# The advantages of cone beam computerized topography (CT) in pain management following total knee arthroplasty, in comparison with conventional multi-detector CT.

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**Original article**

# The advantages of cone beam computerized tomography (CT) in pain management following total knee arthroplasty, in comparison with conventional multi-detector CT

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**Abstract**

**Background**

Revision of total knee arthroplasty (TKA) requires preoperative assessment to identify the causes of failure. Multidetector computerized tomography (MDCT) is a commonly used imaging technique, but is sensitive to certain artifacts, such as metal implants, limiting its use Cone-beam CT (CBCT)is a new technique dedicated to musculoskeletal imaging that is less sensitive to artifacts and could be utilized in knee implantation surgery. CBCT has not yet been validated for this indication, and we therefore undertook a retrospective assessment of MDCT versus CBCT, comparing: 1) image quality; 2) reproducibility of angle measurements; 3) effectiveness in screening for periprosthetic radiolucency and implant loosening; and 4) radiation dose.

**Hypothesis**

This study hypothesized that CBCT provides better image quality, angle measurement reproducibility, and screening for radiolucency and implant loosening at lower doses of radiation than MDCT.

**Patients and Method**

Between October 2017 and March 2018, 28 patients, with a mean age of 61 ± 11.6 years [range, 45-85 years] underwent both MDCT and CBCT for pain following TKA. Two radiologists performed angle measurements on both devices: patellofemoral tilt (PFT), rotation angle of the femoral component (RAFC) and rotation angle of the tibial component (RATC. They also screened for pathological radiolucency and/or implant loosening, and assessed image quality at the various bone/implant interfaces. The mean CT dose index per examination was recorded.

**Results**

Intraclass correlation coefficients for angles and radiolucency screening on MDCT and on CBCT were respectively good (0.73) and excellent (0.82) for PFT, borderline (0.28) and moderate (0.44) for RAFC, excellent (0.82) and excellent (0.96) for RATC, and moderate (0.45) and excellent (0.84) for radiolucency screening. The inter-observer kappa correlation coefficients for diagnosis of implant loosening and image quality assessment for MDCT and CBCT were respectively moderate (0.45) and excellent (0.93) for tibial loosening and low (0.19) and borderline (0.38) for femoral loosening. The mean image quality at the various interfaces for MDCT and CBCT was respectively 2.2/3 and 2.75/3 at the tibia/tibial implant interface, 1/3 and 2.3/3 at the trochlear region/femoral implant interface, 0.9/3 and 2/3 at the femoral condyle/femoral implant interface, and 1.25/3 and 2.1/3 at the patella/patellar medallion interface. The mean CT dose index was significantly lower, by a factor of 1.24, on CBCT (4.138 mGy) than MDCT (5.125 mGy) ($p<00396$).

**Conclusion**

The results of the present study revealed added value for CBCT in the etiological work-up for pain following a TKA. It was reliable and reproducible for the rotation measurement and diagnosis of implant loosening, due to enhanced image quality despite a lower radiation dose than conventional MDCT.

**Level of evidence:** III; retrospective comparative study

**Keywords:** Cone-beam, CBCT, Revision surgery of the knee, Knee arthroplasty, CT-scan

# 1. Introduction

Over the last decade, rates of total knee arthroplasty (TKA) have been increasing as the population ages [1] and the range of indications broadens in younger patients [2,3], with a consequent increase in revision procedures [4,5].There are many reasons why first-line TKA may fail [4], and in France this was the focus of symposia in the annual congresses of the French Society of Orthopedic Surgery and Traumatology (SoFCOT) in 2000 [6] and in 2015, notably identifying: infection, septic or aseptic loosening, laxity, and stiffness [7,8]

Before considering revision surgery, complementary examinations, notably including multidetector CT (MDCT), screen for abnormalities such as rotation disorder and implant loosening. CT scan quality, however, is impaired by metal artifacts [9,10]. Cone-beam CT (CBCT) is a new imaging technique [11] which, like MDCT, uses an X-ray beam rotating around the patient; instead of detector rows, however, it has a flat panel detector. The first published series demonstrated the advantages in dental surgery (implantology) and maxillofacial surgery, with much fewer metal artifacts and significantly enhanced image quality [12,13].

New CBCT devices dedicated to limb imaging exist [14,15], allowing weight-bearing investigation [14]. There have been few reports of their application in orthopedic surgery outside of the foot and ankle [16-18], and in prosthetic surgery in particular. CBCT has not been validated for the indication of etiological assessment for pain following TKA. Therefore, we conducted a retrospective study of MDCT versus CBCT, comparing: 1) image quality; 2) interobserver reproducibility of angle measurements; 3) effectiveness in screening for periprosthetic radiolucency and implant loosening; and 4) radiation dose. The study hypothesis was that improved spatial resolution in CBCT [19] provides better image quality, reproducibility of angle measurements, and screening for radiolucency and implant loosening, at a lower radiation dose.

# 2. Material and Method

## *2.1* Population

All the patients with painful TKA undergoing pain management in our department were included in a single-center retrospective study for the period October 2017 to March 2018. Retrospective analysis of imaging data was approved by the Data Protection Officer (DPO) (n° DEC-18-337).

