)	n.s.
Hip–Knee–Ankle angle (°) (SD)	3.7 (9.7)	11.4 (9.2)	<0.001

SD standard deviation, RA rheumatoid arthritis, OA osteoarthritis, n.s. non-significant

Fig. 1 Two simulations of the predicted tibial cutting using the Akagi line as the anteroposterior axis of the guide. **a** Figure as seen from above. **b** Lateral view. The alignment rod was pointed toward **c** the base of the second metatarsal (MT2) and **d** the distal part of the MT2. MA mechanical axis of the tibia

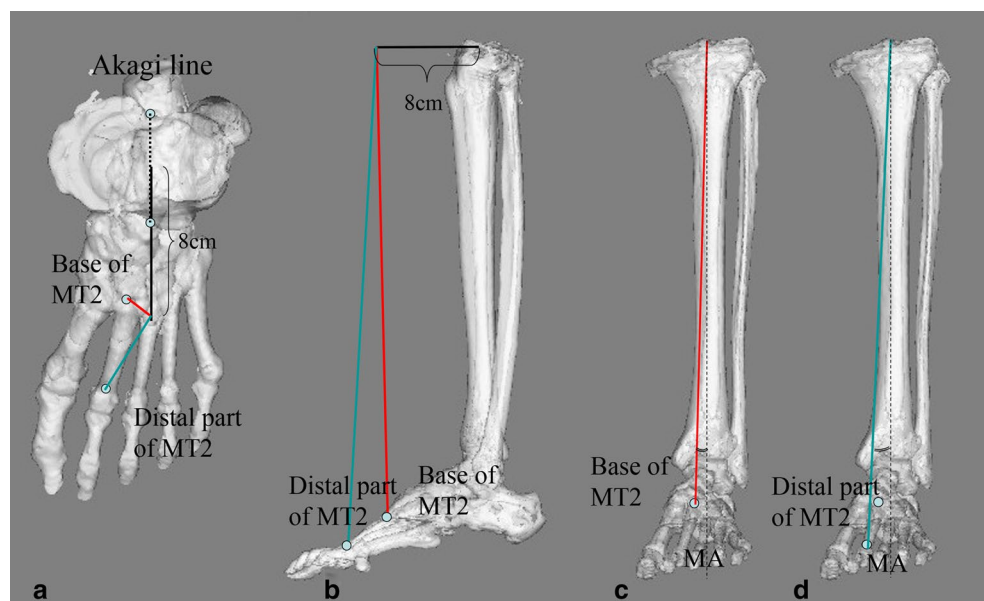




Fig. 2 Angle measurement by preoperative TKA planning. **a** Lateral view. **b** Anteroposterior view. **c** The plane including the distal part of the MT2

osteotomy using the MT2 as a landmark for the extramedullary cutting guide in RA patients with or without foot involvement was also evaluated. The angle between the MT2 axis and the Akagi line was measured. A positive value indicated that the MT2 axis was rotated externally compared with the Akagi line (Fig. 3). This study was approved by the Chiba Rehabilitation Center Institutional Review Board (ID number of approval: Iryou 24-5).

Statistical analysis

Chi square tests were used to analyze the differences in frequency of outlier occurrences between OA and RA groups. Paired *t* tests and Chi square tests were used to analyze the differences of predicted alignment and frequency of outlier occurrences between the base and distal part of the MT2, respectively. The frequencies of outlier occurrence and foot involvement in RA patients were analyzed by Fisher's exact tests. The relationship between the deviation from the MA and the angle between the MT2 and the Akagi line was analyzed by Pearson's correlation. A *p* value <0.05 was considered significant. A sample size calculation showed that for the Chi square tests, a total of 88 knees would allow detection of a moderate effect size ($\omega = 0.3$), with a power of 0.80 and $\alpha = 0.05$.

