Recent Advances in Knee Surgery
Guest Editor: Emmanuel Thienpont

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EDITORIAL

Recent Advances in Knee Surgery
E. Thienpont

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Knee pathology and especially total knee replacement (TKR) have been the focus of research over the last ten years with controversy still existing regarding best practice for the treatment of the degenerate joint [1]. The prevalence of knee arthritis in the population is significant and has been estimated as two to ten percent for men and one and a half to fifteen percent for women [2,3]. Typically controversial subjects for current research are the treatment of anterior knee pain, isolated anteromedial arthritis, lower limb alignment and fast-track postoperative rehabilitation programmes.

In this supplement a review article by Smith et al. covers the contemporary management of anterior knee pain and patellofemoral instability. Patients often present along a spectrum of these two disorders. The key to managing these patients is improving muscle function, weight loss in the obese, and judicious use of analgesics if pain is an important feature. A concomitant diagnosis of hypermobility syndrome is a prognostic indicator for a poor operative outcome [4].

Shifting gear from the patellofemoral to the femorotibial joint leads us to another controversial topic, the surgical treatment of isolated anteromedial osteoarthritis (AM OA). Surgeons and patients have a plethora of arguments for the three popular surgical options of high tibial osteotomy (HTO), unicompartmental knee replacement (UKR) or TKR. Price et al. explain in their review how this surgical dilemma is difficult for both surgeons and patients. They have also shown that the contemporary literature may not always assess the correct endpoints to compare results between different surgical techniques. Furthermore our personal bias (or lack of 'equipoise') may influence our capacity to reach a decision. Despite unproven superiority in the literature for UKR most of us who perform this technique are convinced it is the best solution for the right patient whilst neglecting disease progression in other compartments, higher revision rates and the absence of significant differences as measured with the Forgotten Joint Score (FJS-12) [5–8].

Alignment of the lower limb is another controversial topic. Historical literature showed that neutral mechanical alignment (HKA 180°) with outliers within three degrees was the best guarantee for long-term survival of a TKR [9]. However this classic view has been challenged with better results and survival in slightly undercorrected varus knees [10–12]. Furthermore 20% of patients are dissatisfied after TKA [13], with the quest for better functional results leading to kinematically aligned knees [14]. Obtaining the accurate alignment as exactly planned within three planes, either to obtain neutral, varus or kinematically aligned knees, can be a challenge with conventional instruments. Outliers of the ideal alignment have been observed in 30% of cases [15]. Newer technologies, such as navigation, patient specific instrumentation and robotics have gained in popularity.

The review of Thienpont et al. has shown that navigation does increase the accuracy of TKR but without proven clinical benefits [16].

Finally, today’s patient undergoing TKR wants the process to be as smooth and comfortable as possible. Fast-track programmes have been developed to facilitate the peri-operative period with the aim of as quick a recovery as possible without complications despite pre-existing co-morbidities [17]. Kehlet et al. have shown in their overview of fast-track programmes the many factors that have to be addressed to obtain an ‘optimal recovery’ for the arthroplasty patient [18]. Fast-track programmes lead to a shorter length of stay (LOS) because patients are doing better. This reduction of LOS will be necessary to treat the ever-increasing demand of patients requiring TKR with a concomitant pressure on decreasing economic resources.

The four review articles in this supplement thus try to stimulate the discussion about these controversial topics and hope to help us as surgeons to maybe some day arrive at a consensus about the different treatment options available. A reduction to one type of operation, for one type of pathology is probably not the right solution for a complex problem. Surgeons should be able to combine their knowledge with their experience and their technical capacities to decide what their best offer is for their specific patient.

Conflict of interest

The author has no conflict of interest to report.

References


The contemporary management of anterior knee pain and patellofemoral instability

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ABSTRACT

In this review the evidence for the management of patients with patellofemoral disorders is presented confined to anterior knee pain and patellar dislocation (excluding patellofemoral arthritis). Patients present along a spectrum of these two problems and are best managed with both problems considered. The key to managing these patients is by improving muscle function, the patient losing weight (if overweight), and judicious use of analgesics if pain is an important feature. Hypermobility syndrome should always be looked for since this is a prognostic indicator for a poor operative outcome. Operations should be reserved for those with correctable anatomical abnormalities that have failed conservative therapy. The current dominant operation is a medial patellofemoral ligament reconstruction.

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1. Introduction

The management of the patellofemoral joint disorders of anterior knee pain and patellofemoral instability is complex. In part the difficulties in management can be attributed to the multifactorial nature of patellofemoral disorders where osseous and non-osseous structures influence the biomechanical interaction between the patella and the femoral trochlea. Factors that have been implicated in the presentation of patellofemoral disease include: abnormal quadriceps and hamstring muscle recruitment and timing, compromised medial patellar soft tissue restraints, reduced lateral patellar soft-tissue length and flexibility, abnormal control and stability from the hip, aberrations of foot posture and abnormalities in the bony morphology of the trochlea. Additional factors such as peri-articular connective or soft-tissue irritation, intra-articular cartilage damage, nerve-mediated pain syndromes, systemic conditions, and psychosocial issues have all been implicated in the presentation of anterior knee pain [1,2]. However few patients present with just anterior knee pain, or pure patellar instability but lie on a spectrum between these two extremes (see Fig 1). In managing these patients it is better not to think of these as two separate disorders, although operative procedures have better outcomes for pure instability rather than anterior knee pain, and the latter is best managed non-operatively. However all these patients need to undergo an exercise programme to rehabilitate their muscles, benefit from losing weight if obese, and need pain adequately controlled by medication. They also need to be assessed for hypermobility.

This review discusses the current understanding on the assessment and treatment of patients presenting with anterior knee pain or patellofemoral instability. The management of patellofemoral arthritis and other patellar pathologies are beyond the remit of this review.

2. Pathology of anterior knee pain and patellofemoral instability

There are multiple causes of anterior knee pain and patellofemoral instability with not all individuals displaying the same underlying pathology. Some patients have an underlying biomechanical cause for their poor patellar tracking. This biomechanical cause can be an underlying rotational profile that makes them more prone to lateral tracking of the patella in the trochlear groove, which in turn can be driven by either proximal (hip and pelvis) or distal (foot and tibia) rotational abnormalities. Alternatively, other patients may have a normal femoral or tibial rotational profile and present with central (tibiofemoral-patellofemoral joint) anatomical features. Finally, in a subset of patients the underlying diagnosis may not be a physical cause but a presentation of knee symptoms that are secondary to pain and depression with associated poor coping strategies [3,4].

It is widely acknowledged that both anterior knee pain and patellar instability are associated with lateral tracking of the patella within the femoral trochlea [5]. In cases where the lateralised patella remains constrained within the femoral trochlea, the patient may present with anterior knee pain. However, when patellar lateralisation is severe, and the medial soft-tissues are unable to maintain the patella within the femoral trochlea, patellar subluxation and dislocation can occur. Thus both anterior knee pain and patellofemoral instability can be seen as manifestations along a spectrum of the same pathology. The assessment and treatment of the two conditions can therefore be conducted in the same manner, with alterations according to the proportion of each in the presentation.

3. Assessment of the patellofemoral joint

3.1. Patient history

As with any musculoskeletal assessment, a thorough patient history and clinical assessment are the fundamentals to accurate diagnosis. In assessing patellofemoral instability, the single most important question to answer is whether the patient can describe a convincing report of a dislocation [6,7]. A classic history of patellar dislocation is one of a sudden palpable and visual bony protuberance on the lateral aspect of the knee, with a feeling of the patella “popping out” [6] often followed by a spontaneous reduction of the patella on knee extension [8].

In addition to the history surrounding the dislocation event, patients should be asked about a family history of patellar instability [9]. A positive family history of patellar instability can often be attributed to hypermobility syndrome or trochlear dysplasia [10–14] and may be an important prognostic indicator for recurrent dislocation in certain subsets of patients [10].

By comparison, patients describing a history of anterior knee pain attributable to the patellofemoral joint, classically report retropatellar pain during stair ascent and descent, sitting for any period of time with the knees at 90° such as during driving, at the cinema or theatre, and squattting, running or jumping, particularly from a flexed position. It is important to note that patients with significant anterior knee pain may describe their knee, including the patella, as unstable and giving way, secondary to poor muscle control. This is described as functional instability, compared to mechanical instability, which is due to anatomical abnormalities e.g. trochlear dysplasia.

Due to the overlap of symptoms between patients with anterior knee pain and patellofemoral instability, for patients presenting with anterior knee pain it is important to ask whether there have been any previous episodes of dislocation. Questions relating to aggravating activities can be most insightful for this population e.g. multi-directional, higher-energy activities such as turning during a football game or pushing a shopping trolley around a shopping aisle corner are typical for patellofemoral instability [15]. Nevertheless individuals with more severe instability may report activities such as putting tights or socks on, turning in bed or looking over their shoulder as activities leading to dislocation. They may report either subluxation without frank dislocation all the way up to recurrent dislocation. Distinguishing the different presentations is important as it may provide an indication of the severity of the instability or malalignment driving the underlying anterior knee pain.

Questions on previous episodes of anterior knee pain or patellofemoral instability are important as they can provide an indication of the patient’s perceptions of their management.
It is not uncommon for patients with patellofemoral disorders to see numerous clinicians with varying degrees of success. Patients have reported reduced confidence (self-efficacy) in their treatment or clinicians following previous failed interventions [15]. It is important to be aware whether previous treatments have failed, or which were considered beneficial or successful by the patient thus managing patient expectation as well as their clinical presentation.

An integral part of patient assessment is acknowledging the importance of psychosocial factors along with physical tests [16]. Patients presenting with anterior knee pain reported that anxiety and fear-avoidance beliefs about work and physical activity were significantly associated with poorer functional outcomes. Fear-avoidance beliefs about work and physical activity were also associated with a higher severity of pain. However, whilst their importance has been emphasised, it remains unclear as to the optimal instruments to assess these domains.

3.2. Clinical assessment

A wide variety of clinical tests focussing on assessing the patellofemoral joint have been described. The principal tests are widely summarised in texts by Smith et al [17], Fredericson and Yoon [18], Malanga et al [19] and Lubowitz et al [20] and such tests include; the VMO capability test, hamstring, quadriceps and calf muscle length, patellar tilt and glide, apprehension tests, iliotibial band (ITB) flexibility tests, Thomas test, hypermobility joint assessments, Q-angle, patellar mobility, J-sign, foot arch position, tibial torsion, hip version, standing posture, pain on palpation of the patellar retinaculum, pain on palpation of the retropatellar surface, crepitus, Bassett's sign and Clark's grind test have been recommended. In addition, functional tests such as squatting, hopping and agility tests and joint position sense testing have all been recognised as useful in the evaluation of the global capabilities of these patients [18,21,22].

In an assessment of the commonest clinical examination tests for anterior knee pain, Cook et al [23] reported that a combination of functional assessment and joint specific tests were the most help in elucidating the underlying diagnosis, but assessment of individual tests were unrelated to patient-reported disability scores. In an assessment of 76 participants with anterior knee pain, Cook et al. concluded that the strongest diagnostic test was pain during resisted knee extension (Positive Predictive Value = 82%; Positive Likelihood Ratio = 2.2; 95% CI: 0.99–5.2).

However, a number of authors have concluded that the diagnosis of anterior knee pain should be based on a positive history in conjunction with positive findings on clinical examination but that no single test is sufficiently accurate to diagnose this condition. [24,25]. A number of review papers and a systematic review on this topic have concluded that the evidence-base was in general insufficient to produce any strong conclusions as to the most useful physical test for diagnosis [18,24–27].

In the clinical assessment of a recent patellar dislocation, the examiner may find diffuse parapatellar tenderness and an obvious effusion [28]. Other findings may include a palpable defect in the medial retinaculum due to disruption to the medial capsule and retinaculum following lateral patellar dislocation [7,22,29,30].

In the assessment of chronic patellofemoral instability, five studies have assessed the diagnostic accuracy of physical examination tests. Of the available tests, the apprehension test is the most frequently cited test in textbook and review papers to assess patellar dislocation [19,30–33]. Bassett’s sign is a patellar dislocation-specific test, devised for the assessment of MPFL injury [28] and is essentially ‘pain on palpation of the medial retinaculum’ [12,34,35].

Sallay et al. compared the apprehension test and Bassett’s sign (index tests) to MRI and surgical findings (reference test) on 23 people following an acute patellar dislocation. They reported the sensitivity of the apprehension test and Bassett’s sign and for patellar dislocation was 70% and 39% respectively [36].

