Progress towards understanding anterior knee pain after total knee arthroplasty
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Introduction

The main goal of a Total Knee Arthroplasty is to relieve pain and restore function in a severely diseased or injured knee joint. Although many improvements have been made in surgical techniques and implant design, knee arthroplasties are not able to fully restore a knee to its pre osteoarthritis or pre injury state. However, numerous articles report success in improving quality of life (relieving pain and restoring function) and survival of the arthroplasties. One major problem that remains is the proportion of patients continuing to experience varying degrees of pain after a TKA placement. The location of this persisting pain is usually in the anterior part of the knee. Not only is the pain bothersome, but it is also one of the main reasons for an early revision operation \[5,8,31-32\]. In this thesis, therefore, AKP after TKA will be analysed and some clinical implications discussed.

The first step in understanding AKP after TKA is to look at a healthy functioning knee. According to the theory of Dr Dye, “the healthy knee can be viewed as a biologic transmission with a complex assemblage of living asymmetrical moving parts whose purpose is to accept, transfer, and ultimately dissipate often high loads generated at the ends of the long mechanical lever arms of the femur, tibia, patella, and fibula” \[21\]. Furthermore, he refers to each knee having a unique ‘envelope of function’; a potential range of activity in which it maintains a homeostasis of all surrounding tissues \[21\]. The potential range of activity is different for individual knees, whether healthy, arthritic or with a knee arthroplasty. An arthritic knee can be viewed as a transmission with worn bearings, and thus with a limited capacity to accept and transfer loads. In other words, arthritis causes the potential range of activity to become limited, causing pain and restrictions in daily activities such as walking and cycling, and even pain when at rest.

The fundamental aim of knee arthroplasty or joint replacement surgery is to restore, as far as possible, a normal functioning, pain free knee. Applying Dr Dye’s theory to a TKA patient gives an interesting perspective. A TKA knee can then be viewed as a knee functioning with a combined biologic and artificial transmission with a limited potential range of activity. The limitation is in part due to the use of artificial products containing metals and polyethylene, which
are harder and less flexible than the original cartilage and therefore make it unlikely that the knee will return fully to its pre-injury/pre-arthritis state. A pain free knee with a good function can be described in Dr Dye’s terms as functioning in a zone of homeostasis of all knee tissues. The knee that is structurally overloaded, and thus functioning in a zone of abnormal loading (supraphysiological) of knee tissues is clearly no longer functioning in the zone of homeostasis [21]. If this abnormal loading of the knee continues for long periods of time, a TKA can ultimately fail (i.e. it enters the zone of structural failure) [21]. It is interesting to find out, when AKP after TKA is present, if it has indeed entered the zone of structural overloading and if bringing the knee back into a zone of homeostasis can influence the AKP.

This thesis is intended as a contribution to the process of better understanding AKP after TKA from a number of perspectives. Firstly, the issue of pain is addressed in a systematic review of pain transmission mechanisms and possible causes of anterior knee pain. Secondly, the issue of how to document the outcomes of TKA is addressed by looking at three English PROMs which were translated and validated for use in the Netherlands. Two of these are general outcome measures for knee function and one is specifically for anterior knee pain. Thirdly, TKA design issues are discussed. It has been postulated that a mobile bearing TKA may have certain advantages over a fixed bearing TKA. One such advantage, a lower incidence of AKP, was evaluated in a double-blinded prospective randomised clinical trial. The fourth area addressed is placement of the TKA. As the self-alignment of a mobile bearing may be beneficial in reducing the incidence of AKP, the question arises how and to what extent the malposition of the tibial base plate is corrected by the mobile bearing. This was addressed by a CT-based measurement of component positions in patients with a mobile bearing TKA. Finally, currently used outcome measures do not assess cycling. Since cycling is an activity that is especially relevant to the Dutch population, it is pertinent to consider what effect cycling may have on patients with a TKA and if cycling is a beneficial and recommended activity for TKA patients to maintain homeostasis of all knee tissues.

