The Knee xxx (2015) xxx–xxx

Contents lists available at ScienceDirect

The Knee

# Update on the etiology of revision TKA — Evident trends in a retrospective survey of 1449 cases ☆

Tilman Calliess [a,*], Max Ettinger [a], Natalie Hülsmann [a], Sven Ostermeier [b], Henning Windhagen [a]

[a] Department of Orthopaedic Surgery, Hannover Medical School, Anna-von-Borries-Str. 3, 30625 Hannover, Germany
[b] Orthopädische Praxis und Gelenk-Klinik, Alte Bundesstrasse 58, 79194 Gundelfingen, Germany

ARTICLE INFO

*Article history:*
Received 9 July 2013
Received in revised form 5 February 2015
Accepted 7 February 2015
Available online xxxx

*Keywords:*
Knee
Knee arthroplasty
Failure mechanisms

ABSTRACT

*Background:* A working and complete knowledge of the different causes of dysfunction and pain after TKA is essential for the ability to correctly determine the cause of failure and to address this problem specifically. The purpose of this study was to update the etiology of implant failure. New diagnosis and current trends should be displayed.
*Methods:* All TKA revisions performed in our institution between 2001 and 2010 were reviewed retrospectively. Patient demographics and the precise indication for the surgery were documented. Descriptive statistical analyses and association analyses of both the diagnosis and patient demographics were performed.
*Results:* Within our collective of 1449 revision TKA a total of 40 different pathologies leading to revision surgery were identified and categorized. Overall 68.5% of the revisions were categorized aseptic, 31.5% as septic implant failure. Some recently debated diagnoses like low-grade-infection showed a high increase in incidence whereas classic failure mechanisms like polyethylene wear showed a decrease over the time.
*Conclusion:* We believe that this study successfully updates the current knowledge of different failure mechanisms in revision TKA, which have to be considered on dysfunction or pain after surgery. We were able to evaluate the clinical relevance of each pathology and could shift from implant related problems like wear to more surgical problems like instability and or malalignment over the last years. With a higher alertness to chronic low-grade-infections the incidence of infection is even increasing.
*Level of evidence:* Level II, economic and decision analysis.



## 1. Introduction

With the increasing volume of primary knee replacements a steadily increasing number of revision knee arthroplasties are observed [15]. Therefore we are facing the growing task of more complicated revision surgeries, consuming more health care resources associated with higher cost at each clinical stage [10].

Overall, the results of revision total knee arthroplasties (TKA) have been less successful compared to primary TKA [16]. The key to a successful management of implant failures is the detailed understanding of the pathogenesis, so that it can be targeted specifically. It is published that revision arthroplasties performed on residual pain of unknown origin are of poor outcome and success and may require further interventions [11]. On the other hand, addressing a specific pathology does improve the outcome of revision arthroplasty compared to unspecific procedures [9].

Raising the question "Why are TKA failing today?" a first systematic review on the etiology of revision TKA was given by Sharkey et al. in 2002 (7). They analyzed a collective of 212 revision procedures done in their institution regarding the intraoperatively found pathologies and classified ten different categories. Since then, several authors did likewise and reviewed the incidence and etiology of revision TKA in their collective [3,5–7,12,19]. However, each one used individual glossaries and focused on different pathologies. One limitation of all these papers clearly is a very broad differentiation of diagnosis that is of little clinical use for the attending surgeon. As an example, in all said publications the different types of instability are subsumed in one category, however the concrete failure mechanism can be quite different, as is the treatment and the prognostic outcome. Another example is the term malposition that can stand for malrotation or a joint line elevation. Both have to be analyzed precisely prior to surgery and specifically corrected. So it makes sense to differentiate more in detail and to know the incidence of said pathologies, to maybe adapt treatment strategies in the very beginning.

In addition to this, we can observe some recent developments in the current literature that might have an impact on the etiology of implant

☆ The study was performed at the Department of Orthopaedic Surgery, Hannover Medical School.

