EFORT open reviews

EFORT Open Reviews (2024) **9** 363–374
https://doi.org/10.1530/EOR-24-0034

INSTRUCTIONAL LECTURE: KNEE

How to manage a native stiff knee

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- Knee stiffness is a widely known and worrying condition in several postoperative knees. Less is known about native stiff knee. The aim of this manuscript is to summarize the available literature on native stiff knee epidemiology, classification and treatment.
- In 1989 stiff knee was defined as a knee with less than 50° of total range of motion. If range of motion is <30°, it is defined as an ankylosed knee. Knee stiffness can be divided into three main types: flexion contractures, extension contractures, and combined contractures. Different risk factors have been associated to native stiff knee and grouped into modifiable or not modifiable. Furthermore, risk factors can be divided into patients' related no patients'-related.
- Different treatment modalities can be indicated to treat knee stiffness, including manipulation under anesthesia (MUA), arthroscopic and open surgical release. When stiffness is associated with articular disruption TKA represent an option. TKA in native stiff knee can be challenging for the surgeon. Implant's choice and knee exposure are the first steps. In some cases, additional release and extensive can be considered. A stepwise approach and careful preoperative planning are mandatory to obtain long-term satisfactory outcomes.
- Native stiff knee is a rare but invalidating condition. Different treatment modalities have been proposed as treatment. However, considering that it is frequently associated to sever arthritis, TKA can be an option in painful stiff knees. Nature of knee stiffness necessitates a customized approach to ensure successful management and achieve satisfying outcomes.

Keywords: stiff knee; total knee arthroplasty

Introduction

Knee stiffness is a widely known and worrying condition in several postoperative knees, such as total knee arthroplasty (TKA) or anterior cruciate ligament (ACL) reconstruction (1, 2, 3, 4). However, less is known about native stiff knee. The term 'arthrofibrosis' has often been interchangeably employed with the term 'stiff knee', even if they are two different conditions. Knee stiffness has been described as a knee range of motion (ROM) of less than 50° (5). Conversely, arthrofibrosis is an excessive accumulation of scar tissue or fibrosis in at least one knee compartment (6, 7, 8), and it can be related to different patient's predisposing factors (9). Arthrofibrosis is a particular condition related to stiff knees, with structural disruption of the joint's fibrous connective tissue, originating from inflammation triggered by trauma, surgery or infection. Extracellular matrix proliferation, coupled with the development of adhesions, results in joint's tissue retraction, with consequent pain and restricted knee motion (10, 11). It can be associated to high-energy and multi-ligamentous trauma, as well as to ligament reconstruction. Among literature arthrofibrosis can reach 4% in patient

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who underwent to ACL reconstruction (12), and it can increase up to 23% in patients who underwent reconstruction of two or more ligaments (13). However, different conditions have been historically linked with articular stiffness and arthrofibrosis such as trauma, infective arthritis, cerebral palsy and hemophilia. The aim of this manuscript is to summarize the available literature on native stiff knee epidemiology, classification and treatment.

Definition and epidemiology

The correct definition of 'stiff knee' is still debated. In 1989 it was defined as a knee with less than 50° of total range of motion (14). However, some authors described it as a limitation of flexion between 75 and 90°, while other consider it as a flexion contracture of more than 10°. If knee stiffness is particularly severe, with range of motion <30°, it is defined as an ankylosed knee (15, 16).

Pujol *et al.* divided knee stiffness into three main types: flexion contractures, extension contractures, and combined contractures (3). Each category is associated with various characteristics contributing to its occurrence, and distinct treatment options are outlined for addressing these specific types of contractures.

Flexion contracture

Flexion contracture has been classified as mild (<5°), moderate (15–30°) and severe (>30°) by Bellemans *et al.* (17). Different authors confirmed that 125° of flexion is adequate to complete daily life activities, allowing also for squatting activities. Furthermore, flexion less than 90° affects daily quality of life, and even sitting or climbing stairs can be difficult (18). Frequently flexion contracture can be due to three major anatomic conditions: posterior impingement (ostephytes, foreign bodies, tight posterior capsule), retraction of anterior structures or patella baja (19). Patella baja is usually described in conjunction with quadriceps tendon rupture, cerebral palsy and postoperatively after high tibial osteotomy or total knee arthroplasty (20, 21).

Extension contracture

Extension contracture is poorly tolerated due to its impact on daily life. Five degree of extension contracture can cause strain to the quadriceps tendon during weight bearing, increasing muscle activity and subsequent abnormal load on the patellofemoral joint. In case of limited extension, especially after ACL reconstruction, anterior impingement must be always excluded (cyclops lesions, intercondylar eminence deformity, wrong ACL positioning). However, an extension deficit can also be related to a posterior capsule tightness for a gastrocnemius contractures or brevities. Eventually, adherences located behind the patella and in the suprapatellar pouch can also led to quadriceps adhesion to the anterior cortex of the femur causing extension deficiencies (17). Patellar precut and Tarabichi maneuver (removal of suprapatellar pouch adherences) have been described in literature to overcome anterior stiffness. Furthermore, posterior compartment release and thicker cuts are widely used in posterior stiffness. Patella baja management presents some corrective measures with the aim to reestablishing the joint line. Use of distal femoral augments, tibial tubercle osteotomy with proximal displacement, lengthening of the patellar tendon and placement of the patellar implant in a proximal position can be considered (20, 22).