1. What can cause Anterior Knee Pain after a Total Knee Arthroplasty?
Since AKP is a frequently occurring complication after TKA, the primary need is to elucidate how pain transmission works, what causes the pain in the anterior
part of the knee and what can go wrong with the nociceptive system after a TKA placement. In particular, it is important to identify what structures in and around the PFJ are sensitive to pain \cite{9,46}. The synovium, lateral retinaculum, the infrapatellar fat pad, periosteum and subchondral bone of the patellae are all richly supplied with type IVa Free nerve endings (FNEs) and fibres containing Substance P (Chapter 2) \cite{9}. Assuming that incapacitating AKP is caused by the activation of FNEs, the key is to know how they become active and whether this is due an abnormal mechanical deformation, thermal stimuli or special chemical agent \cite{9,46}.

Several publications \cite{1,5,7-11,19,23-25,31,33,40,49-50,56,62-63,66} support the hypothesis that anything that is able to change the mechanics of the patellofemoral joint (PFJ) can activate these FNE and thus induce AKP after TKA\cite{62}. The nociceptive system seems to be activated by several factors, either alone or in combination: Hoffa impingement, peripatellar synovitis, increased osseous pressure, patellofemoral instability and mechanical changes that alter the PFJ in an abnormal way.

Looking specifically at the patellofemoral joint, one can view this joint as a large sliding bearing that is exposed to the highest loads of any component of human joints \cite{22}. Different biomechanical studies have shown that patella kinematics is very complex due to the combination of rotation, flexion and mediolateral shift \cite{57}. Recently it has been shown that patellofemoral pressure increases up to 1.5-2.5 times after TKA placement compared to a normal knee \cite{38}. These higher pressures on the PFJ is thought to contribute to AKP after TKA \cite{62}.

Some researchers investigated the influence walking has on AKP after TKA. A higher knee extension moment in the early midstance phase of walking causes higher forces on the PFJ and consequently a higher frequency and severity of AKP after TKA \cite{58}. Interestingly, the patients that modify and decrease the PFJ loading had less or no AKP \cite{58}. Muscle balance also has an influence on AKP, for instance the preoperative weakness of the vastus medialis muscle was seen to lead to increased activation of the vastus lateralis, and the ensuing lateral maltracking of the patella can lead to AKP after TKA \cite{49,15}. Weakness of the hip adductors was also seen to lead to a dynamic valgus and thus to lateral patella maltracking, which therefore makes it a contributor to AKP after TKA \cite{49}.

Synovial impingement after TKA can play an important role in postoperative pain \cite{17}. One reason could be that not all nociceptive sources of pain have been removed or addressed during surgery\cite{22}. This can be a source of persistent pain, swelling and dysfunction, despite well placed components \cite{22}.
The most studied aspect of AKP has been the influence of the patella, especially in relation to resurfacing \cite{3-4,8,13,43,53,65,68,48,30}. A meta analysis of 7 high quality studies showed no advantage for resurfacing the patella with regard to AKP \cite{30}. Others looked at the patella height \cite{40,68}, patellar thickness \cite{26,35}, patella baja (pseudobaja) and patella instability \cite{25,44,62}, but these studies could not demonstrate a correlation with AKP after TKA, which is often more a lack of power than proof. Circumpatellar electrocautery denervation of the patella seems to make a difference in favour of less AKP \cite{63}. One study found a lower prevalence of AKP due to the resection of Hoffa’s fat pad \cite{41}. The above mentioned aspects of AKP were not studied in this thesis since we did not focus on them.

2. Documenting outcomes: how is AKP and success evaluated for (Dutch) TKA patients?

With the increase in TKA numbers in recent years, there is a need for valid and reliable patient reported outcome measures (PROMs) for patients with arthritis or severe knee injury, including both those who will undergo or who have already received a knee arthroplasty. In 1998 the Oxford 12-item Knee Questionnaire was developed by Dawson et al. as a self-administered disease and site specific questionnaire, especially intended for knee arthroplasty patients \cite{18}. Since then it has proven to be an effective and widely used outcome questionnaire \cite{20}. The Dutch translation of this questionnaire has proven to be reliable, valid and highly sensitive to change (Chapter 3). In 2001 the International Knee Documentation Committee (IKDC) presented a knee specific subjective outcome measurement tool. The IKDC subjective knee form was designed to measure, for every knee related injury, the presenting symptoms and limitations in function and sports activity due to impairment of the knee. The Dutch version of the IKDC Subjective Knee Form is an excellent outcome measurement tool for knee-related research for all types of knee pathologies (Chapter 4). However, for osteoarthritis of the knee, the Oxford 12 Questionnaire score was shown to have better construct validity \cite{20}. Conclusions should not, therefore, be made about post TKA AKP based on these questionnaires.