* Corresponding author. Tel.: +49 511 5354 593; fax: +49 511 5354 682.
*E-mail addresses:* tilman.calliess@ddh-gruppe.de (T. Calliess), max.ettinger@ddh-gruppe.de (M. Ettinger), natalie.huelsmann@gmx.de (N. Hülsmann), svenostermeier@googlemail.com (S. Ostermeier), henning.windhagen@ddh-gruppe.de (H. Windhagen).

http://dx.doi.org/10.1016/j.knee.2015.02.007
0968-0160/

failure, which have not been considered in the preceding literature. First, new implant materials and designs were introduced addressing former design or wear related failures. Second, new diagnostic methods were introduced to enable detection of specific pathologies [20]. And third, even new diagnoses have been considered, such as the allergy triggered early implant loosening, for example [1]. So, the previously reported mechanisms of failure may not represent contemporary causes of implant failure or even may not have the clinical relevance as reported before. To our knowledge, there is no analysis on the incidence of said pathologies in revision knee arthroplasty to this date.

Accordingly, we see the necessity to, first, update the catalog of diverse mechanisms of implant failure and to realign the glossary on the clinically relevant problems. The purposes of this study were to display our current knowledge of the diverse etiologies of total knee arthroplasty failure today and to determine the incidence of each pathology to display the clinical relevance. In addition, we proposed to outline current trends over the reviewed time period. This would be one essential difference to recent reviews on the current understanding of the etiology of revision TKA [18].

## 2. Methods

The study was conducted at a specialized orthopedic hospital affiliated to the university clinic. Today, approximately 500 primary TKA are performed per year in four different departments. The revision TKA is concentrated in one specialty department with six consultants. For this analysis, all total knee arthroplasty (TKA) revisions performed in our institution between 2001 and 2010 were reviewed retrospectively. Patient demographics, age and gender were documented as well as the precise diagnosis and indication for the surgery. The cause of failure was determined by the attending surgeon. It was based on (1) the preoperative history including all available diagnostic data (e.g. plain radiographs, stress radiographs, CT, scintigraphy, microbiological investigations or allergy testing), and (2) the analysis of intraoperative findings that included an examination of the patient during anesthesia and a gross inspection of the components.

All revision indications were categorized according to the specific failure mechanism. The classification was updated dynamically as more differentiated diagnoses were documented in our database. This was reviewed in conjunction with the current literature on TKA failure mechanism. The resulting class-divided categorization is displayed in Table 1. Only the main indication for revision surgery was considered for determining the particular incidence of each diagnosis.

### 2.1. Statistical analysis

A descriptive statistical analysis of both the individual indication for surgery as well as the patient demographics was performed. This data was considered in relation to the particular year of occurrence to get an idea of dynamic changes over recent years. Association analysis between the patients' age and the specific diagnosis was carried out using correlation analysis and the Chi-Quadrat-Test. A p value of 0.05 was assumed. For this purpose the cohort was subdivided into age related groups. Group one: patients under 55 years, group two: patients between 56 and 60 years, group three: patients between 61 and 75 years, group four: patients between 76 and 85 years and group five: patients 86 years and older. All statistics were done using SPSS Version 19.

## 3. Results

A total of 1449 revision TKA procedures in 1027 patients were included in our analysis. Two hundred eighty-six patients had two or more revisions recorded and a group of 16 patients had more than five consecutive surgeries on their TKA. Considering the revisions with exchange of at least one metal component, 54 interventions were performed on unicondylar prosthesis and 100 on semi-constraint or hinge implants. The rest referred to cruciate retaining or posterior stabilized bicondylar prosthesis. Excluding the early infection revisions that were 100% in-house revisions, the ratio between in-house and the primary surgery at other hospitals was approximately 60:40. Mean age of the patients was 68.2 ± 9.8 years (range 22 to 90 years). 44 patients (4.3%) were younger than 55 years of age, 141 (13.7%) were assigned to age group two, 563 (54.9%) to age group three, 252 (24.5%) could be allocated to age group four and 27 (2.6%) were older than 85 years. The ratio between women and men was almost 2:1, with 685 female and 342 male patients included. Over the years a steady increase of revision arthroplasties performed each year could be observed.

