Archives of Orthopaedic and Trauma Surgery (2019) 139:1133–1139
https://doi.org/10.1007/s00402-019-03212-9

KNEE ARTHROPLASTY

Preoperative planned distance between the skin surface and the guide rod provides accurate posterior tibial slope in total knee arthroplasty

Tadashi Tsukeoka[1] · Yoshikazu Tsuneizumi[1] · Kensuke Yoshino[2]

Received: 28 October 2018 / Published online: 27 May 2019

Abstract

Background Although sagittal tibial alignment in total knee arthroplasty (TKA) is important, no landmark exists to achieve reproducible slope. It is theoretically demonstrated that the preoperative planned distance between the skin surface and the rod can be a useful guide for the tibial slope in the previous imaging study. We conducted this retrospective study to confirm whether the results of the study are repeatable in an intra-operative situation.

Methods Fifty-five consecutive TKAs using the distance from the extramedullary cutting guide rod to the skin surface as a reference guide for the tibial slope were performed and tibial component positioning was compared with 55 knees performed using the accelerometer-based portable navigation. The tibial component alignment was evaluated with a computed tomography (CT)-based three-dimensional (3D) software.

Results The absolute mean deviation from the targeted slope in the proposed method was significantly smaller than the portable navigation (1.0° and 1.7°, respectively, $p=0.0025$). The outlier rate beyond 3° was 0% in the proposed technique (16.4% in the portable navigation, $p=0.0014$).

Conclusions The preoperative planned distance between the skin surface and the guide rod is a useful technique to provide accurate posterior tibial slope in TKA.

Keywords Preoperative planning · Three dimensional (3D) · Total knee arthroplasty (TKA) · Posterior tibial slope · Accelerometer-based navigation

Introduction

Total knee arthroplasty (TKA) survivorship depends upon proper alignment of the limb and prosthesis. Several studies have correlated poor outcomes with coronal malalignment of the components [1–3]. Proper sagittal tibial alignment is also important, as the tibial slope affects stability, range of motion, and contact pressure within the tibiofemoral joint in total knee arthroplasty (TKA) [4–9]. While numerous bone and soft-tissue landmarks for coronal tibial alignment have been advocated and well discussed [10–15], for posterior slope cut, no good anatomic landmark currently exists and it has been poorly discussed how to perform the cut as planned in the literature. It has been demonstrated that computer-assisted surgery (CAS) has improved the accuracy of the alignment of the implant [16–19]. Recently, navigation systems have been developed using accelerometer electronic components. The KneeAlign 2 (KA2; OrthAlign Inc, Aliso Viejo, California) system for TKA is a handheld accelerometer-based navigation device, which seeks to combine the accuracy of CAS techniques with the ease of use of conventional alignment methods [20]. The previous study has reported that this device places 95% of components within ± 2° of a 3° of posterior slope [21].

It is theoretically demonstrated that the distance between the skin surface and the guide rod can be a useful guide for the posterior slope of the tibia [22]. Preoperative CT-based planning software for TKA (ZedKnee) enables to plan the distance between the skin surface and the extramedullary tibial rod to parallelize the rod to the mechanical axis of the tibia. However, there is a doubt whether the alignment rod is placed as planned in an intra-operative situation,

✉ Tadashi Tsukeoka
mdddd940@ybb.ne.jp

1 Department of Orthopaedic Surgery, Chiba Rehabilitation Center, 1-45-2 Hondacho, Midori-ku, Chiba 266-0005, Japan

2 Department of Orthopaedic Surgery, Chiba University, Chiba, Japan

because the soft-tissue depth under the skin may change by patient's condition and leg position. Many studies have demonstrated that conventional instrumentation fails to achieve optimal accuracy in the positioning of the tibial component. Therefore, we should do something to improve the accuracy. Considering the cost and operative time, we decided to use two different techniques, the accelerometer-based navigation and the conventional technique with meticulous three-dimensional planning including preoperative planned distance between the skin surface and the guide rod for posterior slope of the tibia to achieve proper alignment after total knee arthroplasty. In this study, we compared these two techniques in regard to the accuracy of postoperative tibial component alignment to determine which technique provides more accurate positioning of the tibial component in TKA performed by mid-volume surgeons. We hypothesized that KA2 system is still more accurate method in obtaining the targeted alignment as compared with the conventional technique with the preoperative planned placement of the extramedullary guide rod.

