Postoperative radiologic outcome comparison between conventional and computer-assisted navigation total knee arthroplasty in extra-articular tibia vara

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Abstract
Purpose: Total knee arthroplasty (TKA) is the definite treatment for osteoarthritis. Meanwhile, significant inherent extra-articular varus angulation is associated with abnormal postoperative hip–knee–ankle (HKA) angle. Computer-assisted navigation TKA (CAS-TKA) used in patients who have severe varus deformity. The purpose of this study was to compare postoperative radiologic outcome between CAS-TKA and conventional TKA for extra-articular tibia vara.
Methods: A retrospective review of postoperative HKA on standing lower extremity views was conducted in patients who underwent TKA by a single surgeon from 2010 to 2018, including knee with conventional TKA (n = 83) and CAS-TKA (n = 246). Extra-articular tibia vara was assessed by measuring the metaphyseal–diaphyseal angle (MDA) of the tibia in preoperative standing lower extremity view. Postoperative alignment was assessed by measuring the HKA in postoperative standing lower extremity view.
Results: There was no significant difference in age (p = 0.063), gender (p = 0.628), body mass index (p = 0.426), preoperative range of motion (p = 0.524), preoperative HKA (p = 0.306), preoperative MDA (p = 0.523), or postoperative HKA (p = 0.416) between the two groups (conventional TKA and CAS-TKA). There was no significant difference in postoperative alignment for cases with MDA \(\leq 4\) (p = 0.351) or MDA >4 (p = 0.866) in each group. There was a positive correlation between preoperative HKA and postoperative HKA in the CAS-TKA group (p < 0.001, r = 0.243). However, there was no significant correlation between preoperative HKA and postoperative HKA in the conventional TKA group (p = 0.732). Conclusions: There was no significant difference in postoperative alignment between conventional TKA and CAS-TKA in extra-articular tibial vara even for cases with MDA >4.

Keywords
arthroplasty, computer-assisted, knee, replacement, surgery

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Introduction
Total knee arthroplasty (TKA) is the definite treatment for osteoarthritis. One goal of using surgical technique in TKA is to create symmetric balanced flexion and extension gaps.1 To achieve this goal, gap balancing technique and measured resection technique have been used to determine component position.2 Failure to correct malalignment of

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the mechanical axis of the lower extremity will shorten the longevity of TKA.\(^3\)

Extra-articular angulation of the proximal tibia may lead to difficulties in correct implant alignment due to distorted anatomic alignment and landmarks.\(^4,5\) Saibaba et al. have reported that significant extra-articular varus angulation of metaphyseal–diaphyseal angle (MDA) greater than 4° is associated with abnormal postoperative hip–knee–ankle (HKA) angle.\(^6\)

In recent years, computer-assisted navigation TKA (CAS-TKA) has become more popular because it could lead to better accuracy in implanting the prosthesis and realigning lower extremities.\(^7\) Literature data have shown that CAS-TKA can increase the accuracy of proximal tibial cut with the capability to track independent lengthening and shortening collateral ligaments to facilitate sizing of a femoral component that can properly tense these ligaments through a full range of motion (ROM).\(^8,9\) CAS-TKA is effective in assisting surgeons to obtain more accurate alignment in cases with extra-articular tibia vara.\(^10\) However, some authors have reported that CAS-TKA cannot improve alignment in extra-articular tibia vara.\(^11,12\) The purpose of this study was to compare postoperative radiologic outcome between CAS-TKA and conventional TKA for cases with extra-articular tibia vara.

**Materials and methods**

**Patients**

Data of patients who underwent primary TKA were reviewed retrospectively. Inclusion criteria were a primary cemented TKA using Columbus\(^®\) (B. Braun, Melsungen, Germany) implant performed between 2010 and 2018 in our institute by a single surgeon. If a patient underwent TKA on both knees, then both sides of the knee were analyzed. Total 699 knees were enrolled. Exclusion criteria were previous knee surgery, inflammatory arthritis, and missing preoperative or postoperative standing lower extremity view. This series included 235 patients and 329 knees. Of these 235 patients, 215 were females and 20 were males. Their mean age was 72.87 years (95% confidence interval = 72.14–73.60 years; range 53–94 years). The preoperative mean ROM was 107°. If the navigation system was available, the CAS-TKA was performed using navigation system. When the navigation system was being used by another surgeon or system failure, the conventional TKA was performed. A total of 246 (75%) TKAs were performed using computer-assisted navigation system OrthoPilot\(^®\) (B. Braun). The number of conventional TKA was 83 (25%). This research has been approved by the Institutional Review Board of the authors’ affiliated institution (protocol number: KBSMC 2018-06-020).