### *2.2* Image acquisition

All patients underwent MDCTs (Somaton AS 64, Siemens Healthcare, Saint-Denis, France) and CBCT (CBCT OnSight 3D, Carestream Health, Noisy-le-Grand, France). For CBCT imaging, the patient was seated with knee in extension, without weight-bearing (figure 1), enabling comparable knee extension in both devices so as to obtain the same angle measurements [20].

### 2.3 Acquisition protocols

Table 1 shows the two acquisition protocols. For MDCT, a routine protocol was used investigating painful TKA, and for CBCT, the manufacturer's standard protocol was employed.

### *2.4* Assessment

The scans were interpreted retrospectively by two blinded independent radiologists (one junior, one senior) specialized in musculoskeletal imaging, from the university hospital of Lille, France. CBCT was interpreted independently of MDCT. All interpretations were made on the same console with the same interpretation tool (SyngoVia, Siemens Healthcare, Saint-Denis, France).

*a) Angle measurement*

- Patellofemoral tilt (PFT) was measured on transverse slices in both scans as the angle subtended by the axis through the bone-medallion junction and the axis through the prosthetic trochlea (figure 2).
- The rotation angle of the femoral component (RAFC) was measured on transverse slices as the angle subtended by the axis through the bi-epicondylar line and the tangent to the posterior edge of the femoral condyles (figure 2): a positive result was found when the femoral component was in medial rotation, and negative when in lateral rotation.
- The rotation angle of the tibial component (RATC) was measured with line A, tangential to the posterior edge of the tibial plateaus, line B perpendicular to line A through the center of the implant (figure 2), and line C through the center of the tibial component and

the most prominent part of the anterior tibial tuberosity, RATC being the angle subtended by lines B and C (figure 2).

*b) Radiolucency and loosening screening*

The bone/implant interface radiolucency was deemed significant if >2 mm. The number per patient was reported on the Knee Society scoring system [21] (figure 3).

*c) Bone/implant interface image quality*

Image quality was assessed at the various interfaces:

- tibial plateau;
- trochlear component;
- posterior condyles;
- patella.

The assessment was made subjectively, using a Likert scale [22]:

- 0: many artifacts, interface invisible;
- 1: moderate artifacts, interface visualizable but not details;
- 2: few artifacts, interface visualizable with most details;
- 3: no artifacts, interface perfectly visualized.

0 and 1 correspond to zero or poor visualization, precluding precise interpretation; 2 and 3 correspond to good or very good visualization, allowing precise interpretation. Each interface was scored 0 to 3.

*d) Dosimetry*

Dosimetry was reported as the volume CT dose index (CTDIvol) based on the DICOM data. For CBCT CTDIvol, exploration intensity and length were fixed (90 kV, 5mAs (Table 1)) with no changes to the intensity modulation or manufacturer's CTDI. On MDCT, on the other hand, parameters were modifiable and the CTDI was calculated at each review and depended on the patient.

### 2.5 Statistics

Results were collected by an orthopedic surgeon between October 2017 and February 2018. Numerical variables were expressed as the mean, standard deviation and range, and qualitative variables as number and percentage. Distribution normality was checked graphically on histograms and by Shapiro-Wilk test. In the case of significant non-normality without obvious transformation, non-parametric tests were used.

For numerical variables, interobserver agreement was assessed on Fleiss inter-rater reliability [23] with 95% confidence interval, and for qualitative variables on kappa coefficient [24]: excellent (0.81-1.00), good (0.61-0.80), moderate (0.41-0.60), borderline (0.21-0.40), poor (0.00-0.20) or bad (<0.0). The significance threshold was set at 5%. Analyses used SAS software (SAS Institute Inc., Cary, NC 25513, version 9.3).

# 3. Results

### 3.1 Population

Twenty-nine patients were seen in consultation for TKA-related pain and underwent the imaging protocol. One was excluded for patellar dislocation preventing PFT measurement. Thus, 28 patients were included.

Mean age was 61 ±11.6 years [range, 45-85], with 21 women (75%) and 7 men (25%). Mean BMI was 33.6 ± 4 [range, 24.8-43.3]. Implants were all cemented: 15 posterior stabilized (54%), 1 posterior stabilized with tibial extension stem (3%), 5 mediolateral constrained condylar knee (CCK) (18 %) and 7 hinged (25%).

### 3.2 **Angle measurement**

For PFT, ICC was good (0.73; 95% CI: 0.52 – 0.87) on MDCT and excellent (0.82; 95% CI: 0.62 – 0.92) on CBCT (Table 1).

For RAFC, it was borderline (0.28; 95% CI: 0 – 0.61) on MDCT and moderate (0.44; 95% CI: 0.03-0.8) on CBCT. For RATC, it was excellent (0.82; 95% CI: 0.61 – 0.90) on MDCT and excellent (0.96;

95% CI: 0.88 – 0.99) on CBCT. Overall, interobserver reproducibility for angle measurement was better on CBCT.