Although the general knee questionnaires included pain questions, they were not specifically developed to detect AKP. Even with good to excellent scores on these questionnaires, patients can still suffer from AKP. Conclusions should not, therefore, be made about post TKA AKP based on these questionnaires. The Kujala score, also called the Anterior Knee Pain scale (AKPS), is a validated
tool to evaluate AKP. The translation and validation of the AKPS for AKP in knee arthroplasty patients is important: it makes it possible to adequately follow up these patients in the Dutch population and monitor them for AKP after surgery (Chapter 5). The AKPS can now be used by orthopaedic surgeons as well as physical therapists to assess complaints of AKP in patients following knee arthroplasty and can be used to evaluate the effectiveness of certain treatment options, i.e. patellar prosthesis addition or isometric training programs.

3. TKA design and AKP: are there advantages of using a mobile over a fixed bearing TKA?
The theoretical advantage of the mobile bearing TKA is the ability to self align and, therefore, to accommodate small mismatches \[1,12,39,47\]. If this is actually the case, a better patellar tracking could be expected, with a decrease in the incidence of anterior knee pain. Only Price et al, found a small but clinically significant short term advantage for the mobile bearing design \[51\]. Others report no difference when comparing the PS to the cruciate retaining mobile (MBK) \[31\]. There is one study where a mobile bearing had a high rate of anterior knee pain (49,2%) caused by a suboptimal trochlear design \[50\]. The short term outcome of the double blinded, prospective randomised controlled trial, described in chapter 6, was that there was statistically significant lower incidence of reported anterior knee pain in the posterior stabilised mobile bearing (PSM) knees compared to the posterior stabilised fixed bearing (PS) knees.

Theoretically, the design of PSM knees could lead to better Range Of Motion (ROM) during knee flexion activities \[29\]. No differences were observed for ROM between the PS and the PSM groups. The incidence of lateral retinacular release is reported to decrease with the use of a mobile bearing design; however, in this study, the incidence was identical in both groups \[47,52\]. Pagnano et al reported similar results but other authors report a decrease in the incidence of lateral retinacular release from 10% for the fixed to 0% in the mobile group \[47\]. No difference in QoL was detected while comparing the PSM to the PS knee. The influence of anterior knee pain in both the general subjective health questionnaires and the knee specific questionnaires was definitely detected. Patients with AKP reported lower levels of QoL than the patients without AKP. The particular strength of the trial reported in chapter 6 is the equal randomisation with double-blinding, where both groups received the same
three-part prosthesis apart from the tibial insert. Observer- and patient-related bias was thus minimised. This study supports the notion that the PSM TKA demonstrates a clinically significant reduction in the reported incidence of anterior knee pain relative to a PS TKA. Chapter 7 addresses the question of whether the outcome at the short-term follow-up persisted at a longer term, i.e. about 8 years postoperatively. The most important outcome of this study is that a PSM knee does not maintain the lower incidence of anterior knee pain compared to the PS TKA. Kim et al reported less pain in the mobile bearing group compared to a fixed bearing group at a mean follow-up of 2.6 years [34]. Wohlrab et al found a difference in pain scores at three months favouring the mobile bearing, but found no difference after three and five years [67]. Matsuda et al noted that the Nex Gen LPS knee is not fully conformed in the tibio-femoral articular surface, allowing up to 12 degrees of rotational freedom in full extension [42].

In conclusion, most systematic reviews and/or meta-analysis have not shown an advantage of using a mobile bearing[1,6,59,62,61,60]. Due to a recent meta-analysis showing less AKP in the mobile bearing TKA, and our studies, however, it seems that the debate can be reopened as to whether the mobile is part of the solution to AKP [39]. Aglietti et al has suggested that the performance of a mobile bearing knee might decline over time [1]. Yet, even if this difference is only relevant in the short term, it would still seem advantageous to use a mobile bearing TKA for the benefit of patients that experience less pain in this period.