### 3.1. Classification of failure mechanisms

A total of 40 different diagnoses were specified in our collective. The literature review only revealed the implant breakage as an additional intrinsic failure mechanism that did not occur in our collective [12,18]. The resulting catalog of different failure mechanism is displayed in Table 1.

It is noticeable that some of the diagnoses were specified for the first time in our department within the course of the study. The term of singular component malrotation was initially used in 2004, the mid-flexion-instability in 2006, a soft tissue impingement was determined as a cause for residual pain in 2009 and the allergic loosening is a new diagnosis given for the first time in 2006 in our collective. The same applies for the term of low-grade-infection, defined as a presumed primary chronic infection leading to revision arthroplasty within the first years [22]. This specific term was used in 2005 for the first time.

**Table 1**
Display of the apparent failure mechanism leading to revision TKA in our study supplemented with the current literature. The overall incidence of every pathology is displayed in their percentage frequency.

| Aseptic failure | | | | Septic failure |
|---|---|---|---|---|
| Aseptic Loosening | Specified mechanical failure | Unspecified failure | Patello-femoral pathology | |
| – Aseptic Loosening<br>– Total<br>– Partial<br>– Focal osteolysis<br>– Allergic loosening<br>– Failure uni-knee<br>– Asept. Loosen.<br>– Panarthrosis | – Instability (primary or secondary)<br>– Global<br>– Coronary<br>– Anterior–posterior<br>– Flexion<br>– Mid-flexion<br>– Malalignment<br>– Axial<br>– Rotational<br>– Component overhang, overstuffing<br>– Joint line shift<br>– Wear<br>– Polyethylen inlay<br>– Metallic component<br>– Periprosthetic fracture<br>– Implant breakage<br>– Modular component dissociation<br>– Luxation/subluxation<br>– Soft-tissue-impingement | – Arthrofibrosis<br>– Recurrent joint effusion<br>– Hemarthrosis<br>– Chronic synovialitis<br>– Unspecific anterior knee pain<br>– Tumor<br>– Other cpe | – Secondary patella arthrosis<br>– Instability<br>– Maltracking<br>– Lateral patellar facet impingement<br>– Excessive component construct thickness<br>– Patella baja<br>– Tendon rupture/Extensor insufficiency<br>– Avascular necrosis | – Early infection<br>– Low-grade-infection<br>– Late infection |

Please cite this article as: Calliess T, et al, Update on the etiology of revision TKA — Evident trends in a retrospective survey of 1449 cases, Knee (2015), http://dx.doi.org/10.1016/j.knee.2015.02.007

### 3.2. Incidence of TKA failure mechanisms

One thousand four hundred forty-one of the 1449 recorded diagnoses could be assigned to a specific category. The remaining eight are specified as "other" reasons, as the differentiated cause of failure could not be reconstructed (n = 4) or were extrinsic events like fracture pseudarthrosis or a remaining drainage catheter.

Overall 68.5% of the revisions were categorized aseptic and 31.5% as septic implant failure. In revision for aseptic failure, the most prevalent indication for surgery in our collective was a patello-femoral pathology (20.4%), which was addressed by a secondary patella resurfacing plus soft tissue procedures. Aseptic total or partial implant loosening was the second most common indication for TKA revision (19.7%). The incidences of the main failure mechanism are presented in Fig. 1.

### 3.3. Current trends in revision TKA

The further analysis of the incidence of each failure mechanism in relation to the date revealed dynamic change for several diagnoses. Although a total of only 3.3% of the revision procedures were entitled as low-grade-infections, this diagnosis showed a high increase in incidence in the later years of our review period (dark purple-line, Fig. 2). In 2010 11.1% of the TKA revisions were indicated on suspected or proven low-grade-infections. The occurrence and incidence for the other above-mentioned "new diagnosis" is presented in Fig. 2. In contrast to this, one of the classic failure mechanisms in TKA, the polyethylene wear, showed a clear decrease over the time (turquoise-line, Fig. 2).

Considering only the diagnostic groups classified as aseptic or septic implant loosening, a shift from predominantly aseptic to septic entitled revision indications was observed (Fig. 3). All other subgroups, e.g. specific mechanical failure or patello-femoral pathologies, showed a relative constant incidence over the time (Not displayed in graph).