### 3.3 Radiolucency

*a) Number of radiolucent lines*

One hundred and forty-four radiolucent lines were seen on MDCT, versus 112 on CBCT. The two radiologists respectively observed 93 and 51 radiolucent lines on MDCT and 64 and 48 on CBCT. ICC was moderate (0.45; 95% CI: 0.13 – 0.68) on MDCT and excellent (0.84; 95% CI: 0.68 – 0.96) on CBCT (figure 4).

b) *Tibial loosening*

All 28 cases were concordant for tibial loosening on MDCT: moderate kappa (0.451; 95% CI: 0.16 – 0.74). Twenty-seven were concordant on CBCT: excellent kappa (0.93; 95% CI: 0.78-1.0) (figure 4).

c) *Femoral loosening*

Nineteen of the 28 cases were concordant for tibial loosening on MDCT: poor kappa (0.192; 95% CI: -0.18 to +0.57). Twenty-one were concordant on CBCT: borderline kappa (0.387; 95% CI: 0.04 – 0.73) (figure 4). Overall, interobserver reproducibility for radiolucency and loosening was better on CBCT.

### 3.4 Image quality

a) *Tibia/tibial implant interface*

Mean image quality was 2.2/3 on MDCT and 2.75/3 on CBCT for the two radiologists
Kappa was borderline (0.026; 95% CI: -0.36 to +0.41) on MDCT and excellent (1.00; 95% CI: 1) on CBCT (figure 5).

*b) Trochlear region/femoral implant interface*

Mean image quality was 1/3 on MDCT and 2.3/3 on CBCT.

Kappa was poor (0.125; 95% CI: -0.10 to +0.35) on MDCT and good (0.708; 95% CI: 0.33 – 1) on CBCT.

*c) Femoral condyle/femoral implant interface*

Mean image quality was 0.9/3 on MDCT and 2/3 on CBCT.
Kappa was bad (-0,12; 95% CI: -0.25 to +0.01) on MDCT and moderate (0.523; 95% CI: 0.07 – 0.971) on CBCT.

*d) Patella/patellar implant interface*

Mean image quality was 1.25/3 on MDCT and 2.1/3 on CBCT.

Kappa was borderline (0.233; 95% CI: -0.14 to +0.60) on MDCT and borderline (0.362; 95% CI: -0.16 to +0.89] on CBCT.

Overall, image quality for both radiologists was better on CBCT at all interfaces. Figures 4 and 6 show interobserver agreement on the two devices.

### 3.5 Dosimetry

Mean CTDIvol was 5.125 ± 2.01 mGy [range, 2.45-9.67] on MDCT and 4.138 mGy on CBCT: i.e., 1.24-fold greater (p=0.0396).

## 4. Discussion

In the present series, CBCT provided reliable and reproducible analysis of knee implants, by optimizing image quality. This is the first French report of CBCT in knee arthroplasty. Most previously published reports were concerned with cadaveric bones or phantom knees, making this study one of the first to focus on CBCT used in clinical practice [25]. It is also the first in the literature to assess all the CT parameters generally used for hinged or reconstructive implants.

Although great progress has been made in image post-processing with an artifact-reduction algorithm [26,27], metal artifacts are still numerous, impairing image quality. The present study found better image quality with CBCT. Nardi et al. [28] reported similar results for CBCT image quality in bone and soft tissue at 2, 5, 10 and 15 mm around knee implants in the supracondylar region, at the anatomic transepicondylar axis and in the tibia. On a Likert scale from G0 (no visibility) to G3 (perfect visibility), they reported CBCT image quality of generally G2 or G3 in the supracondylar region and tibia, both above and below the tibial plateau. The present study found similar results for the trochlear region and tibial plateau, with the kappa coefficient judged respectively excellent (k>0.8) and good (k=0.71). In contrast, Nardi et al. found poor quality (G0) in the posterior femur, where the present study found a mean quality of 2/3 and moderate kappa (k=0.52). Carrino et al. [29] analyzed CBCT image quality in cadaveric elbows, hands, knees and feet, rated by a radiologist on a Likert scale from 1 (poor) to 5 (excellent); quality was rated as good to excellent in all cases [29]; bone study and joint study were respectively excellent (5/5) and good (4/5), with the best results in the knee and elbow (4/5 and 5/5 respectively) [29].

The literature data (Table 2) matches the present results for femoral and tibial component rotation. Nardi et al. [28] reported almost perfect interobserver correlation coefficients of 0.89 to 0.94 for PFT, RAFC and RATC. Jaroma et al. [25] reported a coefficient of 0.87 (95% CI: 0.74-0.94) for RATC and 0.41 (95% CI: 0.12-0.69) for RAFC, comparable to the present findings. The difference between femur and tibia may be due to the difficulty of analyzing the transepicondylar axis in the femur, thus increasing the scatter of measurement.

A few studies considered the contribution of CBCT in diagnosing implant loosening in knee surgery. Jaroma et al. [25] reported 97% sensitivity and 85% specificity for tibial component loosening, but had no cases of femoral or patellar loosening among their 18 cases. The interobserver correlation for diagnosis of loosening was moderate, with the kappa coefficient ranging from 0.58 (95% CI: 0.38–0.84) to 0.59 (95% CI: 0.35–0.83). Four tibial implants were diagnosed as loose, with no femoral or patellar loosening. However, they did not record the pathological radiolucency, and studied only severe osteolysis, and thus low-grade lesions may have been overlooked. In the present study, pathological radiolucency screening also showed excellent interobserver concordance, with a kappa coefficient of 0.84 [95% CI: 0.68-0.96]. One hundred and forty-four radiolucent lines were observed on MDCT and 112 on CBCT. Frequency was greater in hinged and extension stem models;

this difference may be due to metal artifacts, leading to diagnosis of radiolucency on MDCT despite artifact reduction software.

