Wear patterns in anteromedial osteoarthritis of the knee evaluated with CT-arthrography

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1. Introduction

Debate still exists as to the most appropriate surgical intervention to treat patients with bone-on-bone disease isolated to the medial side. The options for surgery include: total knee replacement (TKR), unicondylar knee replacement (UKR) or high tibial osteotomy (HTO) [1]. The decision to choose one form of treatment over another depends on the relative advantages of each treatment, choices of patient and surgeon and the eligibility for the treatment based on technical exams [1]. The preoperative work-up to decide to which treatment group the patient should be attributed is usually based on history and clinical exam, but of course also on radiographs. Some surgeons utilise stress radiographs to verify the integrity of the lateral compartment before proceeding to UKR [2,3]. However focal cartilage defects on the lateral side or patellofemoral wear could be underestimated in those cases and therefore other authors have questioned the value of stress radiographs [4]. Missing out on contralateral pathology those cases and therefore other authors have questioned the value of stress radiographs [4].

Magnetic resonance imaging (MRI) is the technique of choice for the study of knee pathology. For specific indications such as the study of meniscal and cartilage pathology, computed tomography (CT) arthrography has shown high diagnostic performance compared to MRI and has been used in routine practice in many centers where MRI is less available [6]. We hypothesized that CT-arthrography could help us decide whether a patient with medial osteoarthritis (MOA) in need of a knee replacement could be attributed to one treatment group over the other (UKR vs TKR).

The hypotheses of this study were that: (1) a specific arthritic wear pattern can be recognized in patients that should undergo TKR; (2) wear patterns in other compartments than the medial femorotibial compartment can be linked to the different Kennedy zones and the load bearing axis.

2. Patients and methods

2.1. Sample population

One hundred consecutive patients were retrospectively selected for this study from a series of knee replacements performed by the first author (ET) for primary medial osteoarthritis (MOA) who underwent TKR (N=50) or UKR (N=50) and had a preoperative radiograph showing medial osteoarthritis Kellgren Lawrence (K/L) grade IV, a CT arthrography of the knee executed at our institution and a clinical and radiological follow-up of minimum two years without any complaints about the knee as well as postoperative imaging including radiographs and full leg standing radiographs to eliminate loosening, osteolysis and malalignment.

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Methods: A retrospective study of 100 patients that had either medial unicondylar knee replacement (UKR) (N=50) or total knee replacement (TKR) (N=50). One observer measured lower limb mechanical alignment and osteoarthritis patterns of the knee in each compartment with radiographs, CT-arthrography and full leg standing radiographs.

Results: All patients had Kellgren-Lawrence grade IV osteoarthritis of the medial femorotibial joint with a mean (SD) varus alignment of the lower limb (172° (3.5°) HKA-angle). Zone mechanical axis distribution showed strong correlation with HKA-axis. Arthritis patterns were different for patients selected for UKR or TKR. UKR patients had anteromedial osteoarthritis and wear of the medial facet of the patella in contrast to TKR patients who had medial osteoarthritis associated with diffuse or lateral patellofemoral wear and wear of the central or posterior zones of the lateral compartment. Medial facet wear of the patella is related to more important varus alignment of the lower limb (Kennedy zone 0 and 1).

Conclusion: CT-arthrography imaging can show lesions that are not visible on plain or stress radiographs because of central or posterior localization with surrounding intact cartilage. Patients who develop tri-compartmental osteoarthritis despite varus alignment have probably other risk factors than their mechanical alignment and should be considered candidates for TKR.

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Exclusion criteria were: history of prior open knee surgery except meniscectomy, history of infection or trauma, and neurologic disorders.

Sociodemographic data such as age, gender and body mass index (BMI) were collected for this group of MOA patients. All presented medial bone on bone K/L IV osteoarthritis (OA) [7]. Demographics according to type of arthroplasty are summarised in Table 1. Ethical approval (2012/03MAI/217) was obtained for retrospective analysis of the data from the Ethics Committee of the Saint Luc University Hospital, Brussels, Belgium.

### 2.2. Outcome measures

#### 2.2.2. Radiography

Radiography Knee radiographs obtained immediately before the arthrography examinations included lateral and postero-anterior (PA) weight-bearing views (following the Lyon-Schuss fluoroscopy protocol) and patellar skyline views [8].

Arthrography 10 mL of ionic contrast material (meglumine ioxaglate and sodium ioxaglate, Hexabrix 320 (320 mg of iodine per milliliter); Guerbet, Aulnay-sous-bois, France) were injected into the knee joint under fluoroscopic guidance using a lateral approach.