### 3.4. Correlations analysis between diagnosis and age

Certain correlations between specific diagnosis and patients' demographics could be detected in this study. Revisions due to patella-femoral problems were performed significantly more often in younger patients than in older ($p = 0.03$). The diagnoses recurrent joint effusion ($p = 0.03$) and arthrofibrosis ($p = 0.041$) and malrotation of prosthetic components ($p = 0.04$) are also diagnosed more often in younger patients than in older. In contrast, the diagnoses of acute early infection (n.s., $p = 0.07$) and periprosthetic fractures ($p = 0.01$) were found more often in older patients. The incidence of aseptic loosening, for example, showed no statistical significant difference in the several age groups.

## 4. Discussion

A working and complete knowledge of the different causes of dysfunction and pain after total knee arthroplasty is essential for the ability to correctly determine the cause(s) of failure and to address this problem specifically. The objectives of this study were to update the different causes of implant failure leading to revision surgery in total knee arthroplasty and to outline the clinical relevance and current trends. As a result we were able to differentiate a total of 40 different pathologies assigned to four main categories for TKA implant failure. We were able to demonstrate that new terms and diagnoses were adjoined to the clinical knowledge and this displays dynamic changes in the understanding of dysfunctional TKA. Implant related problems like wear are of less clinical impact today, whereas surgical problems like component malpositioning, instability and infection have a high incidence.

Four major limitations of this study are to be discussed. First, it is a retrospective analysis of diagnoses that are based on the available preoperative data and the intraoperative clinical judgment of the attending surgeon. No postoperative data were included and no outcome data is available. The set diagnoses were not reassessed regarding the accuracy afterwards. This limitation is knowingly accepted in order to illustrate current trends in revision TKA and to display the state of knowledge regarding the etiology of implant failure. This limitation equally applies to the other referenced publications. They all rely on the diagnoses set by the attending surgeon. Second, it is a single center study that might include a bias in the clinical judgment of arthroplasty failure. Third, a reliable differentiation of the specific failure mechanisms in the group "patello-femoral pathology" was not always possible. The majority was declared as secondary patella osteoarthritis to legitimate the secondary patella resurfacing. A combination of soft tissue procedures such as synovectomie, ligament balancing or arthrolysis could often be found in conjunction with these revisions. This indicates the presence of other pathologies potentially mistaken for patello-femoral pathologies in our study. Honestly, the underlying pathologies leading to anterior knee pain after TKA are yet poorly understood [14]. Fourth, the complexity and missing consensus on clear definitions of some specified diagnosis represent an inherent limitation of this study. Even well establish terms like the aseptic implant loosening may be caused by many factors [21] which have not been taken into account here.

Our primary intention was to review our current knowledge of the last 10 years of revision arthroplasty. We were focused on the specific clinical problem of implant failure that needed to be addressed specifically. This resulted in our glossary of failure mechanism in revision TKA