One study has assessed the intra- and inter-rater reliability of various physical examination tests between five orthopaedic surgeons specialising in patients presenting with recurrent dislocations. The results indicated that there was moderate to substantial intra-rater reliability for each of the orthopaedic surgeons. The physical tests that demonstrated high agreement between the surgeon’s first and second assessments included the assessment of tibial torsion (Kappa = 0.84; 95% confidence interval (CI): 0.68, 0.97), popliteal angle (Kappa = 0.80; 95% CI: 0.61, 0.93), and the Bassett’s sign (Kappa = 0.79; 95% CI: 0.60, 0.90). However, the inter-rater reliability between surgeons was consistently poor.

Finally, for any patient presenting with knee pathology it is important to rule out the hip joint as a source of the pathology. By clearly assessing hip range of motion actively and passively, any potential hip pathology such as acetabular labral tears, chondral pathology or Perthes’ disease in children would present as a differential diagnosis of knee pain.

3.3. Stability of the patellofemoral joint

The stability of the patellofemoral joint is dependent upon a combination of soft tissue and bony structures with both the soft tissue and bony structures contributing a variable amount of stability, the degree of which is dependent upon the degree of knee flexion.

Due to the shape of the patella and trochlea, the bony congruency of the patellofemoral joint is poor in the initial phase of flexion. Stability of the patellofemoral joint in the first 30° of flexion is therefore predominantly provided by the balance of tension between static and dynamic soft tissue structures [37]. The static soft tissue stabilizer on the lateral side of the patella is the lateral retinaculum, whereas on the medial side the medial restraints are the medial retinaculum, the medial patellofemoral ligament (MPFL) and the medial patello-tibial ligament. The dynamic restraints acting on the medial side are the quadriceps muscle, in particular the vastus medialis obliquus portion [38].

Arguably the most important medial soft tissue stabiliser is the MPFL. The MPFL is a thickening of the medial patellofemoral retinaculum. Anatomically it originates from the groove between the adductor tubercle and the medial epicondyle, and inserts into the superior two thirds of the medial border of the patella. In full knee extension during active quadriceps contraction the ligament is at its most taut. In this state it is reported to contribute an average of 53% of the force resisting lateral displacement of the patella [39]. During passive motion of the knee joint the ligament is the ‘longest’ at approximately 30 degrees of knee flexion, at which point the patella engages in the trochlea.
After the patella has engaged in the trochlea, the congruency of the patella and the trochlea is the major contributor to patellar stability throughout the remainder of knee flexion [37]. With increasing degrees of knee flexion the importance of the MPFL diminishes and the ligament becomes more lax.

Malalignment of the extensor mechanism of the knee causes both objective and subjective instability. From a surgical perspective the challenge is to identify those patients with abnormalities of the patellofemoral joint that are amenable to surgical intervention. The anatomical dysplasias of the extensor mechanism that contribute to malalignment of the extensor mechanism include patella alta, patellar tilt, sulcus angle, the distance between the trochlear groove and the tibial tuberosity (TTTG) and trochlear dysplasia [40]. Secondary factors that contribute to patellar instability are excessive external femoral rotation, excessive external tibial rotation, genu recurvatum, and genu valgum.

3.4. Radiological assessment of the patellofemoral joint

Radiological assessment of the anatomical factors contributing to objective patellar instability is essential in guiding further management [41]. Radiological assessments include plain radiographs (anteroposterior, lateral and skyline views), magnetic resonance imaging (MRI), computed tomography (CT) and ultrasound (US) [42–45]. Various radiological features occur following an acute dislocation, possibly on the background of morphological features that make patellar dislocations more likely. The lateral radiograph is important for defining a normal groove (Fig. 2), in contrast to a dysplastic groove (see below and Fig. 3).

3.5. Assessment of acute dislocations

In the assessment of an acute patellofemoral dislocation, plain radiographs can be used. It is unusual to find the patella dislocated as relocation typically occurs immediately or when the knee is straightened to allow transfer to hospital. The images allow assessment of any anatomical abnormalities e.g. trochlear dysplasia, and to look for osteochondral loose bodies. Avulsion fractures on the medial aspect of the patella are pathognomonic of a patellar dislocation. In those cases where an MRI is performed after an acute dislocation a number of findings may be observed. These include osteochondral fractures or bone bruising of the lateral femoral condyle or the medial aspect of the patella, a disruption of the MPFL, disruption of the medial patellofemoral retinaculum and a joint effusion [46,47].

As mentioned earlier, the anatomical features that can be assessed reliably radiologically include patellar height, patellar tilt and subluxation, sulcus angle, tibial tubercle-trochlear groove (TTTG) distance and trochlear dysplasia.

3.6. Assessment of patellar height

Patella alta is recognised as a risk factor for patellar dislocation [48]. Patellar height is normally evaluated by measurements obtained from a true lateral, plain radiograph. There are a number of different methods for measuring the height of the patella, as detailed below:

- **Insall-Salvati ratio** [49]. The Insall-Salvati ratio is defined as the ratio between the length of the patellar tendon and the length of the patella as measured on a true lateral radiograph. A ratio of greater than 1.2 defines patella alta and less than 0.8 defines patella infera.
- **Caton-Deschamps ratio** [50]. The Caton-Deschamps ratio is the ratio between the distance from the lower edge of the articular surface of the patella and the anterosuperior corner of the tibial plateau to the length of the patella on a true lateral radiograph. A ratio of greater than 1.2 is defined as patella alta and less than 0.6 is defined as patella infera.

3.7. Patellar tilt (lateral patellofemoral tilt angle) and patellar subluxation

The medio-lateral relationship of the patella to the trochlea is described in terms of patellar tilt and subluxation. Patellar tilt is defined as the angle formed between a line adjoining the most medial and lateral edges of the patella and a reference line, such as the horizontal or a line along the most posterior aspect of the posterior femoral condyles, measured with the knee flexed [53]. In normal knees, the angle subtended between the reference points should be more open laterally. Abnormally large degrees of patellar tilt are believed to be secondary to a number of factors contributing to instability. Those factors include shape of the patella and trochlea and the relationship between the tightness of the medial and lateral static restraints. As well as being measurable by plain radiographs, the patellar tilt angle can be reliably determined by both CT and MRI measurement [52].

Patellar subluxation is an abnormal medio-lateral displacement of the patella compared to the trochlea. Measurements of patellar tilt and patellar subluxation are statistically significantly different between patients with patellar instability and healthy controls and have been reported to demonstrate good discrimination validity [52].

3.8. Sulcus angle

The sulcus angle is observed on skyline radiographs and is a reflection of the shape of the trochlea. It is measured with the knee flexed at 45 degrees with a normal sulcus angle defined as 138° (SD 6°). Davies et al [54] reported a highly significant relationship between the sulcus angle and the degree of trochlear dysplasia, with an increasing sulcus angle also being related to the increasing severity of many of the other features.
of dysplasia, such as patella alta. Davies et al [40] reported that while there was good intra- and inter-observer reliability in the assessment of sulcus angle on plain radiographs, MRI and CT, MRI failed to demonstrate a significant difference in the value of measurements between normal controls and those patients with patellar dislocation [52].

3.11. Trochlear dysplasia

The anatomy of the femoral trochlea is reported to be one of the principal causes of patellar instability. Dejour et al [48] classified trochlear dysplasia by features visible on a lateral plain radiograph (see Fig. 3). The key feature of the classification is the radiological representation of the sulcus floor with respect to the anterior border of the superimposed femoral condyles (the crossing sign). Trochlear dysplasia is classified into four grades depending upon the shape of the trochlea [48,61]. The elements that present within trochlear dysplasia are:

1. Trochlear boss at the entry into the trochlear groove
2. The morphology of the lateral trochlear facet
3. The morphology of the medial trochlear facet [61,62]

3.12. The reliability of different radiological modalities in the assessment of dysplasia of the extensor mechanism

In determining which of the morphological features associated with patellar dislocation can be reliably measured radiologically, a recent meta-analysis demonstrated a reasonable level of inter-observer and intra-observer reliability and discrimination validity for measurements of patellar height by Caton-Deschamps and Insall-Salvati on plain radiographs, the Insall-Salvati ratio assessed by MRI, the sulcus angle as assessed with radiographic, MRI and CT methods and the TTTG assessed using CT [52].

Smith et al [52] reported that a number of different radiological measures have been described to assess the patellofemoral joint. These included the Blackburn-Peel method to assess patellar height [51], congruence angle on MRI [43], boss height [48], trochlear depth [48], lateral patellar tilt angle [43,48], lateral patellar displacement on MRI [43], femoral anteversion on CT [48], patellar morphology [63], patella-lateral condyle index on MRI [43], ventral trochlear prominence, patella–tibia distance, cranio-caudal patellar facet, patellar tendon length, patellar nose, patellar ratio, morphology ratio and lateral trochlear inclination [64]. All have been reported to have statistically significant discrimination validity between patellar instability and healthy controls [52]. However, as each of the above methods involved a single researcher, a meta-analysis could not be used to assess the robustness of the findings.

Conversely, Smith et al [52] also reported that a number of radiological measurements fail to discriminate between patients presenting with a patellar dislocation and normal controls. These included the assessment of the sulcus angle with MRI [43], trochlear depth [64], Wiberg patellar shape classification [63], mean medial–lateral condyle height ratio [65], intercondylar distance, ventral trochlear prominence ratio, cranio-caudal patellar distance, patellofemoral contacting surface, patellofemoral contacting surface ratio, lateral and medial condylar distance and trochlear groove distance [64].

4. Non-surgical interventions for anterior knee pain and patellar dislocation

The vast majority of the literature has investigated different interventions in the management of anterior knee pain rather than patellofemoral instability. The evidence for such interventions for each population is discussed below.

4.1. Exercise

Quadriceps exercise is considered the cornerstone intervention for the management of patellofemoral pathologies given the intimate relationship between the patella within the quadriceps complex [66-68]. Van Linschoten et al [69] reported that exercise addressing the quadriceps muscle significantly improved outcomes, in terms of decreased pain and improved function at short- and long-term follow-up compared with the
usual care of advice and analgesia in primary care in patients
with patellofemoral pain syndrome.

A variety of exercises have been advocated to address
imbalances in the recruitment, timing or general strength
of the vastus medialis obliquus over the vastus lateralis in
patients with anterior knee pain [70]. Whilst there is evidence
that specific-vastus medialis obliquus (VMO) exercises,
when used in collaboration with taping and biofeedback,
may reduce symptoms and improve function over general
quadriceps exercises [2,71], there is also conflicting evidence
suggesting that the VMO cannot be preferentially activated
and there is limited difference in outcome between these
two exercise programmes [66,72]. Nonetheless exercise is a
valued intervention for recruiting the quadriceps complex.
However exercise compliance and effectiveness is reduced
in the presence of pain. Based on this decreased effectiveness,
strategies for managing pain should be considered prior to
prescribing exercise. Alternatively exercises performed in a
pain-free range of motion should be prescribed first to avoid
the potential of ‘flaring’ a patient’s symptoms [73]. Heintjes
et al’s Cochrane review [74] on exercise for anterior knee
pain concluded that whilst there is evidence that exercise is
beneficial in reducing pain and disability for anterior knee pain,
there is strong evidence that open- and closed-kinetic chain
exercises are equally effective.

Whilst the current literature suggests that quadriceps
strengthening exercises are paramount both following patellar
dislocation and patellofemoral instability [75], no studies have
assessed whether there is a difference in clinical outcome
or recurrent symptoms between different types of exercises.
Therefore whilst it is recommended that strengthening
exercises are prescribed to provide greater dynamic stability
for patellofemoral joint stability, it is unclear whether general
quadriceps are superior to VMO exercises, and what dosage in
terms of frequency, rate, intensity or loading should be prescribed.
Two randomised controlled trials (RCTs) have compared the
outcomes of prescribing VMO-specific versus general quadriceps
strengthening exercises for people with anterior knee pain
[76,77]. Both reported that there was no significant difference in
outcome between either exercise regime (p > 0.05).

Whilst patients following patellar dislocation have been
reported to exhibit a proprioceptive deficit, largely through
injury to the medial retinaculum and the MPFL [78,79], no
evidence is currently available to support or refute the inclusion
of proprioceptive exercises in physiotherapy rehabilitation for
this population. Such proprioceptive deficits have also been
demonstrated in anterior knee pain populations [80,81] and
as with the patellar instability literature, no specific exercise
regimes have been investigated to determine whether this can
be modified through exercise. Only Hazneci et al [82] have
investigated the effect of exercise specifically on joint position
sense in this population and have reported that isokinetic exercise in
general demonstrated improvement in proprioception in
those with anterior knee pain.