Materials and methods

This study is a retrospective review of the computed tomographic (CT) results from an institutional review board-approved database. We had two different teams, one of them performed TKA with navigation systems and another performed TKA with preoperative planned TKA technique. Each team had their own patients and decided to perform TKA independently. From December 2014 to September 2016, 44 consecutive patients (10 male and 34 female) received a conventional TKA using the distance from the extramedullary cutting guide rod to the skin surface as a reference guide for the tibial slope (preoperative planned conventional TKA). Eleven patients underwent bilateral TKAs, for a total of 55 knees in conventional cohort. All surgeries in this cohort were performed by the senior author (T.T.) using Persona® CR knee system (Zimmer, Warsaw, Ind). KA2 TKAs were performed between June 2014 and August 2015. Forty-eight patients (5 male, 43 female) were included in this KA2 cohort. Seven patients underwent bilateral TKAs, for a total of 55 knees in the KA 2 cohort. In the KA 2 cohort, the surgery was performed by the two mid-volume (30–60 TKAs per year) surgeons (44 knees by T.L. and 11 knees by Y.T.) using Vanguard® CR knee system (Biomet, Warsaw, Ind). Inclusion criteria were patients with a history of osteoarthritis or rheumatoid arthritis who received a primary TKA. Patients were excluded if they had post-traumatic arthritis or if they required the use of tibial stem extension.

The preoperative knee alignment was assessed by the Hip–Knee–Ankle angle (HKA angle; positive values indicate varus alignment) measured on a full-length weight-bearing X-ray in the standing position. All patients in both cohorts were subjected to CT scan of the entire lower extremity before and after surgery. For 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. Three-dimensional (3D) CT-based preoperative TKA planning software (ZedKnee® LEXI Co., Ltd., Tokyo, Japan) was used to determine the tibial mechanical axis (MA) and to perform the measurements. The tibial MA was defined as a straight line from the center of the appropriate-sized tibial component without the posterior slope to the center of the distal tibial plafond [14]. 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 [23]). In the conventional cohort, the digital 3D preoperative planning software was used in measuring the resection depth of the medial and lateral tibial plateau, the positional relationship between the mechanical axis of tibia and the tibial crest, rotational alignment in tibia. At the same time, the distance between the simulated extramedullary rod and the skin surface was also measured for tibial posterior slope (Fig. 1). The plane including the most anterior point of the predicted tibial cut surface (10 mm below the unaffected side) and parallel to the MA of tibia in the sagittal plane was made (Plane A, Fig. 1b, c). Then, the distance (D) between skin surface 18 cm distal to the predicted cut surface and the Plane A was measured (Fig. 1d). The distance between the cutting slit and the end of the proximal extramedullary tube was 18 cm; therefore, we choose 18 cm as reference point. The depth of the cutting block was about 33 mm (32.64 mm). Therefore, to parallelize the guide rod to the MA of tibia in the sagittal plane, the guide rod was fixed at a distance of 33 mm-*D* mm from the skin (Fig. 1b). This preoperatively planned distance (33-*D* mm) was used intraoperatively (Fig. 1a). Our targeted posterior slope was 7° and we used 7° inbuilt-in cutting slot block. If there was a gap between the cutting block and the bone, the gap was measured and the distal distance between the rod and the skin surface was adjusted considering this distance.