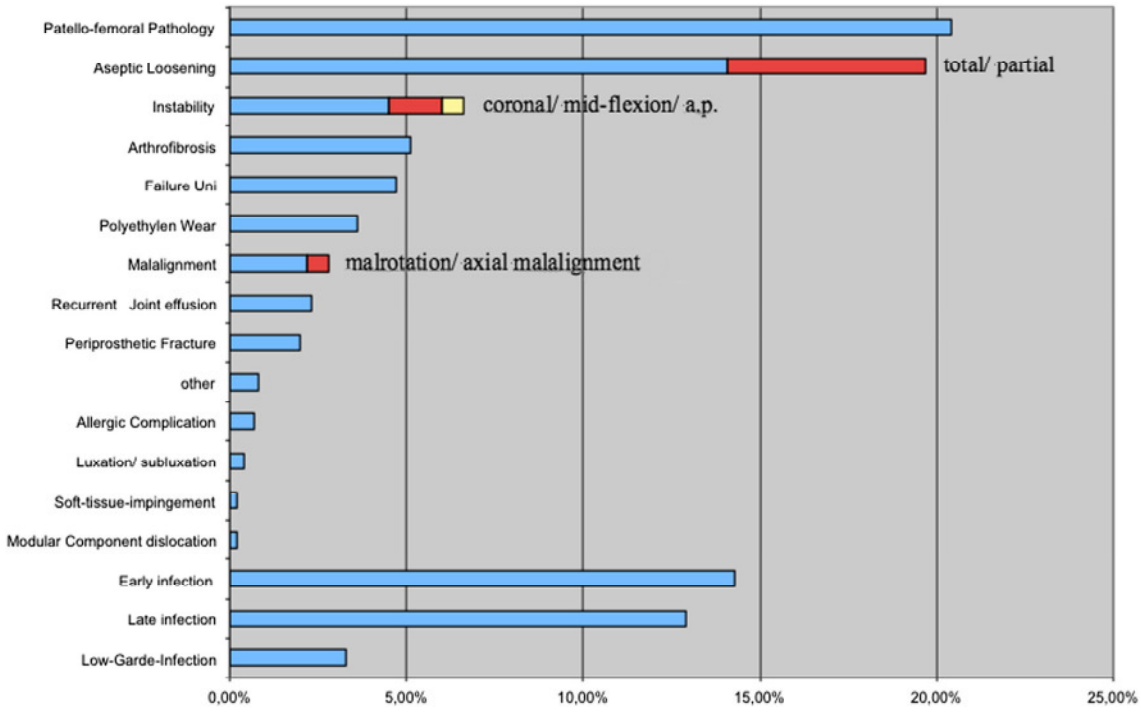


**Fig. 1.** Graphic display of the incidence of the key diagnoses led to revision TKA derived from Table 1.

Please cite this article as: Calliess T, et al, Update on the etiology of revision TKA — Evident trends in a retrospective survey of 1449 cases, Knee (2015), http://dx.doi.org/10.1016/j.knee.2015.02.007

