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Total knee arthroplasty in patients with extra-articular deformity: which strategy to choose? (case report and literature review)

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Background Extraarticular deformity of the femur or tibia may be critical for the success of primary total knee arthroplasty (TKA). Recognizing an extraarticular deformity preoperatively allows a surgeon to choose between various management strategies. The surgical treatment options for correction of an extraarticular deformity include (1) primary TKA, (2) simultaneous corrective osteotomy and TKA and (3) staged corrective osteotomy and delayed TKA. **Objective** To substantiate differentiated approach to treatment strategies for osteoarthritic knee with extraarticular deformity based on international and our own experience. **Material and methods** Comparative analysis of current literature on surgical treatment of extraarticular deformities in arthritic knees was produced. The differentiated approach was illustrated by a clinical instance of a 35-year-old patient with bilateral end-stage gonarthrosis associated with extraarticular deformity of both lower limbs. Staged treatment was considered for the congenital multiplanar multilevel deformity in the shaft of the left femur with 26º valgus alignment, procurvatum, external rotation to be corrected with bifocal osteotomy addressing all components of the deformity and stabilized with interlocking intramedullary nail. Standard TKA on the left side was produced a year later with posterior cruciate ligament (PCL) retention. Acquired uniplanar varus deformity of the right femur was corrected using computer-assisted navigation TKA and the PCL substitution at 5 months after the first procedure. **Results** Knee score improved from 28 to 85 and from 52 to 86 in the left and right sides while functional activity score increased from 42 to 90 and from 52 to 92, respectively, as measured with American Knee Society scoring system (KSS). There is plenty of evidence in the literature that computer-assisted navigation TKA facilitates accurate limb alignment, better flexion angle and improved functional score whereas osteotomies are associated with a higher risk of complications that can result in delayed consolidation or nonunion. **Conclusion** Differentiated approach can be advocated for correction of an extraarticular deformity of lower limb to be addressed with TKA depending on the magnitude (in degrees), the location of the deformity in relation to the knee joint and relevant patient specific charactreristics, such as age, gender, clinical history. Computer-assisted navigation TKA is practical for mild diaphyseal deformity associated with gonarthritis. Corrective osteotomy can be useful for severe diaphyseal deformity or with the apex localized close to the joint for realignment at the first stage.

Keywords: total knee arthroplasty, extra-articular deformity, osteotomy, computer-assisted orthopedic surgery

INTRODUCTRION

Total knee arthroplasty (TKA) has evolved over the past few decades into the first-line procedure for end-stage gonarthrosis. The procedure can help releive pain, correct a deformity, regain range of motion improving functionality of the joint and the lower limb. Gonarthrosis combined with lower limb deformity poses difficulties in preoperative planning and performance of TKA. Three-dimensional evaluation of implant positioning is essential since standard instrumentation cannot be applied with optimum balance of knee stabilizers to be ensured throughout the range of motion [1, 2]. Specific causes of extra-articular deformities include fracture malunion of the femur and/or tibia, previous osteotomies, congenital abnormalities, metabolic bone diseases or dietary factors and infection. Traditionally, intra-articular component of the deformity developed due to wear and tear of the articular cartilage and the bone can be addressed with correcting resection of the femur and tibia and soft tissue release.

Posiibilities of an intra-articular correction of extra-articular deformities of lower limb are limited in TKA. Previous studies have reported that an intra-articular compensatory correction can usually be achieved with TKA if the extra-articular deformity is 15-20° [3] in the coronal plane, 20–25° [4] in the sagittal plane and 10–20° in the vertical plane [5]. The closer a deformity is to the knee, the greater its importance and the effect on the intra-articular correction [6]. Residual postoperative lower limb malalignment can lead to aseptic loosening and/or accelerated polyethylene wear (Fig. 1) [7] as well as to increased revision rates.