The coronal positioning of the cutting block was determined by adjusting the alignment guide to be parallel to the anterior tibial crest [14] which was confirmed by palpation and the preoperative planned cutting level of the medial plateau was used for reference as well.

The technique used for implementing the KA 2 system has been previously described [16]. Targets for the proximal tibial osteotomy were 0° in the coronal plane (perpendicular to the mechanical axis of the tibia) and 3° of posterior slope in the sagittal plane.

The postoperative CT was co-registered to the preoperative CT by a surface-matching algorithm to overlap the

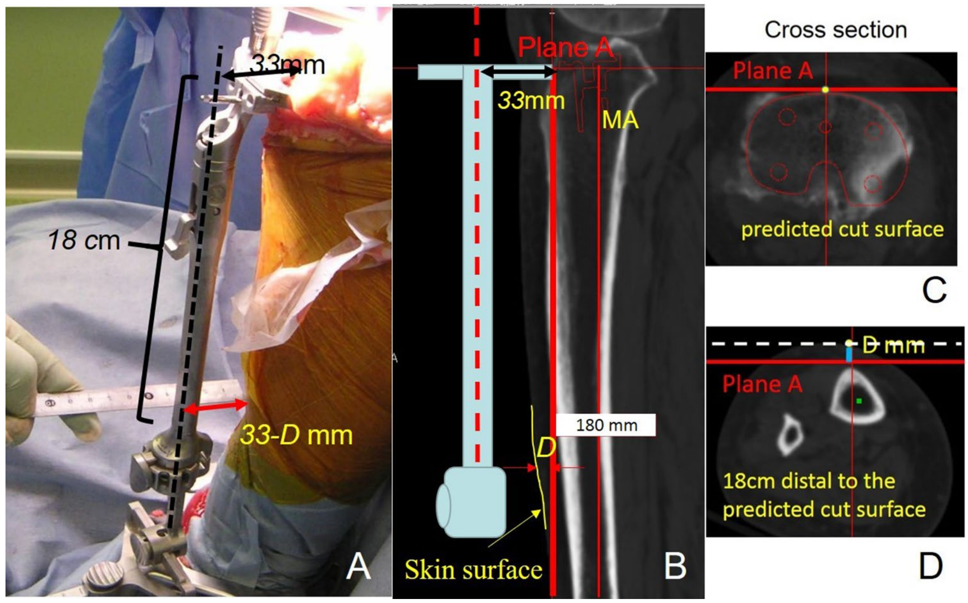

Fig. 1 Plane A including the most anterior point of the predicted tibial cut surface and parallel to the MA of tibia in the sagittal plane was made (**b**, **c**). Then, the distance (*D*) between skin surface 18 cm distal to the predicted cut surface and the Plane A was measured (*D*). The depth of the cutting block was 33 mm. Therefore, to parallelize the guide rod to the MA of tibia in the sagittal plane, the guide rod was fixed at a distance of 33 mm-*D* mm from the skin (**a**, **b**)

pre- and postoperative tibia at the same axis of coordinates in both cohorts by the postoperative alignment evaluation function of the pre-operative planning software, ZedKnee® (Fig. 2a). The tibial component positions were obtained using a CAD-model-based shape-matching technique and the deviation from the targeted tibial component position was measured in the coronal and sagittal planes (Fig. 2b). The relationships between the deviation from the targeted slope and body mass index (BMI) or height were also investigated.

This study was approved by our Institutional Review Board.