Results

The test–retest reliability coefficient was excellent (base of the MT2: 0.995; distal MT2: 0.993). The mean deviations

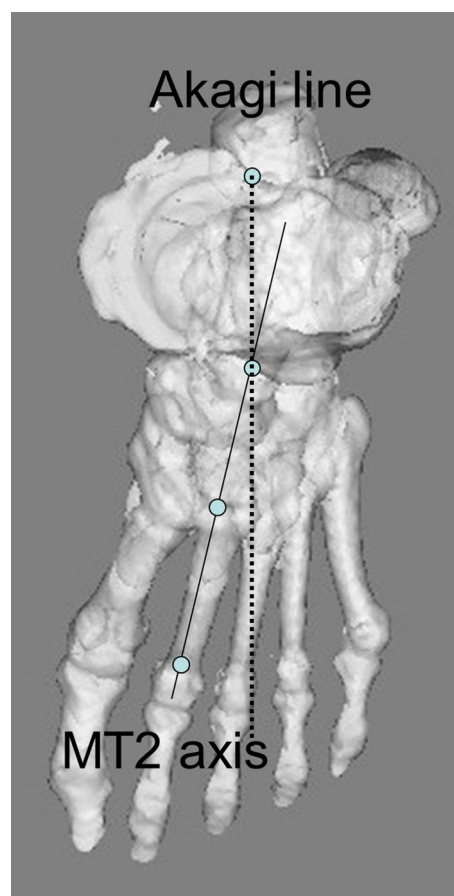


Fig. 3 The angle between the second metatarsal (MT2) axis and Akagi line

from the MA of each simulation are shown in Table 2. A wide range of variability was found in both OA (base of MT2: range 2.9° to −6.9°, distal part of MT2: range 4.5° to −7.9°) and RA patients (base of MT2: range 8.1° to −5.0°, distal part of MT2: range 11.6° to −6.1°), especially when using the distal part of the MT2 (Figs. 4, 5). Statistically significant differences between the base and the distal part of the MT2 were identified with respect to the outlier frequency.

No significant difference between OA and RA was found with respect to the outlier rate (base of MT2; 11.1 vs 14.6 %, n.s., distal part of MT2; 33.3 vs 31.3 %, n.s.). However, foot involvement in RA patients demonstrated a trend toward significance (base of MT2; *p* = 0.078, distal part of MT2; *p* = 0.068).

The mean angles between the MT2 axis and Akagi line (Fig. 2) were $-10.0^\circ \pm 10.8^\circ$ (−40.6° to 18.5°) and $-5.3^\circ \pm 16.5^\circ$ (−41.6° to 45.6°) in OA and RA patients, respectively. Significant positive correlations ($r = 0.84$, $p < 0.001$ for both the base of the MT2 and the distal part of the MT2) were found between the alignment deviation and the angle between the MT2 and the Akagi line.

Table 2 Predicted alignment of tibial cutting (degrees ± SD) and number of outliers

	Base of MT2		Distal part of MT2		<i>p</i> value	
	Predicted alignment	Number of outliers	Predicted alignment	Number of outliers	Predicted alignment*	Number of outliers**
OA <i>n</i> = 45	-1.5° ± 1.6°	5	-2.0° ± 2.2°	15	<0.001	0.011
RA <i>n</i> = 48	-0.2° ± 2.3°	7	-0.6° ± 3.3°	15	n.s.	n.s.
Total <i>n</i> = 93	-0.8° ± 2.1°	12	-1.2° ± 2.9°	30	0.0032	0.0016

SD standard deviation, OA osteoarthritis, RA rheumatoid arthritis, MA mechanical axis, MT2 second metatarsal, n.s. non-significant

* Paired *t* test, ** Chi square test

Fig. 4 Histogram of the deviation from the mechanical axis of the tibia when the alignment rod pointed toward the base of the second metatarsal (MT2)