CT-scan CT arthrograms were performed on a 40-detector row CT scanner (Somatom Definition AS; Siemens Healthcare, Forchheim, Germany). Patients were positioned supine, with the knee in extension. Acquisition parameters were: tube voltage, 120 kVp; reference tube current-time product, 350 mAs with the application of a dose modulation protocol (Care Dose 4D; Siemens Healthcare); detector configuration, 16×0.6 mm; collimation, 0.6 mm; pitch, 0.85; gantry rotation time, 1 s [8]. Image reconstruction parameters were: field-of-view (FOV) 15×15 cm; matrix 512; section thickness/increment 0.6/0.3 mm; bone convolution kernel (U70u). Multi-planar reformats in the axial, coronal and sagittal section thickness/increment 0.6/0.3 mm; bone convolution kernel pitch, 0.85; gantry rotation time, 1 s [8]. Image reconstruction detector configuration, 16×0.6 mm; collimation, 0.6 mm; reference tube current-time product, 350 mAs with the application CT scanner (Somatom Definition AS; Siemens Healthcare, Forchheim, Germany) measured as the Hip Knee (HKA) angle [13]. On the same standing radiograph the load bearing axis was drawn and classified according to the zone mechanical axis classification of Kennedy [14]. To determine the intra-observer agreement, ten randomly selected CT arthrograms and full leg standing radiographs were analyzed twice at a 4-week interval by the same observer [13].

#### 2.2.2. Image analysis

Radiographs One reader (PES), blinded to the CT arthrography findings, graded the femorotibial and the patellofemoral joints on the PA, lateral and skyline radiographs respectively, according to a K/L scale of radiographic OA [7] and according to Iwano et al. for patellofemoral arthritis on the skyline view [9]. Knee OA was defined by a K/L or Iwano grade ≥2. Absence of knee OA was defined by a K/L or Iwano grade <2. The K/L or Iwano grade for each knee was defined as the worst K/L grade of each compartment and the worst Iwano grade of the patellofemoral compartment. Retrospectively 100 knees with K/L IV of the medial compartment without arthritis of the lateral femorotibial or patellofemoral joint were selected for further CT-arthrography analysis.

CT Arthrograms The same reader (PES) evaluated then the medial femorotibial, lateral femorotibial and patellofemoral cartilage that were graded according to a modified Outerbridge classification [10]. Three cartilage areas (anterior, central, posterior) were defined on each femorotibial compartment divided in thirds by three equal parts. Femoral and tibial cartilage were individually described. Three cartilage areas (medial, central and lateral) were defined on each patellofemoral cartilage by the same rules. Each area was analyzed separately. The cartilage was defined as abnormal when there was surface irregularity or any penetration of contrast material into the cartilage until reaching the subchondral bone [11]. Osteoarthritis was defined as Outerbridge IV or more. Subchondral osteolysis as a radiolucent zone under the tidemark of the bone was described in the area of observation. Subchondral bone sclerosis was classified according to Weidow et al. [12].

Full leg standing radiographs Alignment was measured pre- and postoperatively according to the Moreland criteria on standing full leg radiographs using the PACS (Carestream Client version 11.3; Carestream Health, Rochester, NY, USA) measured as the Hip Knee Ankle (HKA) angle [13]. On the same standing radiograph the load bearing axis was drawn and classified according to the zone mechanical axis classification of Kennedy [14]. To determine the intra-observer agreement, ten randomly selected CT arthrograms and full leg standing radiographs were analyzed twice at a 4-week interval by the same observer [13].

#### 3.1. Patient characteristics

#### 3.1.1. Radiographs

All included patients (N=100) were K/L IV of the medial compartment, with K/L in the lateral compartment of no more than II, and with Iwano no more than 2 in the patellofemoral compartment.

#### 3.1.2. CT arthrograms

Wear pattern in function of treatment (UKR/TKR): Anteromedial arthritis (AMOA) was present in 60% and central arthritis in 38% of
the UKR patients with conservation of the posteromedial cartilage (Fig. 1), 2% had posterior arthritis. Lesions of the medial patellar facet were present in 31% and lesions of the medial side of the lateral femoral condyle in 11%. Patients with medial arthritis (MOA) that were selected for TKR presented with medial or central trochlear lesions (32%) or with lateral patellofemoral disease that was present in 18%. Postero medial arthritis either on the tibial level (after ACL tear) or on the femoral level was present in 14%. Subchondral osteolysis of the lateral condyle was present in 16% of the TKA patients as well as either posterolateral condylar lesions (18%) or posterolateral tibial lesions (22%) (Fig. 2). Subchondral bone sclerosis evaluated on ArthroCT and classified according to Weidow et al. [12] showed that UKR patients presented sclerosis over the Anterior Peripheral Medial (APM) side predominantly and TKR patients over the central and posterior areas (CCM, PPM and PCM).