For radiation dose, we found that the CTDIvol was lower in CBCT than MDCT, but our overall results were lower than reported elsewhere [33-35]. This was due to our standard-quality/low-dose MDCT acquisition protocol, which nevertheless was that used in current care for assessment of implant rotation and limb torsion. In 139 CBCT scans in emergency traumatology, all joints taken together, Jacques et al. [36] reported a mean dose-length product (DLP) that was 50.7% lower in CBCT than MDCT: respectively, 101.6 mGy/cm and 206.5 mGy/cm.

The present study has certain limitations. 1) The retrospective design and small sample size limit conclusions. It was not possible to calculate the interobserver concordance according to implant type, due to small numbers (n= 15 and 13). 2) The limited exploration length on CBCT sometimes did not enable imaging of the extremity in certain reconstructive implant stems. The CBCT tunnel diameter is a limitation for this technique, with a 23 cm exploration field for the model used in the present study, varying between manufacturers. On the other hand, the present series included patients with high BMIs who were still able to be examined. 3) We lacked data for other investigations and for implant revision in individual patients, which is considered the gold-standard in diagnosing implant loosening. 4) The intra-observer concordance was not assessed, but could have explained the difficulty in making certain measurements. However, the study objective was not to assess the radiologists' experience on this indicator, as they were all experienced in musculoskeletal imaging, but rather to assess the reproducibility of CTCB measurement. 5) Our use of low-dose X-ray for MDCT may have increased the difference in image quality with respect to CBCT. However, these were routine procedures and the radiation dose could not be tailored to the needs of the study.

## 5. Conclusion

The present preliminary findings demonstrated the interest of cone-beam CT for etiological work-up in TKA pain. Concordance testing on the study parameters were in agreement with the literature. CBCT emerged as a reliable and reproducible means of investigation for angle measurement and diagnosis of implant loosening, due to optimized image quality. Further studies are needed to assess its use in screening for loosening in comparison to the gold standard of surgical revision.

**Disclosure of interest:** The authors have no conflicts of interest to disclose in relation to the present study. Elsewhere, Henri Migaud is Editor in Chief of Orthopaedics & Traumatology; Surgery & Research, and education and research consultant for Zimmer-Biomet, Corin, MSD and SERF. Sophie Putman is an education and research consultant for Corin. Gilles Pasquier is an education consultant for Zimmer-Biomet. Anne Cotten is an education and research consultant for MSD and Novartis. The other authors have no conflicts of interest.

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**Author contributions:** JD: study design, data collection and analysis, article writing; TJ: study design, data collection and analysis, article writing; PM: article writing, data analysis; GP: article writing, data analysis; AC: study design, data analysis, article writing; HM: data analysis, article writing; VM: study design, data collection, article writing SP: study design, examination indications, data collection and analysis, article writing.

## References


1. Barbier A, Koussougbo F, Tosato G, Pinçon C, Guénault N. Pharmacie clinique appliquée aux dispositifs médicaux : information des patients sur les prothèses articulaires : intérêts et optimisation. Le Pharmacien Hospitalier et Clinicien 2018;53: doi 10.1016/j.phclin.2018.02.002

2. Maloney WJ. National Joint Replacement Registries: has the time come? J Bone Joint Surg Am 2001;83:1582-5.

3. Maradit Kremers H, Larson DR, Crowson CS, Kremers WK, Washington RE, Steiner CA, et al. Prevalence of Total Hip and Knee Replacement in the United States. J Bone Joint Surg Am 2015;97:1386-97.

4. Pietrzak J, Common H, Migaud H, Pasquier G, Girard J, Putman S. Have the frequency of and reasons for revision total knee arthroplasty changed since 2000? Comparison of two cohorts from the same hospital: 255 cases (2013-2016) and 68 cases (1991-1998). Orthop Traumatol Surg Res 2019;105:639-645..

5. Kurtz S, Ong K, Lau E, Mowat F, Halpern M. Projections of Primary and Revision Hip and Knee Arthroplasty in the United States from 2005 to 2030. J Bone Joint Surg Am 2007;89:780-5.

6. Burdin P. Huten D. Revision of total knee arthroplasty. Rev Chir Orthop 2011;87 (supplément 5):S143-S198

7. Dalury DF, Pomeroy DL, Gorab RS, Adams MJ. Why are Total Knee Arthroplasties Being Revised? J Arthroplasty 2013;28(8 Suppl):120-1.

8. Pitta M, Esposito CI, Li Z, Lee Y, Wright TM, Padgett DE. Failure After Modern Total Knee Arthroplasty: A Prospective Study of 18,065 Knees. J Arthroplasty 2018;33:407-14.