4. Placement of the TKA: can a mobile bearing correct for malrotation of the fixed tibial base plate after TKA?

An advantage of the mobile bearing tibial component of a TKA is the capacity to self-align according to the mechanics of the joint, in particular the mechanism of the patella and quadriceps muscles. For a fixed-bearing TKA, Berger et al reported that combined component internal rotation is associated with lateral tracking of the patella followed by tilting and potential patellar subluxation [7]. Dislocation and component failure were reported when severe malrotation of the tibial component was present [7]. Barrack et al studied the influence of malrotation on AKP and found a combined internal rotation had a relative risk of AKP, which was five times higher than those without combined component internal rotation [5]. It is thought that a femoral component placed in internal
rotation shifts and tilts the patella medially and this can have a negative influence on the patellofemoral joint \cite{5,7,31-32}. This could be an important reason why secondary resurfacing of the patella does not always solve AKP after TKA \cite{8,43}.

In the study using measurements on CT-scan images, it was observed that the PE-component of the mobile bearing TKA corrects for malrotation of the fixed tibial base plate (Chapter 8). If the tibial base plate is internally rotated, the PE bearing will turn towards external rotation, bringing the rotation of the combined components back towards neutral position. In addition, greater malrotation of the tibial base plate was not correlated with poor outcome in our study population.

These findings are in concordance with the previously reported literature \cite{28,33,36}. Using a mobile bearing knee, Komistek et al showed that in flexion the PE bearing rotation could vary from 8.5 to 9.8 degrees and in extension from 1.9 to 1.0 degrees at 3 and 15 months \cite{36}. This is confirmed by Kessler in a cadaver study, namely that in the presence of femoral component malrotation, a mobile bearing could help maintain axial rotational alignment of the mobile PE bearing with the femoral component \cite{33}. The study indicated that the PE bearing could rotate up to 21 degrees \cite{33}. However, it suggested that the PE bearing has minimal influence in reducing patellofemoral maltracking induced by femur malrotation because the patella follows the trochlear groove and the attachment on the tibial tubercle \cite{33}. Garling et al analysed a mobile bearing PS knee and found limited movement of the PE bearing compared to the tibial component \cite{28}. The femur component showed more axial rotation than the mobile bearing, indicating that the femur component was sliding on the PE bearing \cite{28}.

In conclusion, literature demonstrates a relationship between malrotation and the severity of experienced AKP. If the components of the TKA are malrotated, the knee tissues are overloaded and clearly functioning in a zone of abnormal loading rather than homeostasis \cite{21}. If this abnormal loading of the knee continues for long periods of time, a TKA can ultimately fail (i.e. it enters the zone of structural failure) \cite{21}. Berger et al reported that combined component internal rotation is associated with lateral tracking of the patella followed by tilting and potential patellar subluxation \cite{7}. Dislocation and component failure were reported when severe malrotation of the components was present. If AKP
is present after TKA placement, it is interesting to find out if it is possible to bring the knee back into a zone of homeostasis and thus influence the AKP. This can sometimes be achieved by simple measures, for example in the study by Smith et al, where patients that were able to learn how to walk in a different way could reduce or even had no AKP compared to patients that could not learn how [58]. Other measures include muscle training (the quadriceps/hamstrings and also the hip and trunk muscles, therefore avoiding a dynamic valgus [15,49]), medication (painkillers), taping of the patella or avoiding certain activities. If structural mechanical causes are present, revision surgery may be indicated, but caution is advised within the first 12 months. Revision operations can be divided in three major groups; group 1 is balancing the knee components and/or patella, removing scar tissue, synovectomy (arthroscopic or with an arthrotomy); group 2 is the patella resurfacing group and group 3 is correcting malposition/placement by changing the components (chapter 2)

Avoiding malrotation can also reduce the incidence of reoperation and the associated risks for patients. A common scenario for persistant AKP after TKA is when the patella is secondary resurfaced and pain is still present. This can be due to the fact that the pain was not caused by arthritis of the patella but due to malrotation of the components of the TKA. One of the risk factors of a reoperation are illustrated by a rare case report of an 81-year-old male left with a recurrent haemarthrosis (chapter 9). Though rare, vascular complications are reported between 0,03% and 1,6% of patients undergoing a TKA [55,54]. Arterial aneurysm, pseudoaneurysm and arteriovenous fistula tend to occur in the first few months after the operation, but can also present at a much later stage [54-55]. Other possible complications can also occur after a reoperation due to persistent AKP after TKA. The most devastating is probably an infection, followed by deep vein thrombosis, pulmonary embolism, patellar instability, patellar fracture and other less serious complaints.