Wear pattern in function of the Kennedy zone mechanical axis: Patients with Kennedy 0 axis have in 57% patellar wear (especially medial facet 43%) and in 34% medial trochlear lesions. Kennedy 1 and 2 have lesions on the medial facet in 35% and Kennedy C patients have intact patellae. The Kennedy 1 and 2 patients have intact lateral cartilage on the medial condyle and intact lateral compartment cartilage. The Kennedy 0 patients have cartilage wear on the medial border of the lateral condyle because of tibial spine impingement secondary to the more important varus. Patients with Kennedy 0 have in 63% of the UKR patients femoral wear and not only anteromedial tibial wear.

Wear pattern in function of the BMI and type of treatment (UKR/TKR): In the UKR group, obese patients with BMI >25 had central trochlear wear in 20%. Patients with BMI >30 had medial facet wear (6%), independently of weight about 7% had central patella cartilage wear and none lateral patellofemoral wear. For the TKR patients all patients, independent of BMI, presented with wear over the three areas of patella and trochlea.

3.1.3. Full leg radiographs

The zone mechanical axis or Kennedy classification can be linked to a certain HKA-angle as shown in Table 2 for varus alignment patients. UKR patients had a mean (SD) preoperative HKA-angle of 172° (3.5°) that was corrected to 176° (3.5°) postoperatively. The Kennedy zone mechanical axis was preoperatively zone 1 and postoperatively zone 2 in UKR. TKR patients had a mean (SD)

Table 2

<table>
<thead>
<tr>
<th>Kennedy Classification</th>
<th>Mean (SD) HKA-angle</th>
<th>Range HKA-angle</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>167° (2°)</td>
<td>165°–169°</td>
</tr>
<tr>
<td>1</td>
<td>172° (1°)</td>
<td>170°–172°</td>
</tr>
<tr>
<td>2</td>
<td>175° (1°)</td>
<td>173°–175°</td>
</tr>
<tr>
<td>C</td>
<td>177° (2°)</td>
<td>176°–180°</td>
</tr>
</tbody>
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preoperative HKA angle of 172° (3°) that was corrected to 178° (2°), our objective being undercorrection in the varus knee. The Kennedy zone mechanical axis was preoperatively zone 1 and postoperatively zone C in TKR.

3.2. Intra-observer variability

Intra-observer coefficient of 0.87 observed for the areas (1/3 segments) and a 1° (0.5°) variance for the HKA-angle.

4. Discussion

The analysis of wear patterns of the knee on CT-arthrography has proven beneficial in ameliorating the quality of our patient selection for either unicompartmental or total knee replacement. An anteromedial wear pattern with intact posteromedial condylar cartilage is the ideal indication for UKR. Cartilage wear on the lateral side of the patella or lateral compartment in a varus aligned knee is suggestive for evolving disease and should be treated with TKR. A more varus HKA-angle can lead to patellofemoral wear and impingement of the medial side of the lateral compartment. Patellar wear was not seen more often in obese patients.

The Kaplan–Meier survivorship analysis of a unicompartmental replacement is about 95% (95% CI: 90–95%) at 6 years with 26% of revisions within an 8-year period being performed for disease progression in the lateral compartment and 7% being done within 2 years of the index operation [5,17]. Epinette et al. found disease progression being the second leading reason for failure of the UKRs in their series [18]. A possible explanation, as discussed in other publications, could be that the lateral compartment has not been visualized correctly in a minimally invasive technique and therefore pre-existing osteoarthritis would be underestimated [17,19]. Within these findings lies the importance and the value of CT-arthrography that allows to visualize the other compartments before surgery. In this study group no revision were necessary at follow-up of two years.

The influence of the patellofemoral joint on the outcome of UKR has well been studied and especially lateral patellofemoral degeneration can have an influence [20]. Patellofemoral joint space narrowing as evaluated by standard radiographs to determine cartilage condition has proven unreliable [21] and skyline radiographs can only exclude late stage degenerative changes [22]. This was observed in this study too and especially the frequency of dysplasia of the trochlea and lateral patellofemoral arthritis varus alignment was observed. The Zone Mechanical Axis of these patients was often Kennedy 2 and the medial arthritis was seen post meniscectomy.