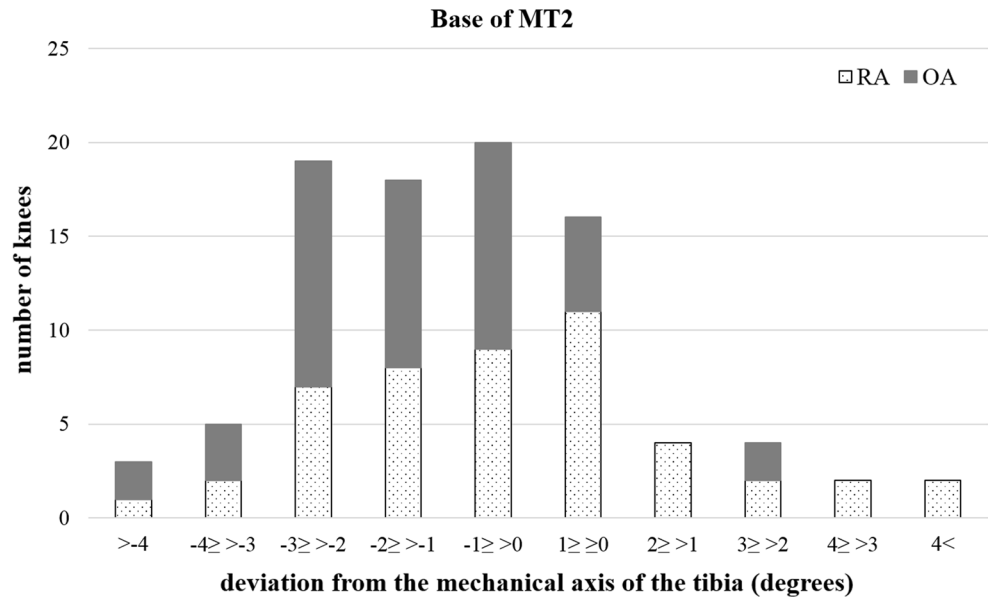
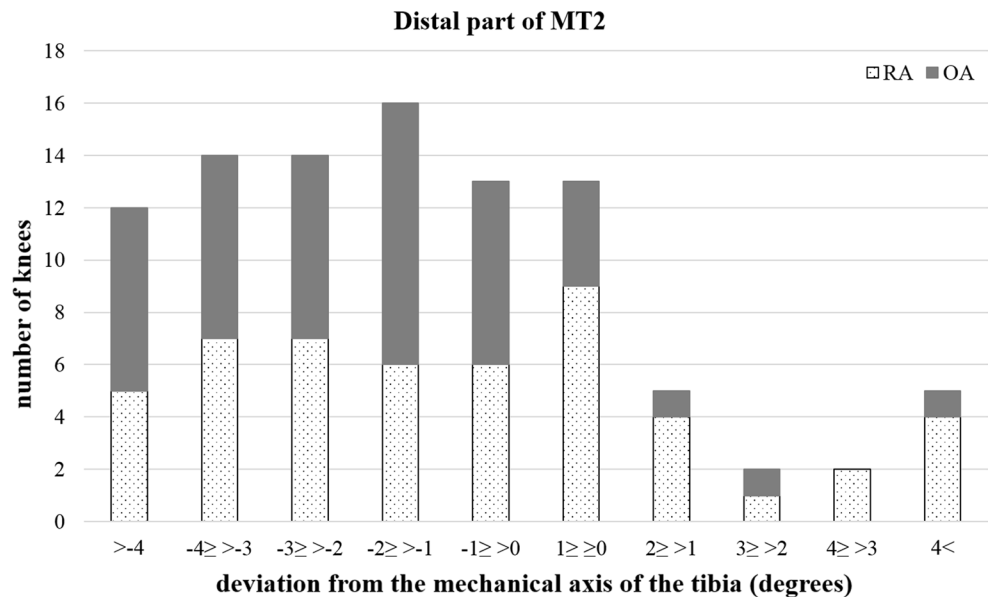


Fig. 5 Histogram of the deviation from the mechanical axis of the tibia when the alignment rod pointed toward the distal part of the second metatarsal (MT2)



Discussion

The main finding of this study was that the outlier rate was relatively high. Outlier rates of more than 10 % were found in both OA and RA groups when the guide was pointed toward the base of the MT2 and more than 30 % when it was pointed toward the distal part of the MT2. A second important finding was that there was no significant difference between OA and RA with respect to the outlier rate. However, foot involvement in RA patients has a negative effect on the predicted tibial cutting alignment.