9. Barrett JF, Keat N. Artifacts in CT: Recognition and Avoidance. Radiographics 2004;24:1679-91.

10. Charbit A, Molina J, Fischer C, Feydy A, Chevrot A, Drapé JL. Gestion des artefacts metalliques au scanner. Journal de Radiologie. 2008;89:1364. doi 0.1016/S0221-0363(08)76113-4.

11. Scarfe WC, Farman AG. What is Cone-Beam CT and How Does it Work? Dent Clin North Am 2008;52:707–30.

12. Korpics M, Surucu M, Mescioglu I, Alite F, Block AM, et al. Observer Evaluation of a Metal Artifact Reduction Algorithm Applied to Head and Neck Cone Beam Computed Tomographic Images. Int J Radiat Oncol Biol Phys 2016;96:897-904.

13. Veldhoen S, Schöllchen M, Hanken H, Precht C, Henes FO, et al. Performance of cone-beam computed tomography and multidetector computed tomography in diagnostic imaging of the midface: A comparative study on Phantom and cadaver head scans. Eur Radiol 2017;27:790-800.

14 Lintz F, Beaudet P, Richardi G, Brihault J. CT-scan in Weight bearing of ankle and foot pathology. Orthop Traumatol Surf Res 2020;107 Suppl 1:In press.

15. Zbijewski W, De Jean P, Prakash P, Ding Y, Stayman JW, Packard N, et al. A dedicated cone-beam CT system for musculoskeletal extremities imaging: Design, optimization, and initial performance characterization: Dedicated cone-beam CT for musculoskeletal extremities. Medical Physics 2011;38:4700-13.

16. Leardini A, Durante S, Belvedere C, Caravaggi P, Carrara C, Berti L, et al. Weight-bearing CT Technology in Musculoskeletal Pathologies of the Lower Limbs: Techniques, Initial Applications, and Preliminary Combinations with Gait-Analysis Measurements at the Istituto Ortopedico Rizzoli. Semin Musculoskelet Radiol 2019;23:643-56..

17. Durastanti G, Leardini A, Siegler S, Durante S, Bazzocchi A, Belvedere C.

Comparison of cartilage and bone morphological models of the ankle joint derived from different medical imaging technologies. Quant Imaging Med Surg 2019;9:1368-82.

18. Manning BT, Bohl DD, Idarraga AJP, Holmes GB, Lee S, Lin JL, et al. Patient Knowledge Regarding Radiation Exposure From Foot and Ankle Imaging. Foot Ankle Specl 2019;1938640019865364. doi: 10.1177/1938640019865364..

19. Brüllmann D, Schulze RKW. Spatial resolution in CBCT machines for dental/maxillofacial applications— what do we know today? Dentomaxillofac Radiol. 2015;44:20140204. doi: 10.1259/dmfr.20140204.

20. Marzo J, Kluczynski M, Notino A, Bisson L. Comparison of a Novel Weightbearing Cone Beam Computed Tomography Scanner Versus a Conventional Computed Tomography Scanner for Measuring Patellar Instability. Orthopaedic Journal of Sports Medicine. 2016;4(12):232596711667356 doi: 10.1177/2325967116673560.

21. Debette C, Parratte S, Maucort-Boulch D, Blanc G, Pauly V, et al. French adaptation of the new Knee Society Scoring System for total knee arthroplasty. Orthop Traumatol Surg Res 2014;100:531-4

22. Phelps AS, Naeger DM, Courtier JL, Lambert JW, Marcovici PA, Villanueva-Meyer JE, et al. Pairwise Comparison Versus Likert Scale for Biomedical Image Assessment. AJR Am J Roentgenol 2015;204:8-14.

23. Fleiss JL. Design and Analysis of Clinical Experiments 1 st ed. New-York : Wiley; 1988.

24. Landis JR, Koch GG. The measurement of observer agreement for categorical data. Biometrics 1977;33:159�74.

25. Jaroma A, Suomalainen J-S, Niemitukia L, Soininvaara T, Salo J, Kröger H. Imaging of symptomatic total knee arthroplasty with cone beam computed tomography. Acta Radiol 2018;59:1500-1507.

26. Stidd DA, Theessen H, Deng Y, Li Y, Scholz B, Rohkohl C, et al. Evaluation of a Metal Artifacts Reduction Algorithm Applied to Postinterventional Flat Panel Detector CT Imaging. AJNR Am J Neuroradiol 2014;35:2164-9..

27. Gondim Teixeira PA, Meyer J-B, Baumann C, Raymond A, Sirveaux F, Coudane H, et al. Total hip prosthesis CT with single-energy projection-based metallic artifact reduction: impact on the visualization of specific periprosthetic soft tissue structures. Skeletal Radiol 2014;43:1237-46.

28. Nardi C, Buzzi R, Molteni R, Cossi C, Lorini C, Calistri L, et al. The role of cone beam CT in the study of symptomatic total knee arthroplasty (TKA): a 20 cases report. Br J Radiol 2017;90:20160925. doi: 10.1259/bjr.20160925..

29. Carrino JA, Al Muhit A, Zbijewski W, Thawait GK, Stayman JW, Packard N, et al. Dedicated Cone-Beam CT System for Extremity Imaging. Radiology 2014;270:816-24.