As acknowledged earlier, the biomechanics of the patello-
femoral joint is dependent on proximal (hip and core stability)
and distal (foot and lower limb) factors, in addition to the
biomechanics of the knee [83]. Consequently, the prescription of
glutei muscle strengthening exercises to improve femoral control
in order to limit excessive femoral internal rotation during
activities, which can induce patellar lateralisation and increase
symptoms has been advocated [84,85]. Current understanding
would suggest that combined exercise programmes of hip
abductors, hip external rotators and quadriceps strengthening
programmes combined provide superior outcomes to quadriceps
strengthening alone [85,86].

4.2. Taping

Patellar taping during exercise to assist in correcting patellar
maltracking and tilt, to promote vastus medialis function through
enhanced proprioceptive feedback and to decrease pain has
been reported [6,87–89]. However, Gigante et al. suggested that
taping does not medialise the patella, and that a biomechanical
mechanism for any change in symptoms is unclear [90].

The use of taping with exercise, and in isolation, for the
management of pain and improved function for people with
anterior knee pain is controversial. Whilst Paoloni et al [91],
Aminaka and Gribble [92], Whittingham et al [93], Mason
et al [94], and Ng and Cheng [95] suggest that taping may be
a valuable adjunct to improve symptoms and correct VMO
to vastus lateralis imbalance, a recent Cochrane review [96]
concluded that there was limited evidence to suggest that taping
can significantly improve outcomes compared to other exercise-
based interventions not incorporating taping. Similarly Akbaş et
al [97], who assessed the addition of Kinesio tape® techniques
to a conventional exercise programme, reported no significant
improvement in the results of participants with anterior knee
pain. However Lan et al [98] concluded that taping may be
less effective in certain subgroups of the anterior knee pain
population, including those with a higher body mass index, larger
lateral patellofemoral angle, and smaller Q-angle. Stratifying this
intervention may therefore be important in the clinical decision
making process.

Whilst the majority of the literature has focused on anterior
knee pain, no studies have specifically assessed the use of taping
following patellar dislocation or in instability. Two case series
incorporated the use of taping following patellar dislocation
[99,100]. However the clinical effectiveness remains unknown.

4.3. Electrotherapy

Whilst the use of electric biofeedback systems in collaboration
with VMO-specific training regimes has been discussed, a
number of other electrotherapy modalities have been described
in the literature. These have included the use of ultrasound,
laser, interferential and transcutaneous nerve stimulation. Based
on the current evidence, which presents a number of major
methodological limitations, there remains inconclusive evidence
that such electrotherapy modalities provide benefit when used in
isolation, but may be useful adjuncts when used in combination
with other treatments such as exercise [101–103].

Whilst the use of electrotherapy within physiotherapy
regimes for patellar dislocation has been suggested, no studies
have assessed the use of specific modalities in a clinical trial.
Three studies, which detailed the rehabilitation programme of
their patients following first-time patellar dislocation, included
muscle stimulation in their physiotherapy programmes [104–
106]. However, since these specific interventions were not
investigated, there is insufficient evidence to support or refute
the use of electrotherapy treatments such as muscle stimulation
for the management of people following patellar dislocation or
with instability.

4.4. Bracing and splinting

As with taping, the principle of bracing or knee orthoses is to
centralise the patella to reduce abnormal tracking between the
retropatellar surface and the femoral trochlea [107]. Whilst this
would appear logical, there is limited research to support their
use in anterior knee pain [108].

Two studies have assessed the use of knee orthoses for the
prevention of anterior knee pain in populations who are at high
risk. Van Tiggelen et al’s [109] cohort of military recruits and BenGal et al’s [110] cohort of young athletes both concluded that the use of a patellofemoral brace significantly reduced the incidence of developing anterior knee pain in strenuous physical activity regimes. Therefore knee orthoses may be valuable for those individuals identified as ‘at risk’.

Knee orthoses and braces have been used in the management following patellar dislocation in order to limit range of motion whilst the surrounding soft-tissues recover post-dislocation. There is limited evidence to support the use of immobilisation or restriction of range of motion with knee orthoses or casting techniques, compared to permitting range of motion without a brace, on clinical outcomes or recurrent dislocation events [111]. No studies have assessed the effectiveness of bracing or knee orthoses during activities or sports for preventing patellar instability or dislocation.

4.5. Foot orthoses

In the anterior knee pain literature, a number of studies have provided favourable evidence for the use of foot orthoses to correct biomechanical abnormalities which may predispose anterior knee pain. Whilst some have reported limited effectiveness in prescribing these interventions [112], pain and function both significantly improved with those prescribed foot orthoses in studies by Barton et al [113,114]. Barton et al’s systematic review [115] also reported that the use of foot orthoses in addition to exercise demonstrated superior outcomes for people with anterior knee pain, compared to the sole use of orthoses. The clinical efficacy of this intervention was also demonstrated to be specifically higher for individuals aged over 25 years, under 165 cm in height, whose worst pain visual analogue scale was less than 53.3 mm, and who had a difference in mid-foot width from non-weight bearing to weight bearing of greater than 11 mm [116].

No studies have investigated the effectiveness of lower limb biomechanical interventions such as foot orthoses for people following patellar dislocation. This is in contrast with textbook recommendations by Howell [117], Cherf and Paulos [118], Post et al [119], King [120], and Woo and Busch [6] who have acknowledged that foot orthoses are important adjuncts to correct leg length discrepancy or excessive foot pronation thereby improving excessive Q-angle which may predispose individuals to instability. However, since these recommendations are made on non-empirical evidence, the role of orthoses remains unproven for their use in patients following patellar dislocation.

4.6. Acupuncture

A small number of trials have investigated the use of acupuncture to reduce pain in people with anterior knee pain [121]. They have reported that acupuncture may be a beneficial adjunct to other interventions particularly in the management of pain [121,122]. Given this, in those people where pain has failed to improve, causing poor exercise compliance, acupuncture may be an appropriate intervention to reduce pain to facilitate exercise.

4.7. Non-steroidal anti-inflammatory drugs

Heintjes et al’s Cochrane review [123] concluded that only non-steroidal anti-inflammatory drugs (NSAIDs) demonstrated the effectiveness in the pharmacological management of short-term symptoms. Simple analgesics such as aspirin produced no significant differences in clinical symptoms and signs compared to a placebo. However, the evidence for the effectiveness of NSAIDs has been recently questioned in a recent review by Dixit et al who considered educating patients about activity modification of risk factors is more important in preventing recurrence and managing symptoms compared to pharmacological interventions [27].

5. Surgical management of patellofemoral instability

The treatment of a patient who has sustained a first time dislocation of the patellofemoral joint still remains controversial. Whilst a variety of different conservative and surgical management strategies have been proposed, the findings of both a recent Cochrane review and separate meta-analysis concluded that there was insufficient evidence to determine whether operative management of patients after a first time patellofemoral dislocation confers any benefit over non-operative management [124,125].

An evaluation of the literature reporting the operative treatment of patients with recurrent patellar dislocation showed a diversity of techniques, indications and interventions [10,104,124,126]. In general, whilst older studies were retrospective case series reporting particular techniques, many used “non-anatomical” methods to improve patellar stability. These have been superseded by more recent “anatomical” approaches designed to reconstruct the MPFL [10,104,126]. Anatomical MPFL reconstruction is reported as having a better outcome than historic techniques [127].

The following sections detail a variety of techniques that are still in the mainstream orthopaedic armamentarium for the surgical treatment of patellofemoral instability.

5.1. Medial patellofemoral ligament repair

During a patellar dislocation the medial patellar soft tissue restraints, in particular the MPFL, are torn or stretched in such a manner to render them incompetent. Repair of the MPFL, as opposed to reconstruction, would seem to be an attractive option. As such, the role and outcomes of primary surgical repair of the MPFL in children and adults has been evaluated by a number of different authors.

For the paediatric population, Palmu et al [10] compared surgical repair of the medial structures with concomitant lateral release to conservative treatment. When comparing surgery to conservative treatment they found no difference either subjectively or functionally in terms of rate of recurrent dislocation. They concluded that, routine repair of the torn medial stabilizing soft tissues is not advocated for the treatment of acute patellar dislocation in children and adolescents [10].

In adults, the literature is divided over the outcomes of MPFL or medial retinacular repair. Sillanpää et al [104] reported that, although the rate of redislocation was significantly lower in adults that had received surgery, there was no difference in subjective outcomes between groups that were either treated surgically or non-surgically. Conversely, Camanho et al [127] reported superior subjective results and a lower rate of dislocation for patients undergoing MPFL reattachment to its site of avulsion (either femoral or patellar insertion) compared to non-operative treatment. However others, using a mixture of techniques to repair the medial structures, have reported no difference in the rate of dislocation between operative and non-operative treatment [126].

Following patellar dislocation the MPFL can be disrupted at three anatomical locations; the insertion on the patella, the femoral insertion and the ligament mid-substance [47,128]. The site of damage appears to be related to the rate of recurrent dislocation. In those patients in whom the femoral insertion has been avulsed, non-surgical treatment has been reported to confer
a greater risk of subsequent instability and lower functional scores than in those patients where the MPFL has been avulsed from either the patella or sustained a midsubstance tear [129].

If the site of avulsion is known, one prospective RCT comparing conservative treatment to MPFL reattachment back to its avulsion site (either the patella or the femur) using a suture anchor technique and showed a significant decrease in the rate of dislocation in the operative group [127]. However, in contrast, surgical repair of the MPFL back to the adductor tubercle using a suture anchor technique confers no benefit over conservative treatment [130]. Mid substance damage to the MPFL commonly occurs in conjunction with avulsion from either the patella or the femoral insertion site [47]. However, the rate of dislocation following conservative treatment appears to be low and repair is generally not indicated [129].

Secondary damage to articular cartilage in patients presenting with a first time dislocation is up to 50% [129]. The surgical treatment of areas of cartilage damage is dependent upon the site and size of the cartilage fragment. If the area of cartilage loss is large and the injury acute, an attempt at reduction and fixation of the fragment should be attempted. In those patients with smaller defects or chronic cartilage loss, microfracture of the defect with excision of the cartilage fragment may be preferable [131,132].

5.2. Medial patellofemoral ligament reconstruction

The indications for MPFL reconstruction are based upon history, clinical examination findings and imaging. MPFL reconstruction as a stand alone procedure is indicated for those patients with recurrent patellofemoral instability in the context of normal anatomy, mechanical alignment and laxity of the medial patellar restraints. A number of different graft materials including the adductor magnus tendon [133,134], quadriceps tendon [135], semitendinosus tendon [136,137], and a mesh-type artificial ligament have all been used [138]. Despite the variety of graft materials, the fundamental features of MPFL reconstruction remain those of anatomical reconstruction and the avoidance of over tensioning of the reconstructed ligament.

5.3. Outcomes of MPFL reconstruction

Smith et al [139] recently analysed the literature reporting the clinical and radiological outcomes of MPFL reconstruction for patellar instability, concluding that MPFL reconstruction does provide favourable clinical and radiological outcomes. However, the methodological limitations of the papers reviewed meant that the conclusions need to be interpreted with caution.

5.4. Tibial tubercle transfer (TTT)

There has been interest in the position of the tibial tubercle (TT) relative to the trochlear groove and the effect of that distance upon the stability of the patellofemoral joint. In trying to reduce the lateralisering forces on the patella one approach is to medialise the TT, thereby decreasing the TTTG distance and improve patellar tracking. In attempting to do this, as with operative interventions addressing the soft tissue restraints in the proximal portion of the knee, multiple techniques have been described.

A number of cadaveric studies examining the effect of medialisation of the tibial tubercle upon patellofemoral biomechanics have reported conflicting results on the effect of patellar stability and subsequent patellofemoral and femorotibial joint contact pressures [140–143]. In summary, while medialisation of the TT would appear to improve patellar stability by decreasing the force needed to resist lateral subluxation, a number of studies have reported the potentially deleterious effect of increases in the contact pressure on the medial patellofemoral joint, the medial tibiofemoral joint and tibiofemoral kinematics [140,141]. However, in a comparison of the two procedures, only medialisation of the TT had the effect of decreasing the total force carried by the lateral facet of the patella induced by an increased Q angle, whereas anteromedialisation of the TT had no effect on the force distributions between medial and lateral patellar facets [143]. Clinically, pure medialisation of the TT in patients with recurrent instability with lateral positioning of the TT, either assessed clinically or by an abnormally large TTTG, back to normal values has been associated with good results [144,145].