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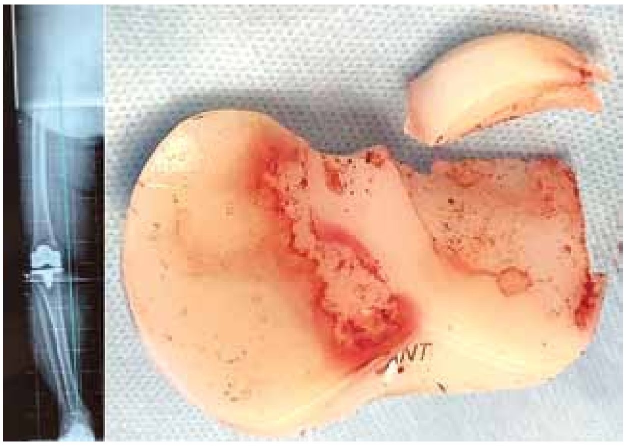

Fig. 1 Premature polyethylene wear and breakage of the tibial insert with persistent varus deformity of the knee

Limb length discrepancy persists with persistent deformity: limb malalignment of more than 20° is always associated with limb shortening and results in gait disturbances, pain in adjacent joints and in the lumbar spine. An unbalanced knee due to flexion-extension gap imbalance would require hinged implant for improving coronal plane stability using extension stems that might be conflicting with distorted intramedullary canal and resultant spatial deviation of implant components. Thus, extra-articular deformities of the femur and tibia in conjunction with end-stage gonarthrosis advanced knee osteoarthritis pose unique challenges for the orthopaedic surgeon during primary TKA. Depending on the magnitude (in degrees) of the extra-articular deformity, the location of the deformity in relation to the knee joint the surgical treatment options for correction of an extra-articular deformity include (1) primary TKA, (2) simultaneous corrective osteotomy and TKA, and (3) staged corrective osteotomy and delayed TKA. There are pros and cons to each of the treatment options, and this highlights the need to discuss risks and benefits of each approach for a given patient in selecting the best option.

The objective of the study was to substantiate differentiated approach to treatment strategies for osteoarthritic knee with extra-articular deformity of the femur and/or tibia based on international and our own experience.

MATERIAL AND METHODS

EMBASE, MEDLINE, the primary component of Pubmed, and eLibrary databases were thoroughly searched by the authors from 1999 to 2019. The following search terms were used as both subjects and key words in English and in Russian: “total knee arthroplasty”, “extra-articular deformity”, “osteotomy”, “computer-assisted orthopaedic surgery”. The inclusion criteria were: 1) publications of any level of evidence; 2) male and female patients of any age; 3) articles in English and in Russian.

The authors included studies that were published in scientific journals and involved patients who had: 1) the extra-articular deformity; 2) underwent the staged approach or the simultaneous approach for correcting extra-articular deformity; 3) computer-assisted navigation; 4) clinical outcomes. In addition, articles were scrutinized for TKA cases in conjunction with an extra-articular deformity corrected with osteotomy or neglected, secured with a fixation method, also featuring prosthesis design used, and evaluating knee functionality.

Case report

A 35-year-old patient E. (height 170 cm, body weight 71 kg, BMI 26.4) was examined by an orthopaedic surgeon at the Vreden Scientific Research Institute of Traumatology and Orthopaedics on February 09, 2017. She presented with complaints of pain following weight-bearing activities and at rest, limited range of motion in both knees being more severe on the left, morning stiffness and deformity of both lower limbs with greater involvement on the left. The patient described the deformity of her left lower limb as congenital, and her right-side deformity developed and progressed after she gave birth to her second child. She started experiencing pain in her left knee in 2000 and in the right knee, in 2014. She received repeat courses of non-sugical treatment including exercise therapy, physical therapy procedures, anti-inflammatory drugs that resulted in short-term (1–2 months) positive effects. In 2014 she underwent arthroscopic excision of a degenerative medial meniscus tear of the right knee with short-term favourable effect. She reported gradual progression of the deformity of the left knee since 2007, and of the right knee since 2016. Pain became persistent and severe on the left in 2016 and on the right, in 2017. Conservative treatment was ineffective.