30. Jazrawi LM, Birdzell L, Kummer FJ, Di Cesare PE. The accuracy of computed tomography for determining femoral and tibial total knee arthroplasty component rotation. J Arthroplasty 2000;15:761-6.

31. Konigsberg B, Hess R, Hartman C, Smith L, Garvin KL. Inter and intraobserver reliability of two-dimensional CT scan for total knee arthroplasty component malrotation. Clin Orthop Relat Res 2014;472:212‑7.

32. Figueroa J, Guarachi JP, Matas J, Arnander M, Orrego M. Is computed tomography an accurate and reliable method for measuring total knee arthroplasty component rotation? Int Orthop 2016;40:709‑14.

33. Koivisto J, Kiljunen T, Wolff J, Kortesniemi M. Assessment of effective radiation dose of an extremity CBCT, MSCT and conventional X ray for knee area using MOSFET dosemeters. Radiat Prot Dosimetry 2013;157:515-24.

34. Tschauner S, Marterer R, Nagy E, Apfaltrer G, Riccabona M, Singer G, et al. Surface

radiation dose comparison of a dedicated extremity cone beam computed tomography (CBCT) device and a multidetector computed tomography (MDCT) machine in pediatric ankle and wrist phantoms. PLoS One 2017;12:e0178747. doi: 10.1371/journal.pone.0178747.

35. Pugmire BS, Shailam R, Sagar P, Liu B, Li X, Palmer WE, et al. Initial Clinical Experience With Extremity Cone-Beam CT of the Foot and Ankle in Pediatric Patients. AJR Am J Roentgenol 2016;206:431-5.

36 Jacques T, Morel V, Dartus J, Badr S, Demondion X, Cotten A. Impact of the implantation of a Cone-beam CT (CBCT) dedicated to trauma of the extremities in an emergency radiology division: a population-based study Orthop Traumatol Surf Res 2021;107:In press.

Table 1: MDCT and CBCT acquisition protocols.

| | ***MDCT*** | ***CBCT*** |
|---|---|---|
| ***Tension*** | *120 or 140 Kv, automatic adaptation by Care Kv system* | *90 Kv* |
| ***Intensity*** | *60 mAs (adaptation by Care Dose system)* | *5 mAs* |
| ***Pitch*** | *0.8* | *Not applicable* |
| *Exploration length* | *Variable according to zone* | *23 cm* |
| ***Metal artifact reduction software*** | *Iterative Metal Artifact Reduction (IMAR)* | *Carestream Metal Artifact Reduction (CMAR 2)* |

Table 2: Interobserver agreement (intraclass correlation coefficient: ICC) for implant rotation in published studies. Values closer to 1 indicate better agreement.

| Author | Date | Device | Concordance (ICC) | |
|---|---|---|---|---|
| | | | Femoral Rotation | Tibial Rotation |
| **Jazrawi et al. [30]** | 2000 | MDCT | 0.90 | 0.93 |
| **Konigsberg et al. [31]** | 2013 | MDCT | 0.39 | 0.67 |
| **Figueroa et al. [32]** | 2016 | MDCT | 0.76 | 0.65 |
| **Nardi et al. [28]** | 2017 | CBCT | 0.89 | 0.94 |
| **Jaroma et al. [25]** | 2018 | CBCT | 0.41 | 0.87 |
| **Dartus** | 2018 | CBCT | 0.44 | 0.96 |

| Bad | Poor | Borderline | Moderate | Good | Excellent |
|---|---|---|---|---|---|
| **<0.0** | **[0 ;0.20]** | **[0.21 ;0.40]** | **[0.41 ;0.60]** | **[0.61 ;0.80]** | **[0.81 ;1.00]** |

Figure legends

Figure 1: Patient positioning for (Lille university hospital).

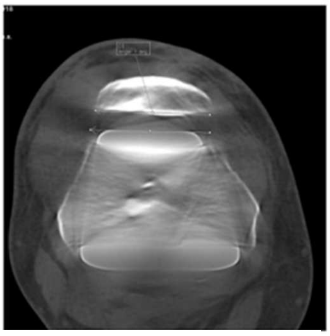
Figure 2: Angle measurements in the various knee prostheses (CBCT image, Lille university hospital).

Figure 3: Screening for significant bone/implant interface radiolucency.

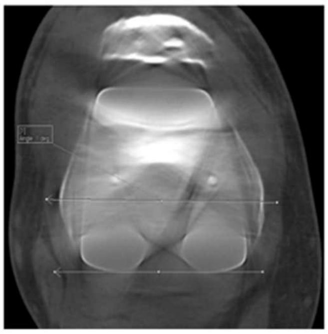
Figure 4: Interobserver concordance (intraclass correlation coefficient) for study parameters on MDCT and CBCT). Values closer to 1 indicate better agreement

Figure 5: Mean image quality rated by the two radiologists at the various interfaces according to device.

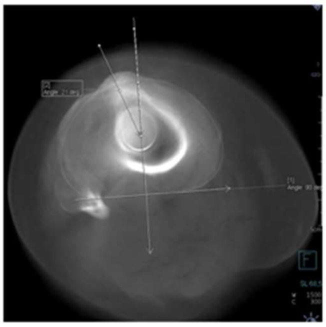
Figure 6: Graphic analysis of interobserver concordance of study criteria according to device.