The importance of patella alta in recurrent patellar instability has been examined and the effect of surgical correction using tibial tubercle transfer [48,50,146,147]. Many authors have reported that in those patients defined as having patella alta (Insall-Salvati ratio >1.2), and excessive medial laxity, distalisation of the tubercle to correct the patella alta, in conjunction with possible TT medialisation to correct an increased TTTG, led to significant improvements in patellar instability [50,146,148–150].

5.5. Trochleoplasty

Severe trochlear dysplasia is a rare condition occurring in approximately 15% of patients presenting to a specialist patellofemoral clinic [151,152]. It is defined and classified radiologically by the presence of decreased height of the medial femoral condyle; a decreased trochlear depth; an increased sulcus angle; and a lateral trochlear facet which is shallow, or sometimes elevated or dome-shaped [14,48,62].

The principal indication for trochleoplasty is for those patients with functional deficits from patellar instability who have a severe trochlear dysplasia after the failure of conservative management [153]. Trochleoplasty is designed to address the morphological features of trochlear dysplasia by forming a neo-trochlea to facilitate patellar tracking. While the surgical techniques that are employed are beyond the scope of this article, all of the procedures involve removal of the trochlear boss or bump, combined with a groove deepening procedure [154–157]. In a large proportion of patients undergoing trochleoplasty, additional secondary procedures such as MPFL reconstruction, tibial tubercle transfer and lateral release are performed simultaneously [158].

5.6. Surgical decision making

There are relatively few reports of the outcomes of trochleoplasty, but the majority of authors report good outcomes in terms of improvement in patellofemoral instability and radiological indices [151,156,159]. However, subjectively, in terms of pain and satisfaction, the procedure has mixed reports. While most patients report that they are satisfied with the outcomes of the procedure, a large proportion of patients report that they have a degree of residual pain following the procedure, with a small proportion reporting that their pain is increased [157,160]. In a recent systematic review Smith et al [153] evaluated the clinical and radiological outcomes of patients after trochleoplasty and concluded that, despite the poor quality of the evidence surrounding trochleoplasty, the procedure appears to be successful in addressing instability and safe at mid-term follow up. However, longer term prospective studies are required to fully evaluate the outcomes of the procedure.

5.7. Surgical decision making

The decisions regarding the surgical approach to patellofemoral instability remains contentious and challenging. Most
orthopaedic surgeons will tailor their operative approach on a patient-by-patient basis depending upon the individual anatomical morphology of the patient’s extensor mechanism. The goal of any intervention is to create a stable patellofemoral joint throughout the full range of motion without creating long term harm in terms of abnormal loading or joint kinematics. Patients presenting with recurrent episodes of instability or subluxation who have failed conservative treatment can be classified into different groups for treatment. After a patellar dislocation the MPFL is almost always either disrupted or rendered incompetent. In those patients that have a normal morphology of the patellofemoral joint, normal patellar height and normal TTTG, MPFL reconstruction alone gives good results. However, in the presence of abnormal morphology of the extensor mechanism creating a laterally directed force, an MPFL reconstruction alone may fail. In such cases, surgery to realign the tibial tubercle may well be indicated.

The indications for tibial tubercle transfer (TTT) are very much open to debate and, as yet, are not subject to a consensus in agreement. In addition, there is no systematic review evaluating the literature surrounding the outcomes of patients who have undergone the different types of tubercle transfer. The use of tibial tubercle transfer is indicated in those patients that have recurrent instability in conjunction with an increased TTTG and/or patella alta. In patients with patella alta and a normal TTTG, MPFL reconstruction in conjunction with tibial tubercle distalisation may be performed. In patients with an increased TTTG (greater than 20mm), medialisation of the tibial tubercle with MPFL reconstruction may be indicated. In patients with increased TTTG and patella alta, medialisation and distalisation of the tibial tubercle in conjunction with MPFL reconstruction may be performed.

Some surgeons advocate performing a simultaneous TTT and MPFL reconstruction in those patients with an increased TTTG in the absence of patella alta. While simultaneous medial TTT and MPFL reconstruction have both been reported as being beneficial in improving stability in patients with an abnormally large TTTG [144,145], there are concerns that such a combined approach might lead to excessive loads on the medial patellofemoral compartment if performed on patients with a normal Q angle [141].

Ostermeier et al [161] compared MPFL reconstruction to TT medialisation in cadavers with normal Q angle and MPFL deficient knee. They reported that medial transfer of the tibial tubercle showed no significant stabilising effect on patellar movement, whereas reconstruction of the MPFL showed a significant stabilising effect on patellar movement. In addition, Watanabe et al [162] reported equivalent clinical results of MPFL reconstruction to TT medialisation in conjunction with MPFL reconstruction in patients with recurrent dislocation of the patellofemoral joint in patients with a normal Q angle.

Despite the interest in trochleoplasty, at present there is no consensus upon whom and at what point to perform a trochleoplasty. In a recent systematic review, Bollier et al [163] advised that trochleoplasty should be reserved for patients only after other pathologies have been corrected and that it is a salvage operation for extreme dysplasia. However it is recognised by those who regularly perform trochleoplasty that the outcomes are better when it is performed as a primary procedure, and not for salvage. For those who do not advocate trochleoplasty, the Fulkerson anteromedialisation of the TT is the preferred option to avoid increasing the patellofemoral joint reaction force in the presence of trochlear dysplasia. It should also be noted that severe trochlear dysplasia is rare.

### 6. Outcome measurement for PFJT pathology

A variety of functional and patient-reported outcome measurements have been used to assess clinical outcomes following patellar dislocation or anterior knee pain [164]. These are summarised in Table 1. Whilst the majority were originally designed for non-patellofemoral joint disorder populations, the Kujala Patellofemoral Disorder Score was specifically designed to assess people with anterior knee pain and patellofemoral disorders [165]. This outcome measure has subsequently demonstrated good reliability, validity and responsiveness of anterior knee pain and patellar instability populations [164,166]. Watson et al [167] reported good reliability with acceptable responsiveness of the Lower Extremity Functional Scale (LEFS) and for people with anterior knee pain, whilst Crossley et al [168] reported that the VAS pain score was a reliable, valid and responsive instrument for this population. Finally, this outcome has also been extensively evaluated for cross-cultural translations and validated in Chinese [169], Persian [170], and Turkish [171].

Whilst these outcomes provide an indication on the functional outcomes of people with patellofemoral disorders, until recently no instrument existed to assess people’s perceptions of patellar instability. The Norris Patellar Instability (NPI) score has been developed based on patient-reported activities which cause symptoms of instability [15]. Consequently the NPI score was assessed in relation to validity and internal consistency, demonstrating good psychometric properties for both evaluations [172].

A number of physical tests have been evaluated as outcome indicators for people with anterior knee pain. These include the assessment of joint reaction force [173], and patellar mobility tests [25]. Loudon et al [174] assessed five functional tests for people with anterior knee pain (anteromedial lunge, step-down, single-leg press, bilateral squat, balance and reach) reporting good intra-rater reliability and were related to changes in pain.

Following Jensen et al [3] and Carlsson et al [175], studies suggesting psychological outcomes were important for people with anterior knee pain, only Thomeé et al [4] has assessed the reliability of psychological outcomes of anterior knee pain symptoms. In their study of 50 people with anterior knee pain, they reported good reliability for the multidimensional pain inventory (MPI), coping strategies questionnaire (CSQ) and Spielberger state trait anxiety inventory (STAI) in this population. They also reported some concerns regarding the high proportion of participants who were “catastrophizing” their pain responses when assessed about coping strategies, suggesting further evaluation in this field is required.

### Table 1

<table>
<thead>
<tr>
<th>Outcome measurement</th>
<th>Original Referenced Source</th>
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<tr>
<td>Kujala patellofemoral disorder score</td>
<td>Kujala et al, 1993</td>
</tr>
<tr>
<td>Tegner level of activity score</td>
<td>Tegner and Lysholm, 1985</td>
</tr>
<tr>
<td>Hughston VAS knee score</td>
<td>Flandry et al, 1991</td>
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<tr>
<td>Lysholm knee score</td>
<td>Lysholm and Gillquist, 1982</td>
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<tr>
<td>Crosby and Insall assessment tool</td>
<td>Crosby and Insall, 1976; Heywood, 1961</td>
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<tr>
<td>Musculoskeletal Function Assessment injury and arthritis survey</td>
<td>Martin et al, 1996</td>
</tr>
<tr>
<td>Fulkerson knee instability scale</td>
<td>Fulkerson and Shea, 1990</td>
</tr>
<tr>
<td>Short Form-36</td>
<td>Ware and Sherbourne, 1992</td>
</tr>
<tr>
<td>Lower Extremity Functional Scale (LEFS)</td>
<td>Binkley et al, 1999</td>
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<tr>
<td>Hall assessment</td>
<td>Hall et al, 1979</td>
</tr>
<tr>
<td>Knee Injury and Osteoarthritis Score</td>
<td>Roos et al, 1998</td>
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Through the use of patient-reported outcome measures, in addition to functional tests such as timed-shuttle runs, hop-tests, dynamometry muscle testing and knee range of motion, pain and subsequent instability episodes, it is possible to assess the global-outcomes of people with anterior knee pain and patellofemoral instability. Paxton et al [166] concluded that multiple outcome instruments are required to assess knee-specific, general health, and activity level domains to truly evaluate the outcomes of people with such patellofemoral disorders.

7. Authors' preferred management

From the history it is important to understand the patient's expectations. Most can be managed non-operatively with advice on losing weight, proper diet and regular exercise, and a rehabilitation programme aimed at building up quadriceps strength and VMOs (if present). It is also important to build up the gluteal muscles. Gluteus maximus controls external rotation of the femur. Weakness leads to uncontrolled internal rotation of the femur which can result in any combination of lateral patellar instability, medial tibiofemoral instability, and/or anteromedial knee pain. Core and pelvic muscle stability and proprioception are also important. Patients with chronic back problems may have knee pain where operations on the knee fail because proper rehabilitation is impossible. Patients with hypermobility need to have an understanding of this condition. In the UK they can access the Hypermobility Syndrome Association website www.hypermobility.org.

In patients with mechanical patellofemoral instability where there are anatomical abnormalities that can be corrected, where conservative measures have failed and the patient is not happy self-reducing their dislocation, and they have significant functional deficits, then the dominant operation is a medial patellofemoral reconstruction. Trochleoplasty is reserved for those with a significant trochlear dysplasia. Other operations such as tibial tubercle osteotomy and rotational osteotomies of the femur and tibia are almost always only needed for those patients with a permanently laterally tracking patella (the patella never engaging the femoral articular cartilage during knee flexion).

In the clinic the primary task is to find out if the knee anatomy is normal. In patients where anterior knee pain predominates, then a normal knee plain radiograph (no trochlear dysplasia or patella alta) indicates that surgery is not a sensible management strategy. In our experience patients who have had multiple operations for patellar instability that have failed, and their plain radiographs show a normal trochlear groove, the diagnosis is invariably hypermobility, with Ehlers-Danlos syndrome the most likely cause. These patients do not do well with an operation whatever their problems.

The majority of patients with patellofemoral problems have normal knee anatomy. This indicates that their problems do not arise directly from the patellofemoral joint, and that the management strategy rests outside it. The management then is to address any poor muscle function. Ultimately the patient must be motivated to get better; without this there is no chance of a successful outcome.

8. Conclusions

Various conservative management strategies are beneficial for anterior knee pain [176]. Similarly following patellar dislocation with recurrent patellar instability symptoms patients respond positively to physiotherapy with acceptable functional and patient-reported outcomes. However, the current trials with anterior knee pain and patellofemoral instability have numerous methodological limitations including imprecise randomisation procedures, duration of follow-up, control of co-interventions, assurance of blinding, accountability and proper analysis of dropouts, number of subjects, and the relevance of outcomes. Therefore current management is based on expert opinion, rather than a strong evidence base.

9. Conflict of interest

The authors have no conflict of interest to report.