Many authors have proposed distal landmarks, such as points 3–5 mm medial to the malleolar center [5], the tibialis anterior tendon [15] and the extensor hallucis longus [16], for the extramedullary cutting guide in TKA. A 5 mm difference in the horizontal plane causes $\leq 1^\circ$ change in the coronal alignment in patients with a 300 mm long tibia ($300 \text{ mm} \times \tan 1^\circ = 5.25 \text{ mm}$), so malalignment is not simply due to the difficulty of distal centering. The rotational mismatch between the proximal tibia and the ankle joint has a great impact on the accuracy of the proximal tibial cut in TKA [3, 13, 18]. This was not considered in these studies, or was there a clear definition of the AP axis at the ankle. If the definition of the AP axis changes, the distance between the projected ankle center on the skin and the points that are recommended as landmarks would also change (Fig. 6), but only by a small amount. The rotational error occurs mainly in the proximal tibia and is amplified by the distance between the bone and alignment rod [18]. Therefore, the outlier rate can be reduced by the surgeon's meticulous attention to avoid the rotational mismatch regardless of which distal landmark on the ankle is chosen. On the other hand, there may be a large rotational mismatch of the MT2 with the tibial AP axis, which is unavoidable because the MT2 is an extra-articular landmark. This rotational mismatch is amplified by the distance between the ankle center and the point used for measurement on the MT2. This is why the outlier rate was significantly lower when the alignment rod pointed toward the base of the MT2 than toward the distal part of the MT2.

Better landmarks than the MT2 have been identified in other studies [17, 18]. Using the middle one-third of the tibial crest [7, 17], a much lower outlier occurrence rate (2 %) should be possible. Another report found no outliers on the simulation TKA when the medial border of the tibial tubercle and the center of the distal soft tissue were used as the proximal and distal centers, respectively, and when the AP axis of the guide was matched to the Akagi line proximally and distally [18]. Considering the high outlier occurrence rate of over 10 %, the MT2 is not a useful landmark compared with these previously proposed landmarks. Furthermore, in a clinical setting, the foot is easy to rotate during surgery. This rotation may adversely affect the reliability of the MT2 as a landmark.

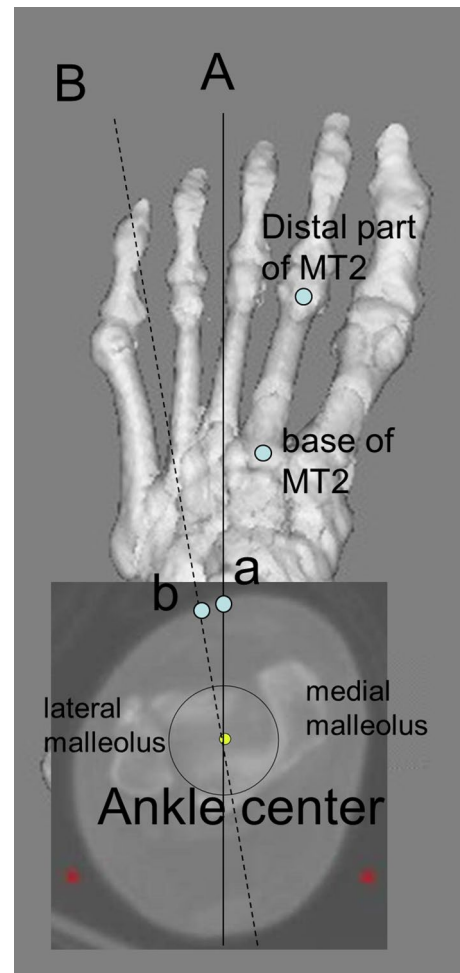


Fig. 6 If the definition of the AP axis at the ankle changes (from A to B), the projected ankle center on the skin would also change (from a to b)

This study has limitations. First, anatomical features may differ with the ethnic origin of patients. Because all subjects in this study were ethnically Japanese, the findings might be difficult to directly extrapolate to a patient population of a different ethnic origin. Second, the results were derived from a simulation using the CT image of the patient with the knee extended and the ankle maintained at 0° of flexion with a leg holder, which was different from the operative posture. Third, this study did not take into account the fact that the foot is easy to rotate and it may adversely affect the reliability of the MT2 as a landmark. Despite these limitations, the results demonstrated that the outlier rate of the predicted tibial osteotomy using MT2 as a landmark was not less than 10 %.

Most of the manufacturers' instruction manuals recommend the MT2 as a distal landmark in TKA, with no evidence of its accuracy. The results presented here serve to alert TKA surgeons to the possibility of outlier occurrence.

Conclusion

It has been demonstrated in this study that surgeons who use the MT2 as a landmark for the extramedullary tibial cutting guide in TKA should aim toward the base of the MT2, but avoid using it in RA patients with foot involvement. Moreover, they should be aware that the MT2 is a less accurate landmark in TKA than other previously reported landmarks. Therefore, the MT2 should not be used alone as a landmark for the extramedullary tibial cutting guide in TKA.