Statistical analysis

Continuous data were summarized as means with standard deviations (SD) and ranges, and comparisons between the two cohorts were performed using a Student's *t* test (one tailed or two tailed). Fisher's exact test was used to analyze occurrence of outliers. Pearson's correlation coefficient was used to measure the degree of relationship between the

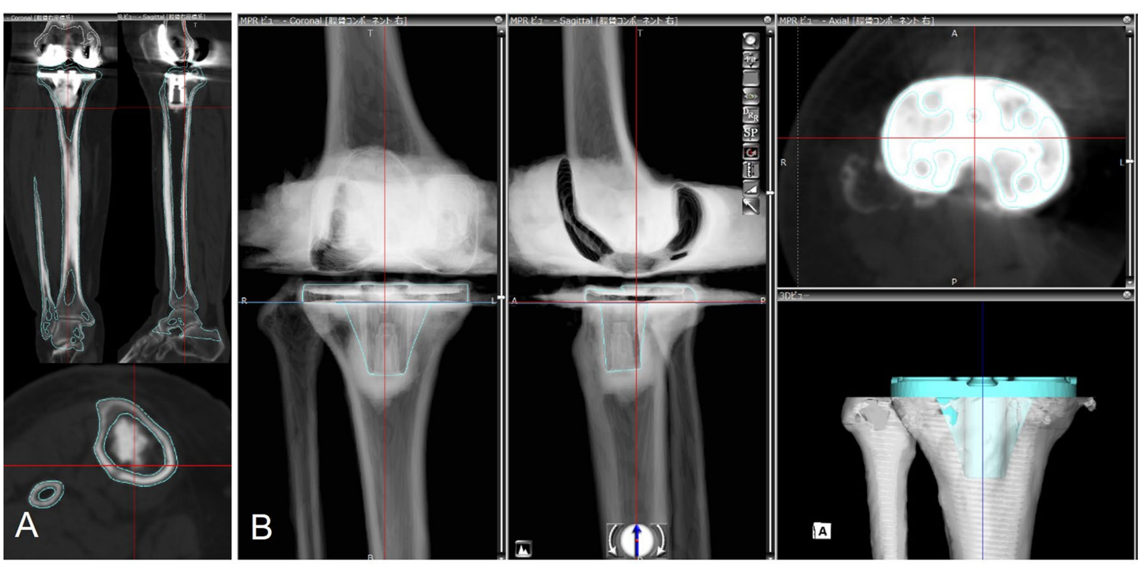

Fig. 2 Postoperative tibial component positioning measurements. **a** Post-operative tibia was overlapped the pre-operative tibia at the same axis of coordinates. **b** Digital reconstructed radiographs were used for the coronal and the sagittal component positioning to reduce the effect of the halation of the implant. Tibial rotation was determined by the backside structure of the component as references

Table 1 Preoperative demographics

	Preoperative planned conventional cohort	KneeAlign 2 cohort	*p* value
Patients (knees)	44 (55)	48 (55)	
Age (years)	74.4 ± 6.4	73.9 ± 8.2	0.74
Height (cm)	153.1 ± 8.1	150.5 ± 7.0	0.10
BMI (kg/m^2)	27.0 ± 4.5	27.0 ± 4.2	0.96
Preoperative HKA angle (°)	11.3 ± 7.6	8.8 ± 8.2	0.09

All values presented as mean ± SD (positive value indicates varus)

BMI body mass index, *HKA angle* hip–knee–ankle angle

Table 2 Coronal alignment

	Preoperative planned conventional cohort	KneeAlign2 cohort	*p* value
Mean absolute deviation from the targeted angle	1.3° ± 1.1°	1.1° ± 1.0°	0.34
Outlier rate (> 2°)	16.4%	20.0%	0.40
Outlier rate (> 3°)	3.6%	5.5%	0.5

deviation from the targeted slope and BMI or height. A *p* value of less than 0.05 was considered significant. A priori sample size analysis with a one tailed Student's *t* test determined that 51 knees were needed to detect a moderate effect size ($d = 0.50$), with a power of 0.80 and an alpha of 0.05. Statcel 2 (OMS Inc. Japan) was used for all statistical analyses. G*Power 3 software (Heinrich Heine University, Dusseldorf, Germany) was used for power analyses. To test intra- and interobserver reliability, each set of postoperative measurements of the tibial component alignment was repeated three times on 30 randomly selected subjects by two of the authors (T.T. and K.Y.). The measurements were considered reliable if the interclass correlation coefficient (ICC) was calculated more than 0.80.