**Surgeon factors and surgical techniques**

The surgeon (H-JJ) was in a high-volume center and he performed more than 3000 cases of TKA in over 30 years including CAS-TKA. Paramedial incision and subvastus arthrotomy were performed using air tourniquet at 300 mmHg under general or spinal anesthesia. After bone resection according to navigation or conventional system, all implants were fixed with cement.

**Navigation system technique.** Kinematic and the required anatomical selected points were registered. Then, the lower extremity alignment by navigation in knee extension (0°) and knee flexion (90°) position was recorded. The osteophytes, anterior, posterior cruciate ligaments, and medial meniscus were removed. A tibial cut was made perpendicular to the long axis of tibia using a cutting block positioned under navigation guidance. After the distal and posterior condyles of femur had been recorded, an optimization of anterior points on the femur with the pointer. The joint gap in extension and flexion was measured with the distractor. Based on the recorded information, the resection plan was established with the help of the computer system. The distal femur resection block was positioned as planned under navigation system, and distal femur was resected. After reassessing the distal resection, the four-in-one cutting guide was positioned as planned rotation alignment using navigation system. Anterior, posterior, and chamfer cut were performed in sequence.

**Conventional system technique.** The osteophytes, anterior, posterior cruciate ligaments, and medial meniscus were removed same as above. Using femur first measured resection technique, femoral intramedullary guide, which was set valgus 6° to femur anatomical axis, was inserted and we fixed cutting block. Then, the distal femur was resected with saw under cutting block. Extramedullary tibial guide, which was set perpendicular to tibia anatomical axis, was inserted toward second toe and fixed with hammer. After removing tibial guide, tibial cutting block was inserted and resected tibia under cutting block. After resection of the tibia plateau, the ligamentary tension was checked to confirm rectangular gap. If the gap was not rectangular, then the additional ligament balancing procedure was performed. Trial was inserted with bearing and we examined flexion and extension gap. Final prosthesis was implanted with bone cement.

**Measurements**

Height and body weight of all patients were reviewed to calculate body mass index (BMI). Preoperative ROM was measured with a goniometer. Surgical time was reviewed on anesthesia record. The extra-articular tibia vara was assessed by measuring the MDA (Figure 1) of the tibia in preoperative standing lower extremity view. MDA was defined as the angle created between the ankle joint line and the line perpendicular to midmedullary of the tibia. We
divided each group into two subgroups based on the preoperative tibial MDA by 4°. Because Saibaba et al. have reported that MDA above 4° was associated with abnormal postoperative HKA. Preoperative and postoperative alignment were assessed by measuring HKA in preoperative and postoperative standing lower extremity view, respectively. HKA was defined as the angle created between the mechanical axis of the femur and the mechanical axis of the tibia (Figure 2). All angles were measured with the cobb angle tool in a picture archiving and communication system (PI View STAR, version 5025; Infinitt, Seoul, South Korea). A single orthopedic surgeon, not the one who operated, measured all MDA and HKA without noticing for which group they belonged to.

**Statistical analysis**

SPSS Statistics for Windows, version 24.0. (IBM, New York, USA), was used for all statistical analyses. Inter-group comparisons were made using independent t-test. In the comparison for gender difference, $\chi^2$ test was performed. The number of cases with MDA $\leq 4^\circ$ and $>4^\circ$ was compared using a $\chi^2$ test. The relationship between variables was analyzed using Pearson’s correlation coefficient in overall cases and in each group. A $p$ value of less than 0.05 was considered statistically significant. All data are expressed as mean ± standard deviation.

**Results**

There was no statistically significant difference in age, gender, BMI, preoperative ROM, preoperative HKA, or preoperative MDA ($p$ value: 0.063, 0.628, 0.426, 0.524, 0.306, and 0.523, respectively) between CAS-TKA group and conventional TKA group. But surgical time of CAS-TKA group was statistically significant longer than surgical time of the conventional TKA group ($p = 0.011$). The number of cases with MDA $\leq 4^\circ$ and $>4^\circ$ in CAS-TKA group was 162 and 84. In conventional TKA group, the number of cases with MDA $\leq 4^\circ$ and $>4^\circ$ were 61 and 22. There was no difference in number of cases with MDA $\leq 4^\circ$ and $>4^\circ$ ($p = 0.198$; Table 1).

No statistically significant difference was found in postoperative HKA ($p = 0.416$) between the two groups. There was no statistically significant difference in postoperative alignment for cases with MDA $\leq 4^\circ$ ($p = 0.351$) or MDA $>4^\circ$ ($p = 0.866$) in each group (Table 2).