Avoiding malrotation could therefore play an important role in preventing AKP [5,7,31-32,45]. A complicated issue associated with preventing malrotation is how to find the ‘perfect’ alignment of the components, especially given the geometric variation among patients. It is unclear what the most ideal alignment for the femoral and tibial components is for an individual patient [5,7,31-32,45,64]. Future research is clearly needed for this difficult topic.
5. The influence of cycling on patients with arthritis and knee arthroplasty

It is well known that cycling can play a role in maintaining general health. It is a physical activity with a relatively low load on the knee compared to walking and running, and with little risk of further degeneration and TKA wear. The ability to cycle can be mainly predicted by age and sex, and not by the specific knee related diagnosis (chapter 10). Each year that the patient gets older, the chances of being able to cycle will decrease by 5%. The chance of being able to cycle is 1.98 times higher for male patients compared to female patients.

Body mass index (BMI) is the only risk factor found for pain experience during cycling. This means that the chance of experiencing knee pain while cycling will increase by 8% with each BMI increase of one unit.

It is estimated that 49 million US citizens cycle at least once a month and over 5 million more than 20 days a month [2]. The bicycle is not only used for sporting activities but also for recreation and as a means of transport. The CPB Netherlands Bureau for Economic Policy Analysis shows that, after the car, the bicycle is the most important mode of transport [14]. As far as we know, no other study has been published assessing the predictors of cycling use in knee patients. Kuster and Ericson emphasise that, compared to walking, cycling gives lower tibio-femoral compressive forces, while improving general health and therefore decreasing polyethylene wear in total knee arthroplasty [37,27]. Studies performed by Ericson and later D’Lima showed that the mean tibio-femoral compressive force is 1-1.2 times body weight (BW) with ergometric cycling, and this compared to normal walking with 2.8-3.5 times BW [16,27]. The tibio-femoral compressive force can further be decreased by increasing the saddle height [27].

Concluding remarks

In the future, the development of biological joint arthroplasties may mean that TKA is better able to restore a pain free knee with a good function. For the present, however, patients need to understand that some anterior knee pain may be a persisting problem, and clinicians need to develop a better understanding of why this is and how to reduce its incidence and severity.

Patients judge the success of their TKA in relation to pain reduction and restored function Measuring satisfaction and outcomes is nevertheless difficult, due to so many factors playing a role: for example, dissatisfaction may
be a demonstration of an unrealistic expectation rather than a reaction to a poor outcome. An essential part of the treatment of TKA patients is therefore to enable them to form realistic expectations of the likely impacts and results. This can best be done prior to surgery through clear communication, education and the use of patient reported outcome measures (PROMs).

For clinicians it is important to understand that anything that is able to change the mechanics of the patellofemoral joint (PFJ) seems to activate FNE and thus induce AKP after TKA.

This AKP is often the presenting symptom and can be considered as the tip of the iceberg. Our patients complain of AKP after a TKA, and not about the malrotation or the instability that is present. If AKP is present, surgeons should try to determine the underlying cause of this pain (which is often multifactorial).

This thesis suggests a number of ways to help determine whether AKP is present after a TKA placement. The Kujala score can be used to measure if AKP is present before and after TKA placement. Furthermore, the Kujala can be used to evaluate different treatment results, for example results of secondary patellar resurfacing.

This thesis also draws a number of conclusions about minimising AKP. It appears that when treating future patients, simply changing to a mobile bearing TKA will not necessarily solve the problem. However, it can have a positive influence on the presence of AKP, especially in the first postoperative years. Correct placement of femur and tibia components is crucial and the mobile bearing can have a forgiving feature, provided it is placed the correct way. Moreover, just releasing the retinacula or resurfacing the patella does not always resolve the AKP problem. It can be concluded that a perfect placement of a well-designed TKA can minimize the chance of AKP, but it cannot be concluded that it will fully prevent it, as many factors are playing a role in the origin of AKP.

In conclusion, anterior knee pain remains one of the major problems patients experience after a TKA placement. The goal for the next decade is to make significant further progress to understand the complex interaction of factors causing AKP in order to know how to prevent and eliminate it.
Chapter 11

References