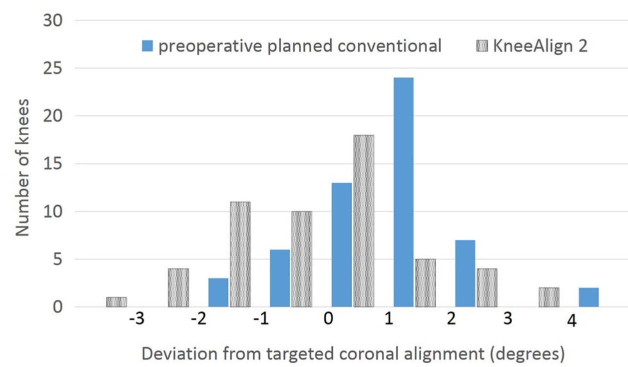

Fig. 3 Histogram of the deviation from the targeted coronal tibial component alignment (positive value indicates varus alignment)

Results

Measurement reliability was excellent for the postoperative tibial alignment. The intraobserver and interobserver mean ICC of coronal tibial alignment was 0.93, with a mean absolute difference of 0.35° (SD 0.262°) and 0.97, with a mean absolute difference of 0.25° (SD 0.18°), respectively. The intraobserver and interobserver mean ICC of sagittal tibial alignment was 0.82, with a mean absolute difference of 0.50° (SD 0.62°) and 0.92, with a mean absolute difference of 0.41° (SD 0.38°), respectively.

There were no statistical significant differences with regard to the preoperative patient age, height, body mass index, preoperative alignment when comparing the preoperative planned conventional and KA2 cohorts (Table 1).

Table 2 and Fig. 3 show the postoperative tibial component alignment in the coronal plane. There was no significant difference between the preoperative planned conventional and KA2 cohort with regard to the mean deviation from the targeted angle and outlier rates in the coronal plane. Table 3 and Fig. 4 show the postoperative tibial slope. Contrary to our hypothesis, preoperative planned conventional TKA provided more accurate sagittal alignment than KA2. We found no significant relationship between the deviation from the targeted slope and BMI ($r = 0.14$, $p = 0.34$) or height ($r = 0.08$, $p = 0.56$).

Discussion

The main finding of this study was that the preoperative planned conventional TKA was highly accurate in achieving the targeted tibial slope. Surprisingly, the KA2 cohort

Table 3 Tibial slope

	Preoperative planned conventional cohort	KneeAlign2 cohort	*p* value
Mean absolute deviation from the targeted angle	1.0° ± 0.7°	1.7° ± 1.5°	0.0025
Outlier rate (> 2°)	10.9%	36.4%	0.0015
Outlier rate (> 3°)	0%	16.4%	0.0014

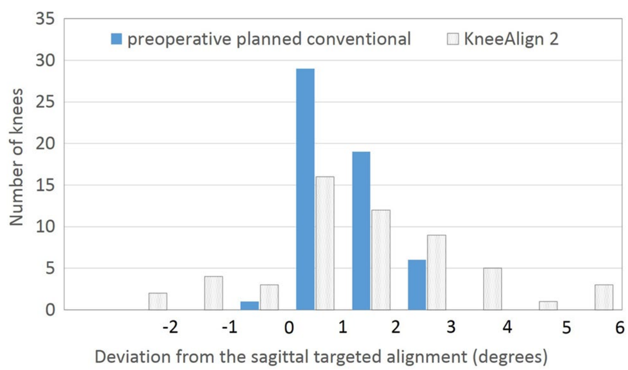

Fig. 4 Histogram of the deviation from the targeted sagittal tibial component alignment. (positive value indicates posterior slope)

Table 4 Studies reporting outlier rate of the tibial component in total knee arthroplasty using KneeAlign 2 (KA2) system