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95] Christiansen SE, jakobsen BW, Lund B, Lind L. Isolated repair of the medial


Review

Uncertainties surrounding the choice of surgical treatment for ‘bone on bone’ medial compartment osteoarthritis of the knee

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ABSTRACT
A number of different surgical interventions can be used for treating antero-medial osteoarthritis (AMOA) of the knee and this choice can present challenges for patient's decision-making. Patients with AMOA can undergo Total Knee Replacement (TKR), Unicompartmental Knee Replacement (UKR) or High Tibial Osteotomy (HTO) for the same pathology. However many uncertainties still exist as to deciding which operation is best for individual patients and the Orthopaedic community has failed to systematically compare treatment options. The relative lack of scientifically based evidence has impacted on the ability to provide clear guidelines on treatment choice, patient suitability and direct patient preference for treatment. This paper, using available evidence, discusses the issue and offers some suggestions for future development.

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1. Introduction and aims

Osteoarthritis (OA) of the knee is a common condition producing pain, swelling, and stiffness in the knee, that in many cases results in a reduction of function for patients [1,2]. In up to 50% of patients the pattern of arthritic change in the knee is found predominately in the medial compartment of the joint, with lesser changes occurring on the lateral side, or patello-femoral joint [3] (Figure 1). Isolated patello-femoral or lateral compartmental OA are less common patterns.

When patients with medial compartment OA develop persistent disabling symptoms, that are not controlled by non-operative treatment, surgical intervention may be required [4]. Patients reach this stage of their disease at different times and although the average age of patients undergoing arthroplasty is around 68 years in the United Kingdom, the range tends to vary between 50-90 years depending on individual circumstances [5]. Debate still continues as to the most appropriate surgical intervention to treat patients with bone-on-bone disease isolated to the medial side whose symptoms are not controlled by non-operative means [6–8]. The options for surgery include: total knee replacement (TKR), unicompartmental (or partial) replacement (UKR) or high tibial osteotomy (HTO) (Figure 2a,b,c) [9–11]. The decision to undergo one form of treatment over another depends...
on the relative advantages and disadvantages of each treatment, patient suitability, and the preferences of the patient. This paper aims to review this debate focusing on the evidence that exists (or is lacking) in support of each treatment option.

2. Antero-medial osteoarthritis of the knee

Osteoarthritis (OA) can affect all three compartments of the knee, but epidemiological studies have shown that the predominant pattern is disease localized to the medial side of the knee [12]. White et al. first described the detailed patho-anatomy of antero-medial OA (AMOA) [13]. The main features are localised femoral and tibial cartilage loss, with specifically antero-medial chondral and osteochondral damage of the tibial plateau, together with intact ligamentous structures, most notably the anterior cruciate ligament (ACL). This pattern has been confirmed by other investigators [14]. When the ACL is damaged, the size of the defect on the tibia is related to the extent of ligament damage [15]. This relationship is sufficiently strong as to allow reliable prediction of the status of the ACL – the greater the extent of the tibial bony defect, the less likely the ACL is to be intact [16]. It has been suggested that at least 30% of patients considering surgery in the UK have this clearly defined pattern, but the true figure may well be higher [3].

3. Total knee replacement

Total knee replacement is the commonest surgical procedure used in contemporary Orthopaedic practice to treat knee OA [11] and is supported by the greatest body of published evidence. In the UK, 80,000 knee replacements are performed annually and in general the operation has proved to be a very successful procedure [17]. It is thought of as a highly cost-effective operation, with a recent publication showing a cost approximately £5,623 per quality-adjusted life year gained for the average patient [18]. However, obtaining an accurate picture of outcome success of TKR in patients with AMOA from published reports can be difficult due to the lack of representation of the AMOA phenotype in any study population and limitations with outcome measures used to capture the success of surgery.

With regard to homogeneity, TKRs are implanted for disease isolated to the medial side of the knee in a significant proportion of patients, yet no outcome data exist for this specific sub-group of patients. Instead, outcome data of TKR for patients with all patterns of OA disease, i.e. a highly heterogeneous group, are often cited and the findings then extrapolated to the specific sub-group with AMOA only. Clearly, the validity of this extrapolation is questionable.

In terms of outcome measurement, for many years the outcome assessment of arthroplasty has relied on survival analysis to estimate the number of prostheses that survive year-by-year following joint replacement [19]. A number of National Joint Registries (NJR) have shown that survival of TKRs in large populations can be as high as 95% at ten years, with reassuring consistency seen in results across registries from different countries [5,20]. Other trends are seen across the different registries with, for example, lower survival figures for younger patient populations (under 60) undergoing TKR [5,21]. Prosthesis survival can be useful as an indication of catastrophic failure but it often fails to represent a true measure of the success of the operation.

To address this there has been an increasing interest (over the last five years) in measuring a more functional or symptom related outcome for TKR. The outcome of TKR using patient reported outcome measures (PROMs), augmenting the survival data mentioned above [22], is now commonplace. The Oxford Knee Score (OKS) questionnaire is a joint specific outcome tool that measures pain and disability before and after TKR [23]. The OKS has been shown to be reliable and it has been taken up nationally in the UK to measure the outcome of TKR [17]. Recent publication from national PROMs data sets suggests that, as with registry survival data, PROMs measurement shows that the majority of patients have a very good outcome after TKR. A major effect size is observed in the improvement in pain and disability. However, further analysis of these data reveals that despite 92% of patients having a measured improvement in PROM scores, approximately 15% of patients are dissatisfied with their procedure [17]. Subsequent studies have substantiated this rate of dissatisfaction and some have attempted to explain the cause. The dissatisfaction appears to be related mainly to residual pain and stiffness after surgery, producing a mismatch in expected and true outcomes [24–26].

The very existence of a level of dissatisfaction after arthroplasty suggests that not all patients are suitable for TKR. Numerous uncertainties and gaps in our knowledge about the procedure remain. As there have been no contemporary publications of population-based results of TKR for treating OA isolated to the medial compartment we are yet to clearly define whether TKR is the treatment of choice. Moreover, we do not know which patients are the best or ideal candidates for TKR. This deficit compounds existing difficulties in decision making further down the line. The information deficit makes it difficult to accurately inform patients about the likelihood of success from TKR, particularly in patients with isolated AMOA.

At present there are no standardised tools for predicting the outcome of TKR intervention at the pre-operative stage, based on patient characteristics. In addition, there are very few published contemporary randomised controlled trials (RCTs) that compare TKR against UKR, and/or HTO. This type of comparative data for TKR will be essential in helping clinicians achieve an evidence [efficacy] based position from which to select management, and also help patients determine their own suitability, and thereby preference, for treatment.

4. Medial unicompartmental knee replacement (medial UKR)

Unicompartmental (or partial) knee replacement on the medial side of the knee offers an alternative treatment option
and in the UK seven percent of all knee replacements performed are of this type [5]. The selection of this treatment option is based upon the perceived benefits when compared to TKR. There is evidence that patients recover faster after UKR [27]. There is some evidence to suggest that they have a superior functional outcome when compared to TKR, although recent population studies from the UK have not identified large differences in PROMs when comparing UKR and TKR [28,29]. In addition, there are data to suggest that patients have less morbidity and lower mortality after UKR [30]. This is supported by evidence from the UK National Joint Register which identified 50% reduction in the patient 90-day mortality rate recorded for patients undergoing UKR compared to a matched series of patients undergoing TKR [5]. However, these apparent advantages of UKR must be weighed against the higher revision rates seen for UKR compared with TKR recorded in the UK NJR. The most recent report (9th Annual Report) showed the revision rate for UKR was approximately 10% at 8 years [5]. The relatively high revision rate for UKR, when compared to TKR, is yet to be fully understood and remains one of the uncertainties. Whatever the reason for it, the trend of a higher revision rate in UKR is observed in all NJRs [21,31,32].

Aside from understanding the reasons for high revision rate in UKR, and despite a substantial body of literature on outcome, (similarly to TKR), our knowledge on indications, suitability and outcome for UKR remains incomplete. As with TKR we do not know if the outcome of UKR can be predicted at an individual level in the pre-operative stage, with any accuracy. As mirrored in TKR, there are no published results from large contemporary RCTs of TKR versus UKR in patients with AMOA. There are some small studies and trials, and many cohort comparisons, but these cohort studies suffer from comparing groups of patients who were deliberately selected to undergo one type of treatment, presumably on their suitability and preference [33,34]. The bias is substantial. In addition, patients would benefit from understanding better the relationship and potential advantages/disadvantages from undergoing HTO rather than UKR. This comparison of outcome for HTO and UKR would be especially useful for younger patients (<60 years) with OA. Although the data is not yet available, there is no question that filling these information gaps will help inform patients and clinicians to make the best decisions when choosing treatment options.

5. High tibial osteotomy

This procedure provides an alternative surgical method to treat AMOA of the knee, where the joint is not replaced [35]. The treatment involves changing the patient’s weight-bearing mechanical axis, by surgically altering the alignment of the tibia (Figure 2c) [36]. The procedure has been performed for many years as an alternative to TKR, particularly in the younger patient (<60) [37]. There is supportive evidence regarding its efficacy and a Cochrane systematic review highlighted the potential benefits the procedure offers to patients in treating AMOA of the knee [38,39]. In recent years there has been an increasing interest in its use as new techniques to provide fixation and to pre-operatively plan the osteotomy have become available [40–43].

There are a number of proposed advantages to this procedure when considered against joint replacement. The joint itself is not opened and the structures around it are preserved. Retention of the natural joint surfaces and ligaments offers the potential for more normal kinematic function [35]. Patients may then expect to return to a greater level of activity than is considered possible after joint replacement. In the majority of cases the procedure is not planned as a treatment for longevity, although operation is considered useful in reliably reducing symptoms into the second decade after operation [44]. The procedure can be, and frequently is, revised to a joint replacement should it fail, although functional results of the revision may not be as good as a primary replacement [45–47].

High tibial osteotomy (HTO) is a potentially attractive treatment option for the younger patient who retains the desire to, and wish to maximize the potential for returning to the highest level of function after surgery. However, there is much less data in the contemporary literature regarding the outcome of HTO compared to TKR and UKR. In particular, there are no large population studies that report, using PROMs, the outcome of HTO in the NHS. Published results tend to derive from single individual centres where surgeons are performing higher volumes of the procedure [38,39,42,44]. Thus suggesting that published results
do not reflect and are less representative of practice across the UK [38]. In addition there are no RCTs that directly compare the outcome of HTO with the outcome of replacement (UKR or TKR). Both these issues create uncertainties over the impact and appropriateness of conducting HTO for AMOA, issues that may delay the uptake of an important surgical intervention.

6. Shared decision-making - which operation should I have?

Over the last 5 years there has been a greater focus on making sure patients are fully involved and engaged in the decisions that are made about their medical care [48]. Making a decision about whether or not to undergo joint surgery is a good example of a discreitional treatment choice that should be made as a shared decision involving both patient and clinician [49]. This issue has been addressed in the UK by the development of a Decision Aid for the treatment of Knee OA for the NHS [50]. Decision Aids, such as this, have been consistently shown to help patients make more informed choices of care [51]. However, the more complex decision of which procedure is best suited to an individual, or whether an individual would be prepared to undergo one type of surgery, but not another, adds another dimension of complexity. The difficulties in comparing between the potential benefits and risks compared across the three treatment options presents a real dilemma for patients and surgeons in deciding which is the optimal treatment choice [52].

The contrasting surgical options available, and lack of consensus, is a potential source of variation seen in clinical practice across patient populations. The dilemma represented by these contrasting options is also not a matter of simple choice. The complexity is well illustrated by the fact that the majority of surgeons in the UK who treat patients with AMOA do not perform all of these treatment options within their practice. In turn, it would be reasonable to assume that surgeons not capable, or not able, to provide a particular operation would not offer it at consultation. Hence patients may not be informed of all the treatment options available [5]. Direct evidence exists to show that surgeons will have an individual preference under these circumstances [8]. The variation in treatment choice for patients with late stage AMOA by surgeons with widely differing levels of familiarity, experience and preference can be up to 59%. Although patients and clinicians must retain a level of autonomy in their treatment choice such wide variation in practice may represent significant unwarranted variation in surgical treatment of AMOA [53,54].

7. Gathering further evidence

If a more standardised approach to offering this surgical care is to be achieved, then improved decision support for patients around this specific treatment choice will be required. However, it is clear that comprehensive comparative data across the three treatment options is not available. To establish the data required to properly inform decisions, a number of different methodologies can be used. Initially, further work should focus on establishing the indications for each procedure type. This could be achieved by a review of existing data sets. Then having established where indications suggest that more than one treatment could be used, comparative data is required to guide further.