References

- Akagi M, Oh M, Nonaka T, Tsujimoto H, Asano T, Hamanishi C (2004) An anteroposterior axis of the tibia for total knee arthroplasty. *Clin Orthop Relat Res* 420:213–219
- Bargren JH, Blaha JD, Freeman MA (1983) Alignment in total knee arthroplasty. Correlated biomechanical and clinical observations. *Clin Orthop Relat Res* 173:178–183
- Cinotti G, Sessa P, Rocca AD, Ripani FR, Giannicola G (2013) Effects of tibial torsion on distal alignment of extramedullary instrumentation in total knee arthroplasty. *Acta Orthop* 84:275–279
- Conteduca F, Iorio R, Mazza D, Caperna L, Bolle G, Argento G, Ferretti A (2013) Evaluation of the accuracy of a patient-specific instrumentation by navigation. *Knee Surg Sports Traumatol Arthrosc* 21:2194–2199
- Dennis DA, Channer M, Susman MH, Stringer EA (1993) Intramedullary versus extramedullary tibial alignment systems in total knee arthroplasty. *J Arthroplast* 8:43–47
- Erdem M, Gulabi D, Cecen GS, Avci CC, Asci M, Saglam F (2014) Using fibula as a reference can be beneficial for the tibial component alignment after total knee arthroplasty, a retrospective study. *Knee Surg Sports Traumatol Arthrosc*. doi:10.1007/s00167-014-2957-x
- Fukagawa S, Matsuda S, Mitsuyasu H, Miura H, Okazaki K, Tashiro Y, Iwamoto Y (2011) Anterior border of the tibia as a landmark for extramedullary alignment guide in total knee arthroplasty for varus knees. *J Orthop Res* 29:919–924
- Iorio R, Bolle G, Conteduca F, Valeo L, Conteduca J, Mazza D, Ferretti A (2013) Accuracy of manual instrumentation of tibial cutting guide in total knee arthroplasty. *Knee Surg Sports Traumatol Arthrosc* 21:2296–2300
- Jeffery RS, Morris RW, Denham RA (1991) Coronal alignment after total knee replacement. *J Bone Jt Surg Br* 73:709–714
- Karade V, Ravi B, Agarwal M (2012) Extramedullary versus intramedullary tibial cutting guides in megaprosthesis total knee replacement. *J Orthop Surg Res* 7:33. doi:10.1186/1749-799X-7-33
- Larsen A, Dale K, Eek M (1977) Radiographic evaluation of rheumatoid arthritis and related conditions by standard reference films. *Acta Radiol Diagn (Stockh)* 18:481–491
- Lotke PA, Ecker ML (1977) Influence of positioning of prosthesis in total knee replacement. *J Bone Jt Surg Am* 59:77–79
- Mizu-uchi H, Matsuda S, Miura H, Higaki H, Okazaki K, Iwamoto Y (2006) The effect of ankle rotation on cutting of the tibia in total knee arthroplasty. *J Bone Jt Surg Am* 88:2632–2636
- Ng VY, DeClaire JH, Berend KR, Gulick BC, Lombardi AV Jr (2012) Improved accuracy of alignment with patient-specific positioning guides compared with manual instrumentation in TKA. *Clin Orthop Relat Res* 470:99–107
- Rajadhyaksha AD, Mehta H, Zelicof SB (2009) Use of tibialis anterior tendon as distal landmark for extramedullary tibial alignment in total knee arthroplasty: An anatomical study. *Am J Orthop* 38:E68–E70
- Schneider M, Heisel C, Aldinger PR, Breusch SJ (2007) Use of palpable tendons for extramedullary tibial alignment in total knee arthroplasty. *J Arthroplast* 22:219–226
- Tsukeoka T, Lee TH, Tsuneizumi Y, Suzuki M (2014) The tibial crest as a practical useful landmark in total knee arthroplasty. *Knee* 21:283–289
- Tsukeoka T, Tsuneizumi Y, Lee TH (2013) The effect of rotational fixation error of the tibial cutting guide and the distance between the guide and the bone on the tibial osteotomy in total knee arthroplasty. *J Arthroplast* 28:1094–1098