Physical examination showed that the patient could walk unassisted bearing weight on both legs and limping on the left side. Medial and lateral aspects were painful at palpation and joints being stable in all planes with no signs of effusion. Both patellae appeared to slide at flexion with tendency to lateralization (on the left > on the right) without subluxation. Radiological examination was performed for both knees.

The staged approach with bifocal correcting osteotomy was considered for the severe triplanar deformity with the perpendicular line to the mechanical axis of the femur passing through the insertion of the medial collateral ligament (the anticipated line of distal resection of the femoral condyles) to gain as much correction as possible.

The first stage of surgical treatment performed on 12.02.17 included bifocal osteotomy at the apexes of the deformities after standard reaming of the medullary canal using additional incisions and intramedullary (IM) nailing produced with a guide wire and statistic distal and proximal 4 interlocking screws using an image intensifier (Fig. 3). The femoral rotational alignment was evaluated radiologically using bone landmarks of the lesser trochanter, femoral condyles and the patella as intraoperative references [8].

The patient was admitted to the hospital for TKA of the right knee on 31.07.18 (Fig. 4) and navigated TKA with a posterior cruciate ligament (PCL)-substituting knee prosthesis was performed for the right knee (Fig. 5a). The patient was admitted to the hospital for the second stage of treatment on 23.01.18 to undergo TKA of the left knee (Fig. 5a). IM nail was removed (Fig. 5a) and TKA with PCL-retaining knee prosthesis was simultaneoulsy produced for the left knee using conventional instrumentation system (Fig. 5b).

Table 1

Anatomical and functional characteristics of lower limbs of the patient

Criteria of physical and radiological assessment	Left lower limb	Right lower limb
Femoral deformity planes	triplanar: valgus, antecurvatum, external rotation	uniplanar: varus
ROM in the knee	0 – 10 –70°	0 – 0 - 90°
Alignment	26° valgus alignment	10° varus alignment
mLDFA	70°	97°
MPTA	83	89
LLD	3 cm	0 cm
KSS knee score	28	52
KSS function score	42	52

Fig. 2 Preoperative radiographs of the left lower limb of a 35 yo patient showing 26° valgus in the coronal plane. Rotation component of the deformity interferes with evaluation of reference lines and angles in different planes

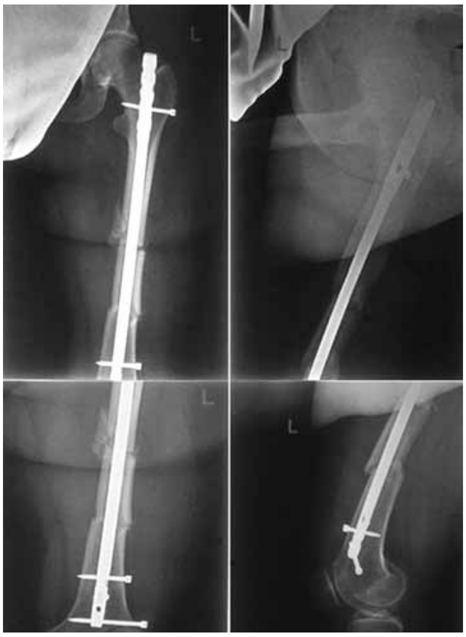

Fig. 3 Radiographs made on the day after surgery

Fig. 4 Radiographs taken at 5 months following the first stage of treatment showing valgus alignment of 11°, mLDFA of 79° (preoperative 70°) and MPTA of 88° in the left knee; varus alignment of 10°, mLDFA of 97° and MPTA of 89° in the right knee

Fig. 5 Radiographs taken at 11 months following the first stage of treatment and 4 months following TKA on the right side showing (***a***) valgus alignment of 11°, mLDFA of 79° (preoperative 70°) in the left knee and (***b***) angles measured after the second stage of treatment

RESULTS AND DISCUSSION

Clinical, radiological and functional assessment of staged treatment made at one year following the last TKA was rated as favorable. Postoperative parameters of the patient are presented in Table 2 and in Figure 6.