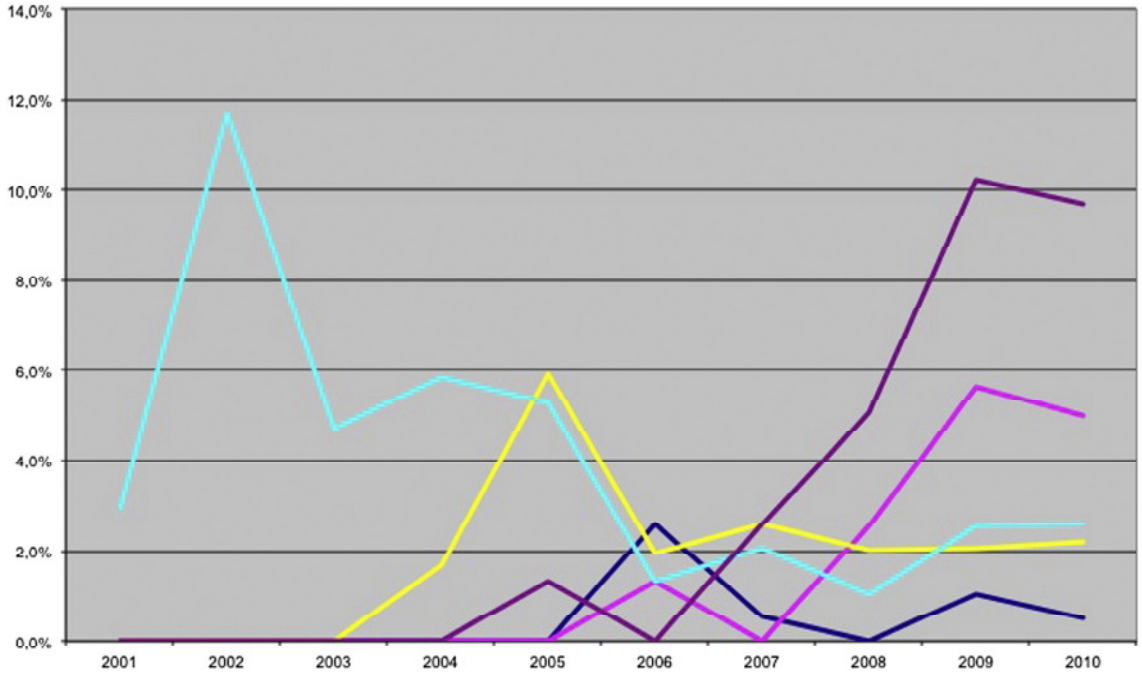


**Fig. 2.** Display of a time-based incidence of selected diagnosis over the years to visualize current trends in revision TKA. The low-grade-infection had its first reference in 2005 and showed clear increase in the clinical relevance over the time, whereas the polyethylene wear decreased in the review period. Other diagnoses like the allergic loosening (2006), mid-flexion-instability (2006) or component malrotation (2004) occurred at a later point in the reviewed period. Deep blue: Allergic loosening, pink: mid-flexion-instability, yellow: component malrotation, purple: low-grade-infection, turquoise: PE-wear. (For interpretation of the references to color in this figure legend, the reader is referred to the web version of this article.)

as displayed in Table 1. With the total differentiation of 40 different pathologies assigned to four main categories our study goes beyond existing literature reviews [18] and provides a more comprehensive summary of the current state of knowledge. As outlined above, a first systematic review on the etiology of revision TKA was given by Sharkey et al. in 2002 [19]. They defined 10 different categories of implant failure regarding the intraoperatively found pathologies. Later, Mulhall et al. assessed the etiology of short and long term modes of failure in a multicenter prospective cohort study [12]. Here, a total of 14 different pathologies leading to revision TKA were given. These categories differ in part from that of Sharkey. In comparison to the yet published overviews on the etiology of TKA failures [3,5–7,12,19], our scheme itemizes umbrella terms like the instability or the malalignment to the specific pathology and with regard to the treatment strategy. This gives additional


**Fig. 3.** Time-based illustration on the judgment of loosened implants to be septic (green) or aseptic (brown) revision. (For interpretation of the references to color in this figure legend, the reader is referred to the web version of this article.)

Please cite this article as: Calliess T, et al, Update on the etiology of revision TKA — Evident trends in a retrospective survey of 1449 cases, Knee (2015), http://dx.doi.org/10.1016/j.knee.2015.02.007

information to the clinical practice. First, based on our category a more targeted treatment could be planned. Second, this data gives the opportunity to review existing clinical algorisms. For example, we are able to display the incidence of a.p. instable TKAs in our collective, what is of value to discuss the primary usage of CR or PS-Designs in primary TKA. In addition, some very recently debated pathogenesis in early implant failure is adjoined to the catalog. So this is the first paper evaluating the clinical incidence of these diagnoses that are discussed in the current literature such as allergic complications, low-garde-infections or mid-flexion-instability.

Regarding the incidence and clinical relevance of said diagnoses, to our knowledge, this study represents the largest published series evaluating the specific failure mechanisms in revision TKA. Publications like Bozic's evaluation of the US Nationwide Inpatient Sample (NIS) database [3] or reports from arthroplasty registries have not been taken into account here, because of the very broad and unspecific differentiation of failure mechanism. Besides infection, the main indication (20.4%) for revision TKA in our collective was due to anterior knee pain or complications related to the patello-femoral joint (pf-joint). This differs from the other mentioned studies. Sharkey describes complications related to the extensor mechanism only half as much as we do [19]. Others range from 15.7% [12] to 1.4% [7]. The other data on the different incidences of each pathology predominately correlates with the existing literature. Septic revision, for instance, had an overall portion of 31.5% of the revisions in our study. The NIS records reveal an incidence of 25.2% [3], others range between 38% to 10.4% [5,12]. Aseptic loosening was the third most common pathology in our collective with 19.7%. In the literature values between 16% and 51% are reported [3,19]. Differences between the studies are presumably due to different study designs. Whereas several authors listed every pathology found during surgery [12,19] others relied on only one surgery indicating failure mechanism [3,5–7]. Moreover, some studies only consider the primary revision after index surgery whereas in our context even multiple revisions on one TKA were included. That especially explains the high incidence of septic revisions in our collective. In our view, the description of every pathology found during surgery may result in an interpretation that is not of clinical relevance. For example, Sharkey gives the polyethylene wear as the main failure mechanism in revision TKA (25%) [19]. However, it is questionable if the described wear in early implant failure would have lead to revision surgery with no other pathology present. Also instability (21.2% [19] vs. our 6%) may be overrepresented in his collective as there is no correlation to clinical symptoms in his context. The described difference in the incidence of patello-femoral revisions may rely on different therapy concepts. In primary bicompartimental TKA the revision of the pf-joint might be a first salvage procedure, however, we, of course, are aware of the poor outcome of the secondary patella resurfacing [13].