Focal lateral compartment cartilage lesions were often present in the center of the condyle or posterior on the lateral plateau leading to the decision of TKR. Cartilage lesions of the medial aspect of the lateral condyle in Kennedy 0 patients were not considered contra-indications for UKR [3]. These are probably secondary to tibial spine impingement and with the implantation of the UKR the varus of the knee will be reduced from Kennedy 0 to Kennedy 1 or 2 according to this study. By this relative valgisation of the varus knee the spine contact is reduced and the conformity of the lateral compartment is increased. This could even be considered as a protective measure for the prevention of disease progression compared to letting the impingement exist in case of non-surgical treatment.

Patellofemoral osteoarthritis is a common condition affecting 24% of women and 11% of men over the age of 55 years with symptomatic osteoarthritis of the knee. About 75% of PFR are performed in females because of dysplasia [23]. Osteoarthritis progression of the femorotibial joint could be responsible for the failure rate of PFR [24]. Nicol et al. described the frequency of this complication in their series to be 12% with a mean time to revision of 55 months (range, 14 to 95 months). They observed that none of the dysplastic knees had developed femorotibial disease compared to 17% of the non dysplastic knees. They concluded that progressive tibiofemoral OA following PFR is less frequently seen when the PF osteoarthritis is secondary to dysplasia of the femoral trochlea [25]. The origin of PF wear should be found in these cases in malalignment of the patellofemoral joint. Femorotibial disease progression is for the same reason related to the coronal alignment of the lower limb with varus being a proven risk factor [26]. In this study the combination of patellofemoral arthritis secondary to dysplasia and medial OA was considered an indication for TKR and none of those patients were revised within the 2 years of our follow-up. According to this study no relation between BMI and medial patellofemoral or lateral femorotibial arthritis could be found.

The observations about anteromedial arthritis were slightly different than the findings of Arno et al. [27]. They observed 20% of anterior wear, 40% of middle wear and finally 35% of the entire surface. In this series 60% anterior and 38% central wear was found. In the Arno et al. study [27] they resected the meniscal tissue and looked at the entire tibial surface, but in this study the anterior part covered by the meniscus was not considered because there is rarely arthritis observed in this area. What in this study was considered anterior was probably classified as central by Arno et al. [27]. Furthermore in the Arno et al. study any patient with wear extending over 1/3 of the area was classified as entire surface wear. There were in this study anterior and central wear were classified individually and patients still considered for UKR. Entire surface wear would be 3/3 of the determined segments and these patients would find themselves in the TKR group [27].

A limitation of CT arthrography is related to its poor diagnostic performance for the evaluation of the ligaments, in particular the anterior cruciate ligament. However this remains a clinical evaluation by the surgeon and a recent paper showed that the survival for a fixed bearing UKA without ACL was the same as long as there was no clinical instability [28]. The ACL could potentially be better evaluated by MRI, but Hurst et al. have shown that the value of MRI in the determination of surgical criteria for UKA is limited [29]. Furthermore, posteromedial arthritis observed on CT-arthrography is suggestive for ACL deficiency. In the 2% of patients in this study group that had no AMOA we saw no clinical or radiological problems after two years of follow up. Another limitation of CT arthrography is its poor diagnostic performance for the detection of intra-substance cartilage or meniscal lesions. These lesions however have little impact on the therapeutic management and the choice between different prosthesis types.

A weakness of this study is of course that the patients were already selected for one type of arthroplasty when we created the two study groups and therefore the selection bias of the senior surgeon (ET) was included. However these selection criteria correspond to published indications in the literature and the evaluator (PES) was blinded to the surgical treatment groups [1,22,28].

The strength of this study is that all patients had a minimal follow-up of 2 years (range 2 to 6 years) and that none of the included patients had been revised for ‘unexplained pain’ or early disease progression of the other compartments [17,18].

5. Conclusion

CT-arthrography allows evaluating cartilage wear in the three compartments of the knee and selecting the right type of prosthesis to partially resurface the joint. Good indications for UKR present with anteromedial arthritis without posteromedial cartilage wear. Isolated medial facet arthritis of the patella is related to degree of varus of the lower limb.
Indications for TKR have lateral facet wear of the patellofemoral joint, cartilage wear of the lateral compartment or tricompartmental wear despite of their varus alignment.

6. Conflict of Interest Statement

ET is consultant for Biomet, Medacta and Zimmer and receives royalties from Biomet, Convatec, Jaypee Brothers and Zimmer. He is board member of the European Knee Associates (EKA). The other authors have no conflict of interest to report.

Author’s contributions

All authors participated in the study design and helped outline the manuscript. ET and PO drafted the manuscript. PES coordinated the data collection. All authors read and approved the final version.

Role of funding source

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References