Therefore, extra-articular deformities of the femur and tibia in conjunction with advanced knee osteoarthritis pose unique challenges even for the experienced arthroplasty surgeon. This observation shows that different strategy can be applied for different sides of one patient. The approach involves a solution for extension space balancing and creating a neutral mechanical axis. Trapezoidal extension space has been shown to be more critical for joint function than residual deformity of the limb that can measure 5 degrees and over [9]. Although TKA performed without additional correction of extra-articular deformity appears to be most acceptable for the patient and the surgeon, it has a number of limitations related to the risk of persistent deformity, artiular imbalance and the need to use more contrained implant designs.

Table 2

Preoperative and postoperative parameters of the patient at one year following left-sided TKA

Limb	left	right
Method	Two-stage treatment: osteotomy followed by TKA	One-stage treatment: computer-assisted navigation TKA
Preoperative mechanical axis of the limb	valgus 26°	varus 10°
Mechanical axis of the limb after osteotomy	valgus11°	–
Mechanical axis of the limb after TKA	valgus 1°	0°
Preoperative ROM	0 – 10° – 70°	0° – 0° – 90°
Postoperative ROM	0° – 0° – 85°	0° – 0° – 95°
Type of implant used	CR	PS
Preoperative Knee Score	28	52
Postoperative Knee Score	85	86
Preoperative Function Score	42	52
Postoperative Function Score	90	92

Fig. 6 Clinical appearance of lower limbs after surgical procedures showing neutral axis of the limbs in frontal and sagittal planes

Due recognition of extra-articular deformity must be ensured by obtaining full-length standing anteroposterior radiographs of both lower limbs. This also helps in assessing the true severity of the deformity during preoperative planning described by Wang J.W, Wang C.J. et al. If the perpendicular line to the mechanical axis at the proposed level of the femoral resection passes through the epicondyles distal to the insertions of the medial and lateral collateral ligaments, a corrective osteotomy is feasible, otherwise there is a greater risk of injury to the key knee stabilizers [3]. For the tibia, if the line drawn from the center of the talus up the shaft of the tibia in the distal fragment of the deformed bone passes through the top of the tibial plateau, correction with primary arthroplasty is feasible. Considerations for intra-articular resection of bone in conjunction with soft-tissue balancing during TKA include the extent, complexity of the deformity involving more than one plane and localization. The closer the deformity is to the joint, the more severe the deformity, the more challenging it becomes to obtain a balanced knee. When coronal deformity in the femoral epicondyle is ⩾ 20° the recommended treatment is concomitant osteotomy and TKA with a long stem prosthesis [6]. Options for fixation include long-stemmed revision prosthesis, intramedullary nails, locking distal femoral plates all of which can be combined with TKA. For femoral or tibial deformities of greater severity, an extra-articular correction with an osteotomy may be needed to achieve a well-aligned TKA. Summary of published literature on TKA in extra-articular deformity is presened in Table 3 and 4.

Table 3

Outcomes of TKA in bone deformity using computer navigation and neglecting extra-articular deformity