	Number of knees	Coronal outlier rate (%)		Sagittal outlier rate (%)	
		> 2°	> 3°	> 2°	> 3°
Nam [21]	47	4.3	NA	5.0	NA
Bugbee [25]	90	NA	6.7	NA	4.5
Iorio [26]	50	4	0	6	0
Huang [27]	53	15.1	3.8	NA	5.7
Steinhaus [28]	49	NA	0	NA	18.4
Fujimoto [29]	48 (early group) 61 (late group)	NA	8.3 3.3	NA	14.6 9.8
Gharaibeh [30]	89	11.2	2.2	6.7	2.2

NA not available

was less accurate than the planned conventional TKA cohort with regard to tibial slope.

Cheng et al. [19] performed a meta-analysis of 41 studies comparing CAS to conventional techniques in TKA. The authors found a significantly better coronal tibial alignment for the CAS group; however, they concluded that further study is needed to determine whether surgeons could use CAS to achieve a targeted tibial slope in TKAs. Nam et al. [20] reported that there was no statistically significant difference in postoperative tibial component coronal alignment between KA2 and CT-free navigation system. Nam et al. [21] also demonstrated that KA2 provides better tibial alignment compared to conventional instruments. Although encouraging evidence has been reported with the use of KA2 in restoration of tibial component positioning [24], there was a wide range of outliers in the coronal and the sagittal plane (Table 4 [21, 25–30]). This study demonstrates that good coronal tibial alignment can be obtained with both the KA2 and the preoperative planned conventional TKA. The use of the anterior tibial crest and the presumed medial resection depth was considered to contribute to the accuracy of the component positioning in the coronal plane in the preoperative planned conventional TKA cohort. In the sagittal plane, the KA2 cohort was less accurate than the planned conventional TKA cohort. In the preoperative planned conventional TKA, because the proximal cutting block can be fixed to the bone under direct vision, the error occurs mainly only at the distal side which has the least soft tissue unlike other previously reported landmarks such as fibula axis and the anterior tibial crest which have the soft tissue in both proximal and distal end. In addition, the depth of the soft tissue was considered by 3D preoperative planning and a 3 mm difference causes only 1° or less change of the posterior slope (180 mm × tan 1° = 3.15 mm). Therefore, the preoperative planned conventional TKA was highly accurate in achieving the targeted slope of the tibial component even in obese patients. In contrast, posterior slope for the KA2 is determined relative to the overall mechanical axis of the tibia, which is defined by the center of the anterior cruciate ligament footprint proximally and the center of the tibial plafond distally, as approximated through weighted interpolation between points registered on the medial and lateral malleoli [21]. Therefore, the registration error can be one of the causes of the sagittal outlier. Another possible reason for the relatively high sagittal outlier rate in KA2 cohort was the cutting error, because KA2 system just provides cutting block orientation.

The present study has several limitations. First, it was retrospective and includes a small number of subjects treated by different surgeons with different implants. However, patients were matched with similar baseline characteristics, and no clear learning curve effect was observed regarding the accuracy of implantation in the sub-analysis in KA 2 cohort. On the contrary, the outlier rate in the late group was significantly worse than in the early group (Surgeon

T.L.'s outlier rates beyond 2° in the first 22 knees and next 22 knees were 18.2% and 59.1%, respectively, $p=0.006$, and outlier rates beyond 3° were 0% and 31.8%, respectively, $p=0.013$). There was no statistically significant difference in regard to outlier rate between both KA 2 surgeons. Second, the cutting error has to be taken into consideration, because KA 2 system just provides cutting block orientation. Therefore, our results performed by mid-volume surgeons (30–60 TKAs per year) might be difficult to directly extrapolate to TKA performed by high-volume TKA surgeons. Third, CT-based 3D preoperative planning software was used for the preoperative planning. However, thanks to the development of the digital imaging technology, we can find the distinct contour of the skin surface even in the plain X-ray. Therefore, we believe that preoperative planning for this technique can be performed in the plain X-ray. Further studies are needed to confirm whether the same accuracy as this study can be obtained by the preoperative planning by the plane X-ray.