**Table 1.** Demographic data.a

|                      | CAS group | Conventional group | $p$ Value |
|----------------------|-----------|--------------------|-----------|
| Age                  | 72.47 ± 6.65 | 74.06 ± 6.94       | 0.063     |
| BMI                  | 26.69 ± 3.81 | 28.40 ± 19.39      | 0.426     |
| Preoperative ROM     | 107 ± 4.6  | 105 ± 3.3          | 0.524     |
| Surgical time (min)  | 123 ± 0.02 | 113 ± 0.02         | 0.011     |
| Preoperative HKA angle | 9.56 ± 5.91 | 10.35 ± 6.51      | 0.306     |
| Preoperative tibial MDA | 3.37 ± 2.44 | 3.16 ± 3.02     | 0.523     |
| MDA $\leq 4^\circ$ cases | 162       | 61                 | 0.198     |
| MDA $>4^\circ$ cases | 84        | 22                 |           |
| Total                | 246       | 83                 | 329       |

CAS: computer-assisted navigation; BMI: body mass index; ROM: range of motion; HKA: hip–knee–ankle; MDA: metaphyseal–diaphyseal angle.

aData are shown as mean ± standard deviation.
Postoperative HKA angle
Preoperative HKA angle
correction during TKA by b one cutting or releasing
Extra-articular tibia vara is often mild and amenable to
correct postoperative HKA, correction of the HKA is com-
pleted intra-articularly by measured resection and ligament
intra-articularly. Ritter and Faris\textsuperscript{22} suggested that
any deformity could be corrected intra-articularly with
careful attention to ligamentous instability. But in severe
extra-articular tibia vara, correction by intra-articular bone
cutting requires extensive resection on the lateral side,
which may induce laxity.\textsuperscript{23}

A postoperative HKA that deviates more than 3\textdegree from
neutral correlates with worse functional outcome and pro-
thesis survival.\textsuperscript{24} Saibaba et al.\textsuperscript{6} have reported that extra-
articular tibia vara measured by MDA is associated with
abnormal postoperative HKA (beyond 180\textdegree 3\textdegree) when
MDA is above 4\textdegree with a sensitivity of 78.1\%, specificity of
62.5\%, and p value of 0.03. This was why our study divided
MDA by 4\textdegree.

We used MDA to measure tibia extra-articular vara, but
there were other ways to measure that. Ko et al.\textsuperscript{25} used the
angle between the tibial anatomical axis and mechanical
axis. Yau et al.\textsuperscript{26} proposed the angle formed between the
midmedullary lines of the proximal and distal thirds of
the tibial diaphysis. Chiu et al.\textsuperscript{27} used the angle between
the midmedullary lines of the proximal and distal halves
of the tibial diaphysis. But Saibaba et al. reported that
MDA showed the most positive correlation with expected
tibial varus angulation (HKA + joint line convergence angle)).

The conclusion of this study is that postoperative HKA
is not significantly different between CAS-TKA and con-
ventional TKA in extra-articular tibia vara even if MDA is
above 4\textdegree. Although CAS-TKA can help the operator to
correct postoperative HKA, correction of the HKA is com-
pleted intra-articularly by measured resection and ligament

There were positive correlations between preoperative
HKA and postoperative HKA in overall cases ($p = 0.001, r$
= 0.187; Table 3). However, in the conventional group,
there were no significant correlations between preoperative
HKA and postoperative HKA ($p = 0.732$), although there
were positive correlations in the navigation TKA group ($p$
$< 0.001, r = 0.243$; Table 4).

**Discussion**

Numerous studies have compared radiologic outcome
between conventional TKA to CAS-TKA. According to
these studies,\textsuperscript{13–17} CAS-TKA shows better postoperative
alignment compared to conventional TKA and CAS-TKA
was reported to be superior to conventional TKA in the
majority of published reports. It was believed that the
use of computer navigation in TKA could make an inexpe-
rienced TKA surgeon more like an expert TKA surgeon.\textsuperscript{12}
However, Burnett and Barrack\textsuperscript{18} and Gharaibeh et al.\textsuperscript{19}
have reported that there is no significant difference
between conventional and CAS-TKA.