Authors	Calvin et al. [10]	Chou иet al. [11]	Liu et al. [12]	Mullaji et al. [13]	Rhee et al. [14]	Shao et al. [15]	Tigani et al. [16]	Bottros et al. [17]	Klein et al. [18]	Catani et al. [19]
Year	2011	2008	2006–2009	2005–2008	2007–2012	2008–2010	2004–2009	2004–2006	2005	2003–2008
Number of patients	1	1	8	34	13	12	9	9	5	20
Plane of deformity	coronal sagittal	coronal sagittal			3 – uniplanar, 10 – biplanar		7 – uniplanar, 2 – biplanar	2 – uniplanar, 7 – biplanar		15 – uniplanar, 5 – biplanar
Age	70	43	68 (60–78)	63,1 (46–80)	69 (52–83)	65,6 ± 7,1	61 (36–77)		60 (50-75)	52 (38–83)
Cause	Sequelae of severe trauma (RTA)	Sequelae of severe trauma (RTA)	7 – MU, 1 –congenital defec	14 – ECT 3 – secondary to HTO, 4 – stress-fracture, 13 –MU	13 – MU	11 – MU, 1 – Blount's disease	8 – MU, vitamin D-resistant rickets			MU
Preop mechanical axis	5,3° varus	8° varus	10,7° varus	166.7° ± 9.3° (163.7°–169.6°)	7.2 ± 11.8° (25° varus – 13° valgus)	10.0° ± 4.4° varus	26° valgus – 19° varus	5.1° varus (14° varus – 2.18° valgus)	2.7° valgus (13.68° varus – 16.28° valgus)	10.4° ± 8.3° varus (26° varus – 13° valgus)
Postop mechanical axis	0°	1° варус	1.2° varus (4.5° varus – 1.5° valgus)	179.1° ± 1.4° (178.6° – 179.5°)	0.2 ± 4.5° valgus (6° varus – 13° valgus)	0.9° ± 0.8°	0 ± 3°	1.3° valgus (0.2 ± 2.58°)	0.6° varus (1.8° varus – 0.4° valgus)	0.8° valgus (1° varus – 2° valgus)
Preop KSS		38	24.63 ± 15.77 (0–45)	49.7 (32–65)	28.8 ± 5.7 (19–35)	40.8 ± 7.7	33 (12–63)	62 (50–75)		48 ± 7.4 (28–67)
Postop KSS		82	84.00 ± 5.95 (77–94)	90.4 (80–95)	89.6 ± 4.6 (80–97)	94.9 ± 2.4	78 (63–90)	92 (83–97)		91 ± 5.4 (81–97)
Preop FS	90		49.38 ± 17.41 (25–75)	47.3 (35–50)		39.6 ± 12.3	32 (10–65)	52 (46–60)		42 ± 6.7 (24–61)
Postop FS	100		87.50 ± 7.56 (75–100)	84.9 (50–100)		95.4 ± 4.0	72 (40–90)	83 (60–100)		85 ± 6.4 (78–93)
Preop range of motion	Flexon contracture 10°. 10–110°	0–90°	85 ± 14.14° (70–110)		83.5 ± 19.8° (50°–125°)	83.7 ± 18.7°	68° (20°–120°)	70° (4°–74°)		7°–74°
Postop range of motion	0°–120°	0–95°	106.2 ± 10.26° (95°–120°)		118.5 ± 10.5° (100°– 135°)	11° ± 8.2°	81° (65°–120°)	97° (0.6°–98°)		0–94°
Design of implant	PS	PS	PS	PS (6 with long tibial stems)	PS – 10, NOS CR or PS – 3	NOS CR or PS – 10, PS– 2	PS – 7, Cons– 1	CR – 5, PS – 4	PS	PS – 16, SM – 4
LLD	2 см	4 см								
Segment and deformity location	F (distal 1/3)	F (distal 1/3)	F –7, FT – 1	F – 17, T – 14	F – 9 (4 – distal 1/3.5 – middle 1/3), T – 4 (4 –proximal 1/3)	F – 11 (9 – shaft, 3 – epicondyles), FT – 1 (1 – shaft)	F – 6, T – 2, FT – 1	F – 9	F – 1, T – 1, FT– 3	F – 11 (5 – middle 1/3, 1 – middle and distal 1/3, 5 – distal 1/3), T – 9 (8 – proximal 1/3, 1 – middle 1/3)
Comments				Extra-articular O/T performed in 3 cases, the rest underwent CN TKA						

F indicates femur; **T** tibia; **FT** femur and tibia; **MU** malunion; **TKA** total knee arthroplasty; **CN** computer navigation; **ECT** excessive coronal tilt; **SM** semiconstrained; **Const** constrained; **CR** cruciate retaining; **PS** posterior cruciate substituting; **KSS** Knee Society Score; **FS** functional score; **HTO** high tibial osteotomy.