Recently, a modified conventional technique of pre-operatively planned placement of intramedullary rod is reported as an equal to or more accurate method than the accelerometer-based navigation in positioning the femoral component in TKA at a mid-volume hospital [31]. Considering the results of the present study, 3D-planned conventional technique can be an alternative to the accelerometer-based navigation system in the mid-volume hospital.

Conclusion

The preoperative planned distance between the skin surface and the guide rod is a useful technique to provide accurate posterior tibial slope in TKA.

Compliance with ethical standards

Conflict of interest The authors declare that they have no competing interests.

References

1. Bargren JH, Blaha JD, Freeman MA (1983) Alignment in total knee arthroplasty. Correlated biomechanical and clinical observations. Clin Orthop 173:178.
2. Jeffery RS, Morris RW, Denham RA (1991) Coronal alignment after total knee replacement. J Bone Joint Surg Br 73B:709
3. Lotke PA, Ecker ML (1977) Influence of positioning of prosthesis in total knee replacement. J Bone Joint Surg Am 59A:77
4. Whiteside LA, Amador DD (1988) The effect of posterior tibial slope on knee stability after Ortholoc total knee arthroplasty. J Arthroplasty 3(Suppl 1):51–57
5. Bellemans J, Robijns F, Duerinckx J, Banks S, Vandenneucker H (2005) The influence of tibial slope on maximal flexion after total knee arthroplasty. Knee Surg Sports Traumatol Arthrosc 13:193–196
6. Massin P, Gournay A (2006) Optimization of the posterior condylar offset, tibial slope, and condylar roll-back in total knee arthroplasty. J Arthroplast 21:889–896
7. Singh G, Tan JH, Sng BY, Awiszus F, Lohmann CH, Nathan SS (2013) Restoring the anatomical tibial slope and limb axis may maximise post-operative flexion in posterior-stabilised total knee replacements. Bone Joint J 95(10):1354–1358
8. Wasielewski RC, Galante JO, Leighty RM, Natarajan RN, Rosenberg AG (1994) T Wear patterns on retrieved polyethylene tibial inserts and their relationship to technical considerations during total knee arthroplasty. Clin Orthop Relat Res 299:31–43
9. Jojima H, Whiteside LA, Ogata K (2004) Effect of tibial slope or posterior cruciate ligament release on knee kinematics. Clin Orthop Relat Res 426:194–198
10. Dennis DA, Channer M, Susman MH, Stringer EA (1993) Intramedullary versus extramedullary tibial alignment systems in total knee arthroplasty. J Arthroplast 8:43–47
11. Erdem M, Gulabi D, Cecen GS, Avci CC, Asci M, Saglam F (2015) 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 23(7):2068–2073
12. Rajadhyaksha AD, Mehta H, Zelicof SB (2009) Use of tibialis anterior tendon as distal landmark for extramedllary tibial alignment in total knee arthroplasty: an anatomical study. Am J Orthop 38:E68–70
13. Schneider M, Heisel C, Aldinger PR (2007) Breusch SJ (2007) Use of palpable tendons for extramedullary tibial alignment in total knee arthroplasty. J Arthroplast 22:219–226
14. Tsukeoka T, Lee TH, Tsuneizumi Y, Suzuki M (2014) The tibial crest as a practical useful landmark in total knee arthroplasty. Knee 21(1):283–289
15. Tsukeoka T, Tsuneizumi Y, Lee TH (2014) Accuracy of the second metatarsal as a landmark for the extramedullary tibial cutting guide in total knee arthroplasty. Knee Surg Sports Traumatol Arthrosc 22(12):2969–2974
16. Confalonieri N, Manzotti A, Pullen C, Ragone V (2005) Computer-assisted technique versus intramedullary and extramedullary alignment systems in total knee replacement: a radiological comparison. Acta Orthop Belg. 71(6):703–709
17. Manzotti A, Pullen C, Confalonieri N (2008) Computer-assisted alignment system for tibial component placement in total knee replacement: a radiological study. Chir Organi Mov. 91(1):7–11
18. Pang CH, Chan WL, Yen CH, Cheng SC, Woo SB, Choi ST et al (2009) Comparison of total knee arthroplasty using computer-assisted navigation versus conventional guiding systems: a prospective study. J Orthop Surg (Hong Kong) 17(2):170–173
19. Cheng T, Zhao S, Peng X, Zhang X (2012) Does computer-assisted surgery improve postoperative leg alignment and implant positioning following total knee arthroplasty? A meta-analysis of randomized controlled trials? Knee Surg Sports Traumatol Arthrosc 20(7):1307–1322
20. Nam D, Weeks KD, Reinhardt KR, Nawabi DH, Cross MB, Mayman DJ (2013) Accelerometer-based, portable navigation vs imageless, large-console computer-assisted navigation in total knee arthroplasty: a comparison of radiographic results. J Arthroplast 28(2):255–261
21. Nam D, Cody EA, Nguyen JT, Figgie MP, Mayman DJ (2014) Extramedullary guides versus portable, accelerometer-based navigation for tibial alignment in total knee arthroplasty: a randomized, controlled trial: winner of the 2013 HAP PAUL award. J Arthroplast 29(2):288–294