Patellofemoral angle (TFP)

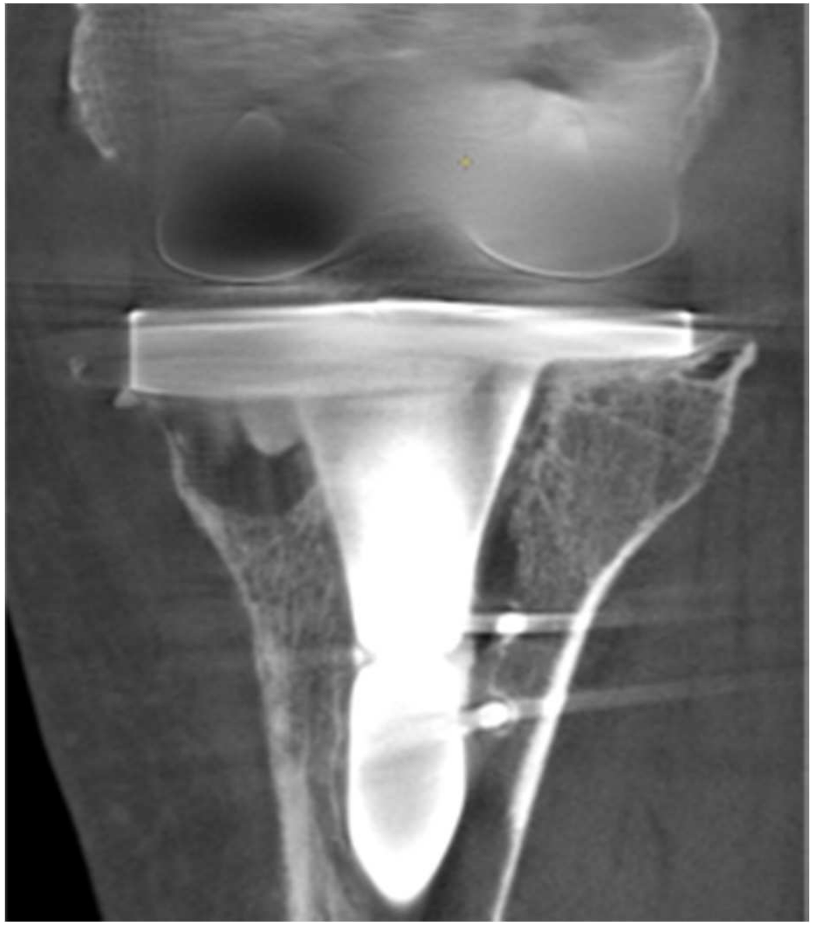


Femoral implant rotation (RADC)



Tibial implant rotation (RATC)

**TDM**



**Cone-Beam**

Figure 4: Interobserver concordance (intraclass correlation coefficient) for study parameters on MDCT and CBCT). Values closer to 1 indicate better agreement

| | | MDCT | | | CBCT | | |
|---|---|---|---|---|---|---|---|
| | | Coefficient | | 95% CI | Coefficient | | 95% CI |
| PFT | ICC | 0.73 | Good | 0.52 - 0.87 | 0.82 | Excellent | 0.62 - 0.92 |
| RAFC | ICC | 0.28 | Borderline | 0 - 0.61 | 0.44 | Moderate | 0.03 - 0.81 |
| RATC | ICC | 0.82 | Excellent | 0.61 - 0.90 | 0.96 | Excellent | 0.88 - 0.99 |
| Radiolucency | ICC | 0.45 | Moderate | 0.13 - 0.68 | 0.84 | Excellent | 0.68 - 0.96 |
| Tibial loosening | Kappa | 0.45 | Moderate | 0.16 - 0.74 | 0.93 | Excellent | 0.78 - 1.0 |
| Femoral loosening | Kappa | 0.19 | Poor | -0.18 -0.57 | 0.38 | Borderline | 0.04 - 0.73 |
| Image quality: Tibia | Kappa | 0.03 | Poor | -0.36 -0.41 | 1 | Excellent | NA |
| Image quality: Anterior femur | Kappa | 0.12 | Poor | -0.10 -0.35 | 0.71 | Good | 0.33 - 1 |
| Image quality: Posterior femur | Kappa | -0.12 | Bad | -0.25 -0.01 | 0.52 | Moderate | 0.07-0.971 |
| Image quality: Patella | Kappa | 0.23 | Borderline | -0.14 -0.60 | 0.36 | Borderline | -0.16 -0.89 |

PFT = patellofemoral tilt; RAFC=Rotation angle of femoral component; RATC= Rotation angle of tibial component

| Bad | Poor | Borderline | Moderate | Good | Excellent |
|---|---|---|---|---|---|
| <0.0 | [0.0-0.20] | [0.21-0.40] | [0.41-0.60] | [0.61-0.80] | [0.81-1.00] |