Table 4

Outcomes of TKA combined with corrective osteotomy

Authors	Hazratwala и co-авт. [4]	Yagi и соавт. [20]	Deschamps и соавт. [5]	Xiao-Gang и соавт. [21]	Lonner и соавт. [22]	Veltman и соавт. [23]	C. H. Jason Fan [24]
Year	2016	2008	2000–2008	2006–2010	1990–1996	2006–2012	2014
Extra-articular correction and TKA	simultaneous	Two-stage procedure	simultaneous (16), two-stage procedure (2)	simultaneous	simultaneous	simultaneous	simultaneous
Number of patients	1	1	78 660 – TKA standalone and 18 with O/T (16 single-stage, 2 two-stage). Outcomes evaluated in a mixed manner and in groups of TKA and TKA + O/T	9 7 – TKA standalone, 2 – TKA + simultaneous O/T (2 – T)	11	21	1
Plane of deformity	coronal sagittal	coronal		5 – uniplanar, 3 – biplanar, 1 – triplanar	5 uniplanar (4 varus, 1 antecurvatum), 5 biplanar (varus and antecurvatum), 1 triplanar (varus, antecurvatum, intorsion)		coronal sagittal vertical
Age	54	65	63 (34–90)	51 (34-69)	63 (40–74)	65.6 ± 7.1	64
Cause	MU	Sequelae of combined trauma (RTA)	MU	1 – femoral dysplasia, 4 – MU	10 – MU, 1 – hypophosphatemic rickets	10 – MU, 7 – NU, 3 – OA, 1 – osteogenesis imperfecta	posttraumatic (RTA)
Pre-op mechanical axis	13° varus	22° varus	varus: 178 ± 4° (172–184°), valgus: 181 ± 2° (175–184°)	11,8 ° (2–21°)	28,3° varus (14°–40°)	F – 12° varus – 15° valgus; T– 17° varus – 11° valgus	16°varus, 15°anteversion (normal 20°–25°)
Post-op mechanical axis	0°	8° varus, 2° varus following TKA		1° (0–4°)	< 2° varus		0°
Preop KSS		6			10 ± 4		
Postop KSS		72			87 ± 11		97
Preop FS		10	44 ± 23		22 ± 10		
Postop FS		85	89 ± 15		81 ± 19		80
Preop range of motion	3–82°	20–50°	flexion 105 ± 26°, extension 5 ± 6°	46,7° (0–100°)	56° ± 17°		0–100°
Postop range of motion	0–115°	−5–70°	flexion 109 ± 21°, extension 0.5 ± 3°	100,6° (85–115°)	89° ± 17°	F – 96° (70–120), T – 108° (45–140)	0–110°
Design of implant	PS	PS	Uni – 3, CR/PS-67, SM – 4, Const– 4,	PS–5, SM – 4	PS – 11	PS and SM (distribution NOS)	NOS
Complications			16 2 – I/O (1 perforation, 1 tear of EA), 10 – P/O (1 – PNP, 1 – PN, 1 – PJI, 2 – PF, 2 – PCS, 1 – NU, 2 – AL, 2 – SL)	1 – DC	1 – NU,1 – PE	2 – PJI, 2 – NU	
Fixation of osteotomy site	IM nail	plate	SCFO fixed with LCP		blade plate – 7, retrograde IM nail – 2, press-fit stemmed prosthesis – 2	K-wires or LCP in group of SCFO and LCP in group of HTO	long IM Gamma nail
Segment and deformity location	F (metaepiphysis, lower third of the shaft)	F (metaepiphysis, lower third of the shaft)	F – 38, T – 36, FT – 4 (47 – diaphysis, 26 – metaphysis, 5 –metaepiphysis)	F – 5 (1 – distal 1/3, 4 – condyles), T – 4 (1 – proximal 1/3, 3 – metaphysis)	F – 11 (9– distal 1/3, 2– middle 1/3)	F – 10, T – 11	F (proximal 1/3)
Comments	preop: recurvatum – 38°, varus – 13°					3 patients died from unrelated reasons	