The type of comparative data required will be variable but the optimum will be in the form of results from RCTs comparing the efficacy of treatment, with outcome based on PROMs. In addition, this RCT data must be supported by controlled population based cohort analysis to compare post-surgical morbidity, infection, mortality, revision rate (early and late survival figures) and patient satisfaction across the treatments options. This work will be complex, as attempts must be made to control comparison of treatments for the same phenotype and degree of OA knee disease, as well as co-morbidities and other factors that are potential confounders (e.g. mental state).

Some of the work has already started to examine these uncertainties. The perceived lack of persuasive evidence to support the use of UKR over TKR has led to TOPKAT (Total or Partial Knee Arthroplasty Trial), a UK based National Institute for Health Research (NIHR) funded multi-centre RCT comparing partial and TKR, with patient related outcome as the primary endpoint and a unique combined device/expertise randomisation design [55]. TOPKAT will give much greater unbiased insight into the relative merits of UKR and TKR and will also provide a platform for work to explore whether differences in UKR and TKR are reflected in patients’ activity and participation levels. Similar large-scale multi-centre pragmatic RCTs studies are now required to compare HTO with UKR and TKR.

In addition, further work is required to understand the differences in revision rate seen between TKR and UKR. Specifically, we need to understand whether these differences relate specifically to the type of implant (partial or total), with one having a genuine increased failure rate, or whether the difference is due to an imbalance in the threshold for revision, i.e. the variation in clinician decision making around the offer of revision surgery in the two groups. Data from the NJRs offer an excellent opportunity to investigate some of these questions and these issues have been identified as research priorities for the British Association for Surgery of the Knee (BASK). Unfortunately, there are no NJR data for HTO and the true population based revision rate for HTO is not known. Similarly, national PROM data have not been recorded for this operation. The knee surgery fraternity must invest time, consideration and resources into how to best address these gaps in knowledge.

Finally, it was not the aim of this overview to cover diagnostic or therapeutic dilemmas such as the absence or integrity of the anterior cruciate ligament (ACL) and its effect on the choice of a specific UKR design or the option of TKR, the presence of patellofemoral arthritis and subjective symptoms. Similarly surgical technical issues such as the use of cemented versus uncemented implants, mobile versus fixed implants or opening wedge versus closing wedge HTOs was beyond the scope of this review. However these questions are important and further focus on defining the indication for each procedure (HTO, UKA & TKR) in subgroups of patients with subtle differences in pathology is required as individualised patient care approaches develop.

8. Improving treatment guidelines and decision support for surgical treatment of bone on bone medial OA of the knee

With time many of the uncertainties discussed above can be addressed. These new data will be a critical part of building the best evidence based guidelines for the treatment of AMOA and building new decision support tools for patients to help choose between treatments when choice exists. However a final point might deal with the balance between obtaining evidence and practicing evidence-based medicine, but at the same time permitting (and even promoting) appropriate clinical autonomy.

Surgical medicine is not a field that will be entirely dictated by RCTs and evidence of group efficacy. Surgery will always need to draw on technical skill, mastery, experience and the ability to problem solve, to a greater or lesser extent. The application of an improved scientific foundation, as outlined here, is certainly not intended to dilute these critical attributes. In contrast, the optimum position (for both patients and clinicians) is a world where evidence based practice provides the robust framework for treatment choice, but the need for autonomy and individual patient/clinician shared decision-making is always retained and respected.
9. Conflict of interest

The authors have no conflict of interest that would interfere with the content of this paper.

References

Can technology improve alignment during knee arthroplasty

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ABSTRACT
Component malalignment remains a concern in total knee arthroplasty (TKA); therefore, a series of technologies have been developed to improve alignment. The authors conducted a systematic review to compare computer-assisted navigation with conventional instrumentation, and assess the current evidence for patient-matched instrumentation and robot-assisted implantation. An extensive search of the PubMed database for relevant meta-analyses, systematic reviews and original articles was performed, with each study scrutinised by two reviewers. Data on study characteristics and outcomes were extracted from each study and compared. In total 30 studies were included: 10 meta-analyses comparing computer-assisted navigation with conventional instrumentation, 13 studies examining patient-matched instrumentation, and seven investigating robot-assisted implantation. Computer-assisted navigation showed significant and reproducible improvements in mechanical alignment over conventional instrumentation. Patient-matched instrumentation appeared to achieve a high degree of mechanical alignment, although the majority of studies were of poor quality. The data for robot-assisted surgery was less indicative.

Computer-assisted navigation improves alignment during TKA over conventional instrumentation. For patient-matched instrumentation and robot-assisted implantation, alignment benefits have not been reliably demonstrated. For all three technologies, clinical benefits cannot currently be assumed, and further studies are required. Although current technologies to improve alignment during TKA appear to result in intra-operative benefits, their clinical impact remains unclear, and surgeons should take this into account when considering their adoption.

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Surgical robotics

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1. Introduction

Although the risk of revision total knee arthroplasty (TKA) has fallen over the last two decades [1], and there have been substantial advances in patient recovery following surgery [2], the increasing demands placed on implants means that implant failure remains a concern [3].

Soft-tissue balancing, rotational position and implant alignment are all associated with long-term implant survival among patients undergoing TKA [4]. Specifically, re-establishing a neutral mechanical axis may both improve the functionality of the knee and increase its survival by minimising eccentric stresses on load-bearing surfaces [2]. Malalignment in TKA is associated with increased polyethylene wear [5], pain [6], and early implant failure [7–12], with malalignment greater than 3° increasing the likelihood of implant failure and medial bone collapse approximately 17-fold [13].

Malalignment greater than 3° is estimated to occur in up to 30% of TKA procedures with conventional instruments [11,14–16], with a trend towards increased malalignment and increased variability amongst less experienced surgeons [14]. Hence, there is a need for more accurate implantation systems, especially for less experienced and low-volume surgeons.

The restoration of proper mechanical alignment in TKA is achieved by using joint angle measurements derived from preoperative full-leg films of the hip-knee-ankle (HKA) complex. Weight-bearing, full-leg radiographs of the HKA have been long considered the ‘gold standard’ for surgical planning due to their intuitive display of the whole joint [17,18]. However, due to inaccuracies of instrumentation and difficulties in achieving three-dimensional (3D) positioning of an implant using two-plane imaging, reproducible results are not always attained.

In order to overcome these drawbacks, computer-assisted navigation was developed to give surgeons a more accurate method for achieving a neutral mechanical limb axis [2]. However, these systems, whether image-based or imageless, rely on the accurate identification of landmarks by the surgeon [2,19], which involves a significant learning curve and significant variability [20–22]. Furthermore, computer-assisted navigation is associated with substantial capital costs and increased operative time [4,23].

More recently, patient-matched instrumentation (PMI) has been introduced as a solution to the limited precision of standard instrumentation and the per-operative time loss with navigation. The technique utilises magnetic resonance imaging (MRI), computed tomography (CT) and/or radiographs to manufacture instrumentation that matches individual patient anatomy [23,24], rather than the intra-operative anatomic identification of landmarks by the surgeon [2]. Patient-matched instrumentation (PMI) is thought to enhance implant alignment [2], which theoretically should improve surgical outcomes and reduce the risk of revision [19]. Nevertheless, the identification of landmarks is still open to human error, the length of time required to manufacture individual patient instrumentation delays surgery, and it is not clear whether the reduced costs associated with increased operating room efficiency and sterilisation costs offset those of the pre-operative imaging studies and instrument manufacturing [23].

Another form of computer-assisted technology in TKA is robot-assisted implantation. This technology may be active, in which the robot performs all or part of the bone preparation steps, or semi-active, in which the robot constrains the surgeon within a pre-defined surgical plan [2,7,25]. Robot-assisted implantation has many of the same advantages and disadvantages of computer-assisted navigation, including increased costs and operative times [2].

After a review of an arbitrary sample of studies that revealed suspected methodological limitations, we carried out a systematic review of the international literature on these much-vaunted but potentially unproven technologies. The authors examined published studies comparing computer-assisted navigation and conventional instrumentation in TKA, as well as the best available evidence on PMI and robot-assisted implantation. Reflecting the extensive investigations that have already been carried out into computer-assisted navigation and conventional instrumentation, we collated meta-analyses and pre-appraised literature comparing the two approaches, whilst data from case series and original publications with a higher level of evidence was used to assess the merits of patient-matched instrumentation and robot-assisted implantation. Due to differences in methodological approach and measured outcomes between the studies, the review is primarily descriptive/narrative.

2. Methods

2.1. Search strategy

An extensive PRISMA compliant search of the PubMed database was conducted in April 2013, with no restriction on language or the year of publication. The NCBI MeSH browser thesaurus was used to identify search terms and combinations of keywords in full text. The following search terms were identified: "total knee arthroplasty"; "primary"; "navigation"; "meta analysis"; "systematic review"; "patient matched instrumentation"; "customized instrumentation"; and "surgical robotics". These were ordered using Boolean operators as “1” AND (“2” AND “3” AND (“4” OR “5”) OR (“6” OR “7”) OR (“8”)) to give: total knee arthroplasty AND (primary AND navigation AND (meta analysis OR systematic review) OR (patient matched instrumentation OR customized instrumentation) OR (surgical robotics)).

In addition, health technology assessment databases were examined for re-appraised literature on the topic of surgical navigation. Bibliographies of identified publications and published reviews were also hand-searched for potentially relevant articles. All references cited in the identified reviews were manually searched for potentially relevant studies.

2.2. Inclusion criteria

Only published papers describing outcomes following primary TKA were reviewed. All published systematic reviews and meta-analyses that presented information on the relationship between computer-assisted navigation and conventional instrumentation, on PMI, and on robot-assisted implantation were eligible for review. In addition, original publications examining PMI and robot-assisted implantation that presented information on implant alignment were eligible.

2.3. Data collection

Two reviewers (ET, PF) independently scrutinised the list of titles and, if available, the abstracts to determine their potential usefulness. A consensus method was used to resolve disagreements and the third reviewer (AP) was consulted.

The study characteristics were extracted. These included, where available: publication year, study design, sample size, and primary result. From all eligible studies, relevant data were abstracted in duplicate, using a standardised data extraction sheet.
2.4. Participants

Participants of all age groups were included. Where possible, sub-group analyses (for example, age or geography) were performed.

2.5. Outcomes

All studies that reported on implant alignment in the coronal and sagittal plane and/or restoration of the mechanical axis were included. The analysis was not restricted to a particular definition of malalignment, as different studies used different criteria.

The effect size between different outcomes, demonstrated as a risk ratio, was either extracted from the published article or, if it was not reported in the article, calculated by the reviewers. Risk ratios were defined as the probability of malalignment among the patients exposed to alignment aids divided by the probability of malalignment among the unexposed patients operated on using standard instrumentation. Odds ratios were defined as the odds (the probability of malalignment divided by the probability of correct alignment) among the exposed divided by the odds among the unexposed. Risk (odds) ratios between 0 and 1 imply that the exposure is associated with a lower risk (odds) of malalignment. Risk (odds) ratios greater than 1 imply that the exposure is associated with a higher risk (odds) of malalignment.

3. Results

The PubMed and hand search yielded a total of 171 citations for initial assessment. After reviewing the titles and reading the abstracts, 52 studies were selected for further analysis. Six publications were excluded on more detailed examination [26–31], leaving 46 eligible studies [32–41]. After preliminary data analysis, a further 16 studies were deemed to contain no clinically relevant data, repeated data from previous publications or did not fit the parameters of our study [2,19,23,37,42–53], resulting in 30 studies for review. Of these, 29 were English language studies, and one was German [32].

Computer-assisted navigation was compared with conventional instrumentation in 10 studies [32–36,38–41,54]. PMI was assessed in 13 publications [55–67], and outcomes with robot-assisted implantation were reported in seven studies [25,68–73]. One meta-analysis comparing computer-assisted navigation with conventional instrumentation presented separate effect measures for studies performed with standard radiography and CT [37]. These effect measures are presented separately in our analysis.

3.1. Computer-assisted technology versus conventional instrumentation

The ten meta-analyses eligible for inclusion described a total of 239 studies, of which 118 were fully randomised controlled trials (RCT), comparing computer-assisted navigation and conventional instrumentation in 28,763 TKA procedures (see Table 1). Two reviewers assessed the majority of these meta-analyses, although three studies did not specify the number of reviewers [32,34,36]. Only two analyses recorded the number of studies that were blinded [38,39], and just two noted the use of concealed allocation [38,40]. The type of computer-assisted navigation employed was specified in four analyses [34–36,38]. Just two studies each calculated the average age of the patients [33,40], and the number of complications [33,35], whilst one study recorded the number of patients lost to follow-up [35].