The third intention was to evaluate the incidence of different diagnoses regarding the date of occurrence so as to display current trends in revision TKA. To our knowledge this is the first study dealing with that issue. We were able to demonstrate that new terms and diagnoses such as the low-grade-infection [4,22] or allergic complications [1,17] were specified in our collective during the investigation period. Even other earlier described pathologies such as the component malrotation [2] or the flexion instability [20] were implemented into our clinical routine during that time. To us, this displays dynamic changes in the understanding of dysfunctional TKA. Moreover it mirrors the development and better availability of new diagnostic methods to detect the described specific pathologies. For example, the better availability of CT scans for the rotational analysis [2] or stress radiography to evaluate the stability in flexion should be mentioned [20]. One considerable finding was the increasing sensitivity of septic implant failure in discrimination to aseptic complications. This is consistent with the latest observation of arthroplasty registries. Other “classic” problems of implant failure such as polyethylene wear are clearly declining. However, we were not able to observe a significant change or a visible trend in the relative frequency of interventions targeting unspecific knee pain or recurrent effusion as initially expected and hypothesized. An explanation for this might be the fact that for some of the pathologies no clear definitions are available at the moment. For example, flexion-instability might lead to anterior knee pain, but while there are methods to display this problem [20] there is a lack of information where the cut-off levels for a relevant instability would be [8].

This study successfully summarizes the current knowledge of different failure mechanisms in revision TKA, which have to be considered on dysfunction or pain after surgery with 40 different diagnoses that were specified in our collective. It is the first paper evaluating the incidence and clinical relevance of said specific pathologies. The evaluation of our data shows a shift from implant related problems like wear to more surgical problems like different types of instability and or malalignment. The incidence of infection is still high and even increasing with a higher alertness to chronic low-grade-infections.

## Conflict of interest

Each author certifies that he or she has no commercial associations (eg, consultancies, stock ownership, equity interest, patent/licensing arrangements, etc) that might pose a conflict of interest in connection with the submitted article.

## Ethical review committee statement

Each author certifies that his or her institution has approved or waived approval for the human protocol for this investigation and that all investigations were conducted in conformity with ethical principles of research.