22. Tsukeoka T, Tsuneizumi Y (2016) The distance from the extramedullary cutting guide rod to the skin surface as a reference guide for the tibial slope in total knee arthroplasty. Knee 23(2):314–317
23. 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
24. Nam D, Cross M, Deshmane P, Jerabek S, Kang M, Mayman DJ (2011) Radiographic results of an accelerometer-based, handheld surgical navigation system for the tibial resection in total knee arthroplasty. Orthopedics 34(10):e615–e621
25. Bugbee WD, Kermanshahi AY, Munro MM, McCauley JC, Copp SN (2014) Accuracy of a hand-held surgical navigation system for tibial resection in total knee arthroplasty. Knee 21(6):1225–1228
26. Iorio R, Mazza D, Drogo P, Bolle G, Conteduca F, Redler A, Valeo L, Conteduca J, Ferretti A (2015) Clinical and radiographic outcomes of an accelerometer-based system for the tibial resection in total knee arthroplasty. Int Orthop 39(3):461–466
27. Huang EH, Copp SN, Bugbee WD (2015) Accuracy of a handheld accelerometer-based navigation system for femoral and tibial resection in total knee arthroplasty. J Arthroplasty 30(11):1906–1910
28. Steinhaus ME, McLawhorn AS, Richardson SS, Maher P, Mayman DJ (2016) Handheld navigation device and patient-specific cutting guides result in similar coronal alignment for primary total knee arthroplasty: a retrospective matched cohort study. HSS J 12(3):224–234
29. Fujimoto E, Sasashige Y, Nakata K, Yokota G, Omoto T, Ochi M (2017) Technical considerations and accuracy improvement of accelerometer-based portable computer navigation for performing distal femoral resection in total knee arthroplasty. J Arthroplasty 32(1):53–60
30. Gharaibeh MA, Solayar GN, Harris IA, Chen DB, MacDessi SJ (2017) Accelerometer-based, portable navigation (KneeAlign) vs conventional instrumentation for total knee arthroplasty: a prospective randomized comparative trial. J Arthroplasty 32(3):777–782
31. Tsukeoka T, Tsuneizumi Y, Yoshino K (2019) An accelerometer-based navigation did not improve the femoral component positioning compared to a modified conventional technique of preoperatively planned placement of intramedullary rod in total knee arthroplasty. Arch Orthop Trauma Surg. 139(4):561–567