Extra-articular tibia vara is typically seen in Asian
patients with varus osteoarthritis.\textsuperscript{20} This has made it
difficult to attain proper coronal alignment and correct
implant positioning in TKA because the tibial anatomical
axis does not align with the tibial mechanical axis.\textsuperscript{21}

| Table 2. Postoperative radiological results.\textsuperscript{a} |
|----------------------|-----------|--------|
|                      | CAS group | Conventional group | p Value |
| Postoperative HKA angle | 2.74 ± 2.36 | 2.50 ± 2.19 | 0.416 |
| Postoperative HKA angle in case MDA ≤ 4\textdegree | 2.86 ± 2.34 | 2.53 ± 2.39 | 0.351 |
| Postoperative HKA angle in case of MDA > 4\textdegree | 2.50 ± 2.38 | 2.41 ± 1.56 | 0.866 |

CAS: computer-assisted navigation; HKA: hip–knee–ankle; MDA: metaphyseal–diaphyseal angle.
\textsuperscript{a}Data are shown as mean ± standard deviation.

| Table 3. Correlations between variables in overall cases.\textsuperscript{a} |
|----------------------|-----------|--------------|
|                      | Postoperative HKA angle | Preoperative HKA angle | Preoperative tibial MDA |
|                      | Pearson correlation | p Value | Pearson correlation | p Value | Pearson correlation | p Value |
| Postoperative HKA angle | 0.187 | 0.001 | 0.015 |
| Preoperative HKA angle | 0.187 | 0.001 | 0.021 |
| Preoperative tibial MDA | 0.015 | 0.781 | 0.699 |

HKA: hip–knee–ankle; MDA: metaphyseal–diaphyseal angle.
\textsuperscript{a}Correlation is significant at 0.01 level (two-tailed).

| Table 4. Correlations between variables in each group.\textsuperscript{a} |
|----------------------|-----------|--------------|----------------------|
|                      | Conventional group | Preoperative HKA angle | Preoperative tibial MDA |
|                      | Pearson correlation | p Value | Pearson correlation | p Value |
| Conventional group | Postoperative HKA angle | 0.038 | 0.027 |
| Preoperative HKA angle | 0.732 | 0.806 |
| Preoperative tibial MDA | 0.027 | -0.135 |
| Preoperative tibial MDA | 0.806 | 0.222 |
| CAS group | Postoperative HKA angle | 0.243 | 0.009 |
| Preoperative HKA angle | <0.001 | 0.891 |
| Preoperative tibial MDA | 0.096 | 0.133 |

CAS: computer-assisted navigation; HKA: hip–knee–ankle; MDA: metaphyseal–diaphyseal angle.
\textsuperscript{a}Correlation is significant at 0.01 level (two-tailed).
balancing. Mullaji et al.\textsuperscript{11} found no significant difference in the postoperative HKA with varus exceeding 20° between conventional TKA group and CAS-TKA group.

The interesting point was that CAS-TKA showed significantly positive correlation between preoperative and postoperative HKA although there was no significant correlation in the conventional TKA. In the conventional TKA, without considering the preoperative HKA, the distal femur was resected valgus 6° to femur anatomical axis and proximal tibia was resected 90° to tibia anatomical axis. But in CAS-TKA, cutting was based on preoperative HKA which is registered on the computer, so it is assumed that correlation occurred in this process.

This study has some limitations. First, the evaluation of cases was retrospective. Since the type of surgical method was determined by surgeon’s choice, the subjective preference of the surgeon was involved inevitably. Thus, there was unavoidable selection bias. Second, only radiologic outcomes in a single coronal plane were evaluated. Subsequent studies that deal with clinical outcomes and measurements in a sagittal plane are needed. Third, according to patients’ posture and flexion contracture, measurement error of radiological parameter of simple X-ray might have occurred. Therefore, high-quality randomized controlled trial studies are needed in the future to overcome these limitations.

**Conclusions**

There is no statistical difference in postoperative alignment between conventional TKA and CAS-TKA for extra-articular tibial vara even in cases with MDA >4°.