Four studies calculated the operative time for computer-assisted navigation versus conventional instrumentation (see Table 1) [32–35], indicating the mean increase in operative time with computer-assisted navigation across the four studies was 20 minutes.

Table 2 presents the alignment outcomes for computer-assisted navigation versus conventional navigation for outlier cut-off angles of > 2° and > 3° from the mechanical axis, as well as for individual alignment planes. For overall mechanical axis malalignment > 3°, the likelihood of outliers was substantially reduced with the use of computer-assisted navigation compared with conventional instrumentation, and effect measures (i.e., odds and risk ratio) ranged from 0.21 to 0.76 [33–36,38–40,54]. For mechanical axis malalignment > 3°, the reduction in the likelihood of outliers for computer-assisted navigation versus conventional instrumentation was comparable, and effect measures ranged from 0.19 to 0.79 [32–36,38–40,54]. While the likelihood of malalignment of > 2° or > 3° for individual planes was reduced to a similar degree with computer-assisted navigation (see Table 2), the smaller number of studies recording those outcomes makes definitive conclusions more difficult. However, in one study [34], studies with a cut-off of 3° were combined with those with a cut-off of 2° to indicate that the odds ratio of outliers for the coronal femoral implant angle was 0.19 (95% confidence interval, CI 0.077–0.392), and that for the coronal tibial implant angle was also 0.19 (95% CI 0.068–0.411). Other outcomes could not be meaningfully assessed due to a lack of data.

3.2. Patient-matched instrumentation

As shown in Table 3, of the 13 studies assessing PMI, five used Visionaire Patient Matched Technology (Smith & Nephew...
<table>
<thead>
<tr>
<th>Study</th>
<th>Mechanical Axis Malalignment &gt;2°</th>
<th>Mechanical Axis Malalignment &gt;3°</th>
<th>Tibial Component Coronal Plane Malalignment &gt;2°</th>
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Inc. Memphis, USA) [55,57,60,64,67], and four studied the Signature Personalised Patient Care System (Biomet Inc, Warsaw, USA) [56,59,61,65]. Three studies used OtisMed custom guides (OtisMed, Hayward, USA) [58,62,66]. In one study [63], the Signature, TruMatch (DePuy Inc, Warsaw, USA), Visionaire, and Patient-Specific Instruments (Zimmer Inc, Warsaw, USA) systems were compared with conventional instrumentation. Patients were fully randomised in only two studies [60,63], and quasi randomised in a third [64]. Five studies were prospective studies [55,57,58,62,67], while three were retrospective analyses [56,59,61]. One study was a cohort analysis [65], and one a case series [66].
Eight studies reported on mechanical alignment in TKA with PMI [55,56,59,61–63,65,67], and five compared mechanical alignment between PMI and standard instrumentation [56,59,61,63,65]. The proportion of patients with malalignment > 3° varied between 0.09 [59] and 0.37 [61], at an average of 0.22 (95% CI, 0.19–0.26). The risk ratio for malalignment ranged from 0.39 [59] to 0.91 [61], at an average of 0.74 (95% CI: 0.58–0.94, p = 0.02).

Although the risk ratio of outliers with PMI suggested a reduction over comparator groups, the reductions were not as great as those seen with computer-assisted navigation and was significant in only one study [59].

With regard to the alignment of individual components, the results were incomplete. Only six studies reported on this aspect of implant success [42,56,57,59,63,67], with data from only three allowing a comparison between the two techniques [57,59,63]. Boonen et al. found improved alignment of the femoral component in the coronal plane (RR = 0.15, p = 0.001) and of the femoral component in the sagittal plane (RR = 0.47, p < 0.001) [56]. Victor et al. found an increased risk of tibial component malalignment in the coronal plane (RR = 4.7, p = 0.028). The remainder of the results did not significantly favour either of the two techniques [64].

Eight studies [55,58,60–62] reported on mean operative time or reduction in operative time. Five studies allowed a comparison in surgical time. Differences in tourniquet time varied from 5 minutes [61] to 13 minutes [62] in favour of patient-matched instrumentation. Total reduction in operative time ranged from 12 minutes [61] to 10 minutes [56] to 7 minutes [60]. Studies consistently showed a reduction in surgical time, even though in one study the difference was only marginal. Postoperative clinical outcomes were recorded too inconsistently for analysis.

3.3. Robot-assisted implantation

Of the seven studies eligible for analysis, three examined the CASPAR system (URS Ortho, Rastatt, Germany) [25,69,71], three assessed the ROBODOC system (Integrated Surgical Systems, Davis, US) [70,72,73], and one looked at the MAKO Tactile Guidance System (MAKO Surgical Corp., Fort Lauderdale, US) [68]. The classic and anatomic forms of the ROBODOC system were studied in one investigation [73]. The patients were randomised in just three studies [70,72,73], while three studies were prospective analyses [25,71], one was a retrospective study [68]. A total of 323 TKAs were performed with surgical robotics (range, 13–70) and the average age of the patients ranged from 62.7 to 69.0 years. Minimum follow-up ranged from less than a month in one study [70] to 5.1 years [25]. Operative time was recorded in just four studies [25,69,71,72], and indicated that the average length of surgical procedures with robot-assisted implantation was 150 (range 95–229) minutes.

Postoperative mechanical axis alignment was assessed in five studies [69,72,73]. Mechanical alignment outcomes showed consistent and satisfactory results. Standard deviations from the mechanical axes of 1.6° [72], 1.7 (classical alignment method) and 2.0° (anatomical alignment method) [73], and 0.6° were reported [69], while Bellemans et al. reported all procedures led to a mechanical axis within 1° of neutral alignment [25]. Alignment outcomes in the other individual planes were not recorded with sufficient regularity or consistency to allow definitive, or even partial, conclusions to be drawn. A similar lack of data hampered other analyses. Interestingly, two studies recorded Hospital for Special Surgery and Western Ontario and McMaster University scores [72,73], and the findings suggested that robot-assisted surgery is potentially associated with improvements in both measures.

4. Discussion

The present review has confirmed the findings of several previous meta-analyses that computer-assisted navigation for TKA achieves substantial and meaningful reductions in the number of outliers compared with conventional instrumentation [32–38,40,41,54]. For PMI, only one study of five that record sufficient data found a significant improvement in the number of outliers [59]. Furthermore, the only published RCT trial to include outlier data found no improvement in alignment with PMI compared to standard instrumentation [63]. However, all comparative studies consistently showed a point-estimate of the risk ratio smaller than one for mechanical alignment. This does not preclude an effect in favor of PMI, even though the effect may have been too small to reach the level of significance in the current studies. For the other alignment planes, the results were inconsistent and not unequivocally in favor of PMI. For robot-assisted implantation, a lack of data within studies, poor methodology, and a lack of consistent recording of data between studies means that it is impossible to draw firm conclusions on the ability of this technology even to improve alignment. Given that the systems have been designed expressly to achieve that outcome, it represents the most basic assessment of their performance.

For all the technologies and approaches encompassed by our review, their overall impact on clinical outcomes cannot be reliably determined from the available data. Again, this is due both to a lack of information within individual studies and a lack of consistency between studies. This lack of proven clinical applicability is cited in the conclusions of studies included in our review as something that should be addressed in future studies [34–36,39,56,60,62,63], and we can only affirm this. Furthermore, some investigators of PMI [61–64], and robot-assisted implantation [25,70,73], have not only questioned the clinical value of these technologies but also whether they should be recommended at all in their current form. The current lack of relevant data makes these concerns impossible to allay.

Another aspect to consider is that of cost-effectiveness. While one study suggested that PMI is economically effective when compared with conventional instrumentation [31], other investigators questioned the cost-effectiveness of PMI [19,23,43,44,61], robot-assisted implantation [71], and computer-assisted navigation [74]. Further studies that are designed to answer these important questions are required before any recommendations can be made. It is interesting to note a recent study that sought to define the implant cost and performance thresholds under which innovative TKA implants are cost-effective. It found that innovative implants need to decrease actual TKA failure, not simply radiographic wear, by ≥ 55% over standard implants to be considered cost-effective [75]. It is not unreasonable to expect that a similar percentage would be required to demonstrate cost-effectiveness for implant guides.

5. Conclusions

The results of our review demonstrate that computer-assisted navigation results in significant and reproducible improvements in alignment during TKA, compared with conventional instrumentation. Whether these improvements translate into meaningful clinical benefits has not, however, been demonstrated, and should be examined in further studies. For PMI and robot-assisted implantation, any alignment benefits have yet to be conclusively shown and, consequently, any related clinical benefits are a long way from being realised. It is therefore a matter of urgency that these expensive and time-consuming
technologies are thoroughly investigated in well-constructed studies.

6. Conflict of interest

None of the authors have a conflict with the present publication.

Acknowledgements

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Review

Fast-track knee arthroplasty – status and future challenges

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ABSTRACT

Background: Fast-track programs have been developed for different surgical procedures leading to higher patient satisfaction and lower morbidity. This concept has been extended to knee arthroplasty in recent years. The purpose of this narrative review was to discuss the different aspects of fast-track knee arthroplasty.

Method: Both authors searched the contemporary literature on minimally invasive knee arthroplasty and review articles on fast-track surgery aiming to summarize recent developments.

Results: Length of stay after knee arthroplasty is influenced by preoperative risk factors, anaesthetic and surgical techniques, pain, orthostatic intolerance, cognitive function, sleep disturbances, bleeding and anaemia and finally muscle function and rehabilitation.

Conclusions: Fast-track surgery reduces the length of stay and the morbidity after knee arthroplasty.

Clinical relevance: Optimisation of pre-, per- and postoperative pathway for knee arthroplasty reduces morbidity after this type of surgery and results in shorter length of stay.

Keywords: Knee arthroplasty
Fast-track
Outcome
Convalescence
Enhanced recovery

1. Introduction

During the last 15 years, programs to enhance postoperative recovery, decrease morbidity and convalescence as well as hospital stay (LOS) have been developed across surgical procedures – the so called “Fast-track surgery” or “Enhanced recovery after surgery” concept [1–3]. These developments are based upon procedure-specific analyses of the various components important to enhance recovery including preoperative optimisation and information, intraoperative anaesthetic and analgesic techniques, surgical techniques, postoperative pain treatment, fluid management, use of traditional care principles (drains, tubes, catheters, monitoring, etc.) and postoperative rehabilitation techniques (Table 1).
Such programs have also been developed in total knee (TKA) and hip (THA) arthroplasty with great success decreasing hospital stay to about two to four days in contrast to previously four to twelve days [3–9]. Importantly, these recent developments have allowed discharge to home instead of discharge to rehabilitation facilities as otherwise used in many places [3]. Fast-track TKA (and THA) has been reviewed recently [3,4,8] and here more recent developments are summarised as well as a focus on future challenges discussed.

2. Material and methods

Both authors analysed recent review articles [3,4,8] and articles about fast-track concepts and treatment optimisation in contemporary knee arthroplasty. An extensive PRISMA compliant search was performed on MEDLINE and Google scholar without restrictions on language or the year of publication. Search terms and Boolean operators were ‘fast track’ AND ‘knee arthroplasty’ OR ‘knee replacement’ AND ‘rapid recovery’ AND ‘knee arthroplasty’ OR ‘knee replacement’. After eliminating duplicates and reading 122 abstracts, 76 articles were retained and read in full. Of these 60 were appropriate and utilised for this narrative review on fast-track knee arthroplasty.

3. Postoperative length of stay (LOS)

Fast-track surgery is primarily based upon an evidence-based revision of peri-operative care programs, allowing earlier achievement of conventional discharge criteria [1,2]. Optimisation of recovery should be based upon analysis of “Why in hospital?” [10], where data from TKA have shown that pain, dizziness and general weakness together with organisational factors are important for the first 24 hours [10]. However, at 48 hours postoperatively, pain has a smaller role while dizziness, general “weakness” then become the most common explanations for prolonging hospital stay [10]. Such data demonstrate the future challenges and where progress is necessary. Nevertheless, many institutions in several countries have shown that an overall adjustment of perioperative care according to existing evidence (Table 1) will reduce LOS to two to four days with discharge to home [2–10].