## References

[1] Bader R, Bergschmidt P, Fritsche A, Ansorge S, Thomas P, Mittelmeier W. Alternative materials and solutions in total knee arthroplasty for patients with metal allergy. Orthopade Feb 2008;37(2):136–42.
[2] Berger RA, Rubash HE, Seel MJ, Thompson WH, Crossett LS. Determining the rotational alignment of the femoral component in total knee arthroplasty using the epicondylar axis. Clin Orthop Relat Res Jan 1993;286:40–7.
[3] Bozic KJ, Kurtz SM, Lau E, Ong K, Chiu V, Vail TP, et al. The epidemiology of revision total knee arthroplasty in the United States. Clin Orthop Relat Res Jan 2010;468(1):45–51.
[4] Costerton JW. Biofilm theory can guide the treatment of device-related orthopaedic infections. Clin Orthop Relat Res Aug 2005;437:7–11.
[5] Fehring TK, Odum S, Griffin WL, Mason JB, Nadaud M. Early failures in total knee arthroplasty. Clin Orthop Relat Res Nov 2001;392:315–8.
[6] Gioe TJ, Killeen KK, Grimm K, Mehle S, Scheltema K. Why are total knee replacements revised?: analysis of early revision in a community knee implant registry. Clin Orthop Relat Res Nov 2004;428:100–6.
[7] Hossain F, Patel S, Haddad FS. Midterm assessment of causes and results of revision total knee arthroplasty. Clin Orthop Relat Res May 2010;468(5):1221–8.
[8] Ishii Y, Matsuda Y, Ishii R, Sakata S, Omori G. Sagittal laxity in vivo after total knee arthroplasty. Arch Orthop Trauma Surg May 2005;125(4):249–53.
[9] Lakstein D, Zarrabian M, Kosashvili Y, Safir O, Gross AE, Backstein D. Revision total knee arthroplasty for component malrotation is highly beneficial: a case control study. J Arthroplasty Oct 2010;25(7):1047–52.
[10] Maradit Kremers H, Visscher SL, Moriarty JP, Reinalda MS, Kremers WK, Naessens JM, et al. Determinants of direct medical costs in primary and revision total knee arthroplasty. Clin Orthop Relat Res Jan 2013;471(1):206–14.
[11] Mont MA, Serna FK, Krackow KA, Hungerford DS. Exploration of radiographically normal total knee replacements for unexplained pain. Clin Orthop Relat Res Oct 1996;331:216–20.
[12] Mulhall KJ, Ghomrawi HM, Scully S, Callaghan JJ, Saleh KJ. Current etiologies and modes of failure in total knee arthroplasty revision. Clin Orthop Relat Res May 2006;446:45–50.
[13] Munoz-Mahamud E, Popescu D, Nunez E, Lozano LM, Nuñez M, Sastre S, et al. Secondary patellar resurfacing in the treatment of patellofemoral pain after total knee arthroplasty. Knee Surg Sports Traumatol Arthrosc Sep 2011;19(9):1467–72.
[14] Parvizi J, Mortazavi SM, Devulapalli C, Hozack WJ, Sharkey PF, Rothman RH. Secondary resurfacing of the patella after primary total knee arthroplasty does the anterior knee pain resolve? J Arthroplasty Jan 2012;27(1):21–6.
[15] Pedersen AB, Mehnert F, Odgaard A, Schroder HM. Existing data sources for clinical epidemiology: the Danish Knee Arthroplasty Register. Clin Epidemiol 2012;4:125–35.
[16] Saleh KJ, Rand JA, McQueen DA. Current status of revision total knee arthroplasty: how do we assess results? J Bone Joint Surg Am 2003;85-A(Suppl. 1):S18–20.

Please cite this article as: Calliess T, et al, Update on the etiology of revision TKA — Evident trends in a retrospective survey of 1449 cases, Knee (2015), http://dx.doi.org/10.1016/j.knee.2015.02.007

[17] Schuh A, Lill C, Honle W, Effenberger H. Prevalence of allergic reactions to implant materials in total hip and knee arthroplasty. Zentralbl Chir Jun 2008; 133(3):292–6.
[18] Seil R, Pape D. Causes of failure and etiology of painful primary total knee arthroplasty. Knee Surg Sports Traumatol Arthrosc Sep 2011;19(9):1418–32.
[19] Sharkey PF, Hozack WJ, Rothman RH, Shastri S, Jacoby SM. Insall Award paper. Why are total knee arthroplasties failing today? Clin Orthop Relat Res Nov 2002; 404:7–13.
[20] Stahelin T, Kessler O, Pfirrmann C, Jacob HA, Romero J. Fluoroscopically assisted stress radiography for varus–valgus stability assessment in flexion after total knee arthroplasty. J Arthroplasty Jun 2003;18(4):513–5.
[21] Sundfeldt M, Carlsson LV, Johansson CB, Thomsen P, Gretzer C. Aseptic loosening, not only a question of wear: a review of different theories. Acta Orthop Apr 2006; 77(2):177–97.
[22] Trampuz A, Zimmerli W. Diagnosis and treatment of implant-associated septic arthritis and osteomyelitis. Curr Infect Dis Rep Sep 2008;10(5):394–403.

Please cite this article as: Calliess T, et al, Update on the etiology of revision TKA — Evident trends in a retrospective survey of 1449 cases, Knee (2015), http://dx.doi.org/10.1016/j.knee.2015.02.007