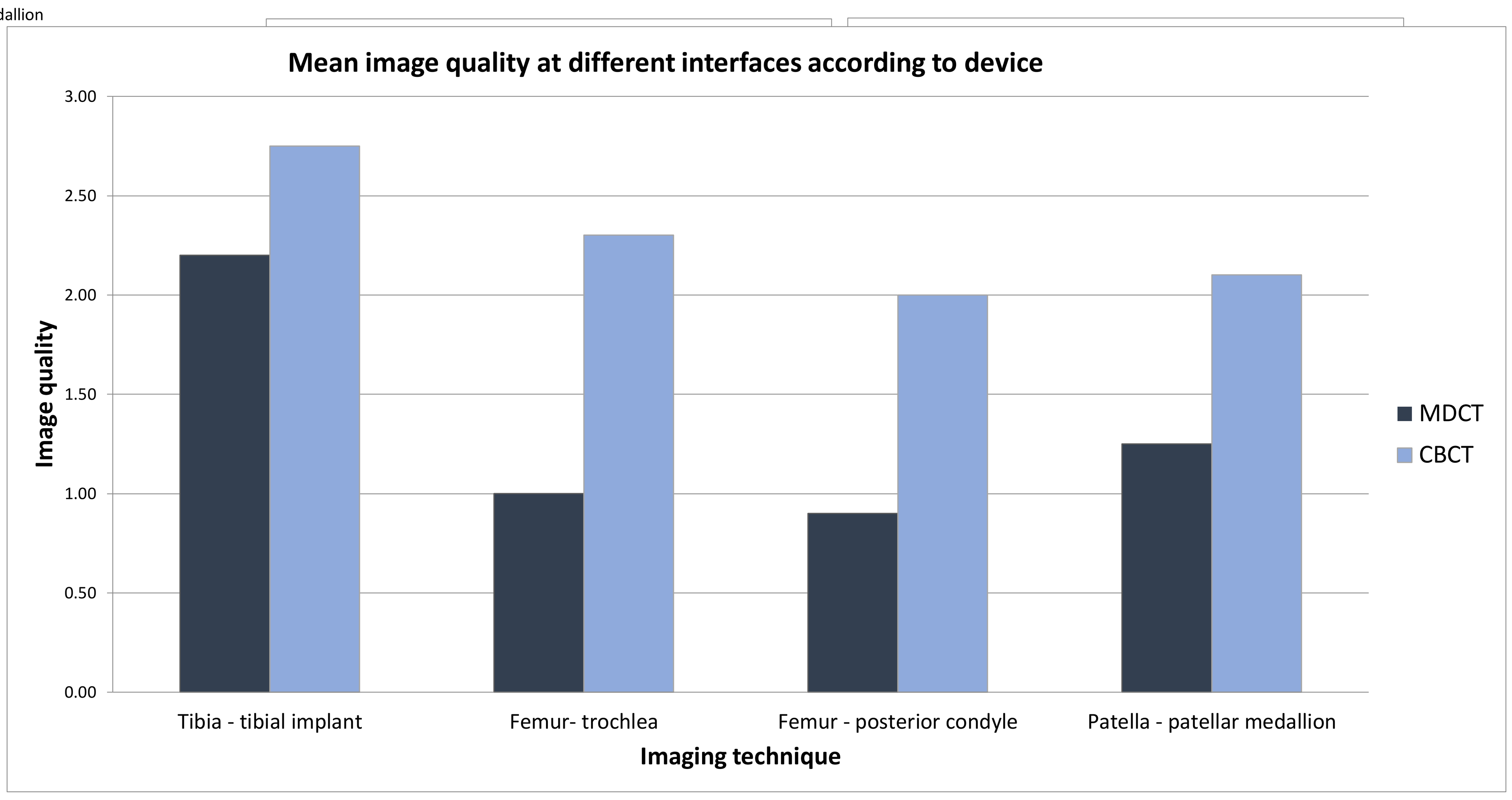
| | Tibia - tibial in | Femur- trochl | Femur - poste | Patella - patellar medallion |
|---|---|---|---|---|
| MDCT | 2.20 | 1.00 | 0.90 | 1.25 |
| CBCT | 2.75 | 2.30 | 2.00 | 2.10 |

| Tibia | MDCT | CBCT |
|---|---|---|
| Obs 1 | 2.1 | 2.6 |
| Obs 2 | 2.3 | 2.9 |

| Fémur Ant. | MDCT | CBCT |
|---|---|---|
| Obs 1 | 0.6 | 2.1 |
| Obs 2 | 1.4 | 2.5 |

| Fémur Post. | MDCT | CBCT |
|---|---|---|
| Obs 1 | 0.5 | 1.7 |
| Obs 2 | 1.3 | 2.3 |

| Patella | MDCT | CBCT |
|---|---|---|
| Obs 1 | 1.3 | 2.3 |
| Obs 2 | 1.2 | 1.9 |



| | MDCT | CBCT |
|---|---|---|
| PFT | 0.73 | 0.82 |
| RAFC | 0.28 | 0.44 |
| RATC | 0.82 | 0.96 |
| Radiolucencies | 0.45 | 0.84 |
| Tibial loosening | 0.45 | 0.93 |
| Femoral loosening | 0.19 | 0.38 |