Understanding the reasons patients remain hospitalized and the prevention of these eventualities as well as social planning reduce length of stay after TKA.

3.1. LOS and preoperative risk factors

Although large consecutive series have shown LOS after TKA to be two to four days [5,9,11], further studies are required to identify specific groups of patients preoperatively who may not follow a fast-track setup [11,12]. However, detailed analysis of large-scale data supports that no patient should be excluded from such well-defined programs since age, preoperative smoking and alcohol use, preoperatively treated cardio-pulmonary disease, living alone or with preoperative use of mobility aid has little influence on achieving a fast-track TKA [11,13]. However, detailed studies are required on the role of other risk factors such as diabetes, renal and cerebral disorders etc.

With the recent advances in postoperative care most segments of patients are eligible for fast-track programs today, however the individual co-morbidity that could unleash other processes that destabilise the homeostasis of patients have to be studied further.

3.2. Anaesthetic technique

Previous data, including from randomised trials (RCTs), have suggested that spinal anaesthesia may be preferable compared to general anaesthesia [14]. However, such trials have usually not used modern intravenous (IV) anaesthetic techniques and furthermore not been assessed in a fast-track setup. Preliminary data suggest that we should reconsider these data and that general anaesthesia may be preferable in a fast-track program [15]. Also, the traditional use of a stay in the post-anaesthesia care unit (PACU) should be reconsidered, since the use of an opioid-sparing fast-track setup may reduce or even eliminate the conventional stay in the PACU unit [16].

The criticism of general anaesthesia has to be tempered when looking at today’s advanced techniques leading to optimised prevention of nausea and vomiting as well as the reduction of opioid-induced hyperalgesia.

3.3. Surgical technique

Minimally invasive TKA is a surgical adaptation of the existing technique that focuses on a smaller skin incision, avoiding patellar eversion and utilising quadriceps sparing approaches [17–20]. The length of the skin incision in TKA is proportional to the surface area of sensory changes in the front of the knee [21]. The frequently used medially based incision could damage the infrapatellar branch of the saphenous nerve. Neuropathic pain could be related to direct nerve damage or indirectly by neurogenic inflammation [22]. Avoidance of patellar eversion results in a better postoperative range of flexion and probably less quadriceps damage in the process of eversion [17]. Since quadriceps function can be reduced following TKA, the choice of incision and muscle handling may be important and further detailed studies on muscle function and early recovery are required with minimally invasive techniques [19] or a subvastus versus medial parapatellar approach [10,23]. Current literature has shown that the distal part of the arthrotomy, at the level of the medial collateral ligament, plays an important role in recuperation after TKA [19] and that the proximal part of the arthrotomy influences the capacity of early straight leg raising and quadriceps function [20].

Less invasive approaches seem to allow patients to mobilise quicker and to experience less movement evoked pain leading to a reduction of co-morbidity created by immobilisation and opioid consumption.

3.4. Pain

Modern postoperative pain treatment is procedure-specific, since efficacy and side effects of different analgesic regimes are different between procedures [24,25]. After TKA, the use of a peripheral nerve block has been considered the gold standard,
but due to a well-documented risk of falls from impairment of quadriceps muscle function, this technique may not be optimal in fast-track TKA [22,26]. Instead, oral multimodal non-opioid analgesia with paracetamol, NSAID or preferably a Cox-2 inhibitor and a high volume local anaesthetic intraoperative wound infiltration may be preferable [27]. Additional use of a gabapentinoid is also recommended [28] although future dose-finding studies on efficacy versus side effects combined with other non-opioid analgesics are still required. More recently, a single preoperative high-dose glucocorticoid has been shown to be very effective on post-TKA pain and early recovery, even on top of an otherwise multimodal non-opioid regimens [29]. Therefore, large safety studies on preoperative glucocorticoid treatment are awaited with interest before final recommendations [30]. Otherwise, optimised pain treatment may include ketamine or anxiolytic therapy in pain catastrophizers and require future study [25].

Multimodal or balanced analgesia is the combination of two or more drugs that combined are more effective and reduce the need for opioid analgesics reducing the potential side effects of these latter drugs.

3.5. Orthostatic intolerance (OI)

The ability to mobilise may be impaired after major joint arthroplasty (and other major procedures) [31,32] leading to dizziness, nausea, vomiting, etc. Recent studies have demonstrated OI to be due to an impaired peripheral vasoconstrictor response and thereby reducing brain oxygenation during mobilisation in up to 20% of patients 24 hours after surgery [31]. Current studies are in progress to evaluate whether this is caused by an impaired baroreceptor function, a central neurogenic mechanism or a peripheral vascular deficit. Studies from other procedures (prostatectomy) [32] have shown that orthostatic intolerance may not be explained by a suboptimal fluid management, and that the "functional hypovolaemia" cannot be treated with fluid alone.

Patients with orthostatic intolerance showed impaired haemodynamic responses to changes in position without association between bleeding, postoperative haemoglobin (Hb) concentration or opioid use [31].

3.6. Muscle function and rehabilitation

Several studies have shown a pronounced loss of quadriceps muscle function amounting to about 70–80% two to three days after a TKA [33], which may contribute to the early general “weakness” leading to prolonged hospital stay [10]. Every effort should therefore be made to evaluate the mechanisms for such large impairment of leg muscle function after TKA [34] and where pain, swelling, use of a tourniquet, the surgical approach and inhibitory reflexes may contribute.

Obviously, due to the pronounced loss of muscle function after TKA, rehabilitation efforts have been in focus, but where existing principles of physiotherapy based upon RCTs have not been entirely successful [33]. This also applies to rehabilitation efforts [35,36], where the feasibility and the quantitative effect of preoperative exercise have been limited compared to the postoperative loss of function [33]. Therefore, current efforts are focused on the potential beneficial effects of very early (within 2–4 days) strength exercise and demonstrated to be feasible [33]. Altogether, optimisation of fast-track TKA will require more focus on the early two to four weeks of postoperative recovery of muscle function and measures for improvement.

Quadriceps muscle function will be impaired after surgery and prehabilitation can lead to a superior muscular level avoiding loss of function under the level of early mobilisation and weight bearing.

3.7. Postoperative cognitive dysfunction (POCD) and sleep disturbances

The risk of postoperative delirium and a more chronic (three months or more) impairment of cognitive function (POCD) is well recognised after TKA [37]. Pathogenic risk factors may include pain, opioid use, sleep disturbances and inflammatory responses [38]. Interventions against delirium and POCD will therefore be multifactorial and preliminary data have been positive by reducing both early delirium [39] and later cognitive dysfunction by a well organised fast-track setup with discharge to home and multimodal opioid-sparing analgesia [40]. Postoperative sleep disturbances have been reduced by fast-track TKA [40], but sleep disturbances still remain a problem for the first postoperative night and with increased daytime sleep and decreased activity during the first post-discharge week [41]. Future progress will require more detailed information on preoperative high-risk patients, optimised non-opioid multimodal analgesia techniques, better sleep drugs and reduction of the inflammatory response [38].

Early postoperative cognitive decline is observed at least up to nine days after surgery and daytime sleep is increased after fast-track arthroplasty [41].

3.8. Bleeding, anaemia and transfusion

These topics are important to be considered in optimising fast-track TKA and include pre-, intra- and postoperative factors [43–45]. Preoperative anaemia should be recognised, since it increases transfusion rate, morbidity, and readmissions [43] and may potentially be treated with iron or erythropoietin [44]. Intraoperative reduction of bleeding should be made with current evidence-based techniques [44]. The influence of surgical approaches on bleeding have not been extensively researched but minimally invasive surgery has been suggested to reduce blood loss [18]. Several review studies have proved that the use of IV or topical tranexamic acid makes a substantial difference for blood loss [46–48]. The indications for use of transfusions require further study in relation to postoperative anaemia and function [43–45].

Transfusion is linked to an increased LOS and co-morbidity. Recognizing anaemic patients at risk before surgery and an adapted blood sparing or salvage programme for this segment of patients is advised.

3.9. Thromboembolic prophylaxis

TKA is a well-documented model for the need for prolonged thromboembolic prophylaxis. However, most randomised studies have been performed with a traditional care setup and not including very early (from the day of surgery) mobilisation and early discharge, despite immobilisation being an important pathogenic factor for thromboembolism [49]. Preliminary data from fast-track TKA suggest that conventional post-discharge prolonged thromboembolic prophylaxis may not be required [49]. Obviously, further large-scale multicentre consecutive studies or RCTs are required to provide final answers on the optimal technique of thromboembolic prophylaxis in TKA. Recent changes in the AAOS and ACCP guidelines open the door for the use of aspirin after TKA [50]. Several studies have shown aspirin to be as efficient as low molecular weight heparin (LMWH) or Coumadin [51]. A recent paper showed an interesting concept of using LMWH during the hospital stay and aspirin at discharge with low deep venous thrombosis (DVT) rates [52].
The classic concept of postoperative immobilation after TKA is no longer valid. The risk of bleeding and related complications has to be evaluated versus the risk of DVT and pulmonary embolism (PE).

3.10. Safety issues

Fast-track surgery has not been developed to reduce LOS but rather to provide the “pain and risk free operation” [1], which also applies to TKA. So far, fast-track TKA large consecutive data suggest a reduced morbidity compared to existing literature and pre-institutional data [5,7,9,11]. This also applies to readmissions [4]. However, further data are required to separate safety issues regarding specific “medical” complications (cardio-pulmonary-, urinary-, renal-, cerebral morbidity and falls, etc.) versus direct “surgical” complications (fractures, infections, etc.) [11,53].

Short length of stay with a high re-hospitalisation rate is of no value. Specific risk analysis for future complications should be studied.

3.11. Organisational and economic issues

An optimised fast-track TKA requires profound organisational changes which includes multidisciplinary collaboration between orthopaedic surgeons, anaesthetists, nurses and physiotherapists [3,4,54]. A successful program also requires a specific joint arthroplasty section in the orthopaedic department [4]. Reduction of LOS may also depend on the day of surgery, as operations towards the end of the week may be followed by longer LOS [4], since in-hospital facilities may not usually be optimal during the weekend [55]. The additional need for post-discharge nurse and physiotherapy assistance after fast-track surgery continues to be debatable, but has not been demonstrated to be required [1,2,4].

Cost of hospitalisation can be reduced by a shorter length of stay and allow more patients to be treated with the same society resources.

4. Future challenges

Although major progress has been demonstrated with fast-track TKA over the last five to ten years, challenges still exist for future progress [2,56]. This especially applies to safety issues with an improved understanding of specific preoperative risk factors that may allocate such patients into a different fast-track programme with potentially a few more days of hospitalisation with active monitoring, mobilisation and physiotherapy. In this context, there is an urgent need for optimisation of multimodal non-opioid analgesia especially after discharge, since sub-acute pain for the first weeks (months) after TKA are predominant [57] and may influence activity, rehabilitation efforts and even longer term functional outcome. Such studies should define the composition, drugs and duration of analgesic treatment. Other pain issues relate to the development of techniques for preoperative identification of high-risk pain patients (pain catastrophizers, hyperactive nociceptive system, etc.) [58]. In the future, more focus should be made on “medical” versus “surgical” morbidity [53], since approaches for improvement will be different. Also, the mechanisms of long-term sequelae on muscle function, and postoperative cognitive disturbances should be evaluated. Finally, the above mentioned topics relate to primary TKA, but future focus should be upon revision TKA, where little fast-track data exist [59,60], and where problems in relation to surgical technique, pain and morbidity may be more complex than in primary TKA.

In summary, the concept of fast-track TKA (as well as other surgical procedures) has demonstrated major progress to enhance recovery, thereby reducing the need for postoperative hospitalisation as well as to shorten convalescence. Consequently, data have also shown reduced morbidity, but future challenges will require optimisation of all components of pre-, intra- and postoperative care principles to achieve the “pain and risk free” TKA [2,3] (Table 1)

5. Conclusions

Fast-track TKA is a concept that puts the patient centrally and health care workers should use their medical experience to foresee potential complications before they happen, even if they are rare. Therefore patients need to be informed so they can become our partners in their health rehabilitation. A combination of preoperative optimisation, advanced anaesthetic and surgical techniques should aim for the reduction of the use of opioids and allow early mobilisation and fast recuperation of muscle function. Patient adapted and titrated pain and blood management, thromboembolic prophylaxis and reduction of non-proven traditional care principles should reduce the length of stay providing optimised care for the arthroplasty patient.

6. Conflict of interest

The authors have no conflict of interest to report.

References

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