**Declaration of conflicting interests**

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**References**

1. Laskin RS. Flexion space configuration in total knee arthroplasty. *J Arthroplasty* 1995; 10: 657–660.
2. Daines BK and Dennis DA. Gap balancing vs. measured resection technique in total knee arthroplasty. *Clin Orthop Surg* 2014; 6: 1–8.
3. Denham RA and Bishop RE. Mechanics of the knee and problems in reconstructive surgery. *J Bone Joint Surg Br* 1978; 60-B: 345–352.
4. Bottros J, Klika AK, Lee HH, et al. The use of navigation in total knee arthroplasty for patients with extra-articular deformity. *J Arthroplasty* 2008; 23: 74–78.
5. Chauhan SK, Scott RG, Breidahl W, et al. Computer-assisted knee arthroplasty versus a conventional jig-based technique. A randomised, prospective trial. *J Bone Joint Surg Br* 2004; 86: 372–377.
6. Saibaba B, Dhillon MS, Chouhan DK, et al. Significant incidence of extra-articular tibia vara affects radiological outcome of total knee arthroplasty. *Knee Surg Relat Res* 2015; 27: 173–180.
7. Alcelik IA, Blomfield MI, Diana G, et al. A comparison of short-term outcomes of minimally invasive computer-assisted vs minimally invasive conventional instrumentation for primary total knee arthroplasty: a systematic review and meta-analysis. *J Arthroplasty* 2016; 31: 410–418.
8. Barrett W, Hoeffel D, Dalury D, et al. In-vivo alignment comparing patient specific instrumentation with both conventional and computer assisted surgery (CAS) instrumentation in total knee arthroplasty. *J Arthroplasty* 2014; 29: 343–347.
9. Tantavisut S, Tanavalee A, Ngarmukos S, et al. Accuracy of computer-assisted total knee arthroplasty related to extra-articular tibial deformities. *Comput Aided Surg* 2013; 18: 166–171.
10. Tigani D, Masetti G, Sabbioni G, et al. Computer-assisted surgery as indication of choice: total knee arthroplasty in case of retained hardware or extra-articular deformity. *Int Orthop* 2012; 36: 1379–1385.
11. Mullaji A, Kanna R, Marawar S, et al. Comparison of limb and component alignment using computer-assisted navigation versus image intensifier-guided conventional total knee arthroplasty: a prospective, randomized, single-surgeon study of 467 knees. *J Arthroplasty* 2007; 22: 953–959.
12. Yau WP, Chiu KY, Zuo JL, et al. Computer navigation did not improve alignment in a lower-volume total knee practice. *Clin Orthop Relat Res* 2008; 466: 935–945.
13. Suero EM, Lueke U, Stuebig T, et al. Computer navigation for total knee arthroplasty achieves better postoperative alignment compared to conventional and patient-specific instrumentation in a low-volume setting. *Orthop Traumatol Surg Res* 2018; 104: 971–975.
14. Todesca A, Garro L, Penna M, et al. Conventional versus computer-navigated TKA: a prospective randomized study. *Knee Surg Sports Traumatol Arthrosc* 2017; 25: 1778–1783.
15. Moskal JT, Capps SG, Mann JW, et al. Navigated versus conventional total knee arthroplasty. *J Knee Surg* 2014; 27: 235–248.
16. Hetaimish BM, Khan MM, Simunovic N, et al. Meta-analysis of navigation vs conventional total knee arthroplasty. *J Arthroplasty* 2012; 27: 1177–1182.
17. Cheng T, Zhao S, Peng X, et al. 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* 2012; 20: 1307–1322.
18. Burnett RS and Barrack RL. Computer-assisted total knee arthroplasty is currently of no proven clinical benefit: a systematic review. Clin Orthop Relat Res 2013; 471: 264–276.

19. Gharabeh MA, Solayar GN, Harris IA, et al. Accelerometer-based, portable navigation (knee align) vs conventional instrumentation for total knee arthroplasty: a prospective randomized comparative trial. J Arthroplasty 2017; 32: 777–782.

20. Yoo J, Kang Y, Chang CB, et al. The relationship of the medially-offset stem of the tibial component to the medial tibial cortex in total knee replacements in Korean patients. J Bone Joint Surg Br 2008; 90: 31–36.

21. Tang Q, Zhou Y, Yang D, et al. The offset of the tibial shaft from the tibial plateau in Chinese people. J Bone Joint Surg Am 2010; 92: 1981–1987.

22. Ritter MA and Faris GW. Management factorials in TKR: total knee replacement following extra-articular deformities. Orthopedics 2003; 26: 969–970.

23. Catonné Y, Sariali E, Khiami F, et al. Same-stage total knee arthroplasty and osteotomy for osteoarthritis with extra-articular deformity. Part I: tibial osteotomy, prospective study of 26 cases. Orthop Traumatol Surg Res 2019; 105: 1047–1054.

24. Huang NF, Dowsey MM, Ee E, et al. Coronal alignment correlates with outcome after total knee arthroplasty: five-year follow-up of a randomized controlled trial. J Arthroplasty 2012; 27: 1737–1741.

25. Ko P, Tio M, Ban C, et al. Radiologic analysis of the tibial intramedullary canal in Chinese varus knees: implications in total knee arthroplasty. J Arthroplasty 2001; 16: 212–215.

26. Yau W, Chiu K, Tang W, et al. Coronal bowing of the femur and tibia in Chinese: its incidence and effects on total knee arthroplasty planning. J Orthop Surg 2007; 15: 32–36.

27. Chiu K, Yau W, Ng T, et al. The accuracy of extramedullary guides for tibial component placement in total knee arthroplasty. Int Orthop 2008; 32: 467–471.