F indicates femur; **T** tibia; **FT** femur and tibia; **TKA** total knee arthroplasty; **O/T** osteotomy; **MU** malunion; **IM** intramedullary; **I/O** intraoperative; **P/O** postoperative; **EA** extension apparatus; **PNP** peroneal nerve palsy; **PJI** periprosthetic joint infection; **PN** patellar necrosis; **PF** periprosthetic fracture; **NU** nonunion; **AL** aseptic loosening; **SL** septic loosening; **PE** pulmonary embolism; **DC** delayed consolidation; **Uni** unicondylar; **SM** varus-valgus constrained; **Const** constrained; **CR** cruciate retaining; **PS** posterior cruciate substituting; **LCP** locking compression plate; **HTO** high tibial osteotomy; **KSS** Knee Society Score; **FS** functional score; **SCFO** supracondylar femoral osteotomy; **PCS** patellar clunk syndrome

The mechanical axis was shown to be more accurately restored in navigated TKA than in combined TKA and osteotomy: from 0 to 1.3° and from 0 to 2°, respectively. In our observation, the neutral mechanical axis was achieved on the right whereas the residual 1° valgus was seen on the left. Despite the differences in accuracy of limb alignment that can be achieved with two surgical approaches a ±3° deviation from the axis is considered acceptable and the above deformity had no impact on the clinical outcome.

Clinical benefits of computer navigated TKA include better range of motion and greater arc of knee flexion than that achieved with combined TKA and osteotomy: 0–102.4° and 0–97.6°, respectively. The range of motion in the case presented was less than that reported in the literature measuring 0–95° on the right and 0–85° on the left, with computer-assisted arthroplasty being superior to traditional instrumentation. A higher complication rate is reported for TKA following bone osteotomy than for navigated TKA, the higher complication rate is secondary exclusively to delayed consolidation and nonunion. Although computer-assisted navigation systems have been shown to improve functional outcomes there is no significant differences in clinical advantages of TKAs performed with and without computer navigation (Fig. 7).

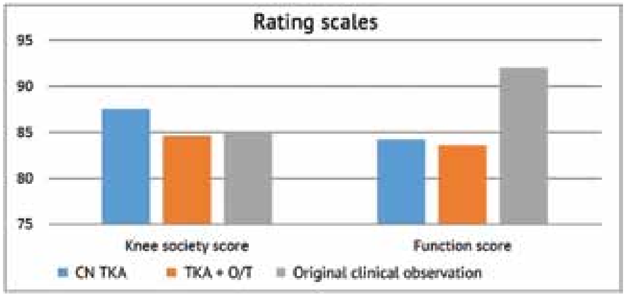

Fig. 7 Outcomes evaluated with KSS and Function score

CONCLUSION

Differentiated approach can be advocated for correction of an extra-articular deformity of lower limb to be addressed with TKA depending on the magnitude (in degrees), the location of the deformity in relation to the knee joint and relevant patient specific characteristics, such as age, gender, clinical history. Although computer-assisted navigation provides accurate limb alignment during surgery, an extent of deformity correction is limited by relevant symmetric balanced flexion and extension gaps to be ensured with soft tissue releases. Otherwise, the options at surgery would include use of semiconstrained or hinged implants with intramedullary extension stems that may be difficult to apply due to extra-articular deformity. The scenario may require a single- or double-stage correction of extra-articular deformity followed by conventional TKA with stable and reliable osteosynthesis.

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