Combined contracture

A coexisting condition of flexion and extension contracture can also be present. If the range of motion is less than 30° it can be considered as a ankylosed knee, which is usually painless (16, 23). Conditions such tibial plateau fractures and arthrofibrosis can usually lead to a combined contracture affecting the range of motion in flexion and extension either (24, 25).

Risk factors

Different risk factors have been associated to native stiff knee and grouped into modifiable or not modifiable (26). Furthermore, risk factors can be divided into patient related and not patient related (Table 1). A brief description of the most important risk factors is listed in the table.

Hemophilia (patient related not modifiable)

Continuous joint bleeding in hemophilic patients can cause chronic synovitis and consequent hemophilic arthropathy, which is typically characterized by massive

Table 1 Risk factors for native stiff knee.

	Risk factors
Patient related	
Modifiable	>BMI
	Depression
Not modifiable	Female sex
	Cerebral palsy
	Hemophilia
	Diabetes mellitus
	Cerebral palsy
Not patient related	Fractures
	Infections
	Previous surgeries
	ACL reconstructions

ACL, anterior cruciate ligament; BMI, body mass index.

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osteophytes and stiffness (27) (Fig. 1). Post *et al.* described three stages for hemophilic arthropathy development: stage 1 consists of bleeding (acute phase); stage 2 is related to a massive inflammatory response (subacute phase); stage 3 is characterized by the presence of massive degeneration with osteophytes and stiffness (chronic phase) (28). In presence of multiple episodes of hemarthrosis and the consequent development of hemophilic arthropathy, knee flexion contracture (KFC) is not rare in these patients, with 50% of severe hemophiliacs patients suffering for a KFC (29, 30).

Infections (not patient related)

Septic arthritis is a relatively common condition with a reported annual incidence of 9.2 cases per 100.000 population, highly linked with possible life-threatening consequences (31, 32). Classification of septic arthritis was described by Gacther *et al.* (33), divided it in four stages according to arthroscopic and radiological finding. In their cohort the efficacy of arthroscopic irrigation plus systemic antibiotic therapy decreased with increasing severity of the initial stage of infection: 96% in stage I, 95% in stage II and 67% in stage III, insufficient results have been showed in stage IV (34). Mortality rates linked with septic arthritis reported among literature are around 10–15% (35, 36, 37), while patient reported poor outcome rates reported are 20–30% (37, 38). Conversion rates to arthroplasty 1 year after septic arthritis have been reported around 1.33% (39). Pre-existing condition such as rheumatoid arthritis, oral corticosteroid consumption, diabetes and recent trauma can be considered as potential risk factors for septic arthritis development (37). During septic arthritis host reactivity causes a massive macrophage-induced inflammation which leads to cartilage and bone erosion (40). Usually stiffness after septic arthritis affects flexion more than extension due to a progressive arthrofibrosis of the suprapatellar pouch and tightness of the posterior capsule (24).

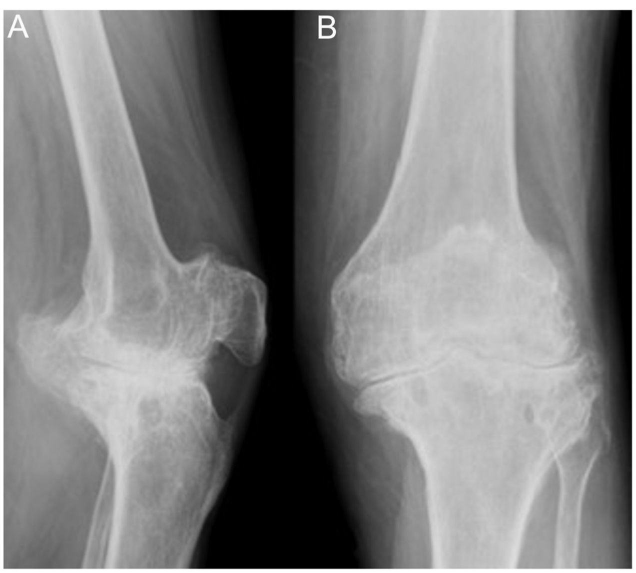

Figure 1

Preoperative X-ray of a 55-year-old hemophilic male patient (A, lateral view; B, anteroposterior view).

Fractures (not patient related)

Tibial plateau fractures constitute 1% of all fractures (41), and surgical treatment with reduction and fixation is often required. Even with good reduction, the incidence of posttraumatic osteoarthritis has been reported in ranges between 24% and 60%, with possible development of knee stiffness (42, 43).

Particularly, Gaston *et al.* in a study on 63 patients concluded that 20% of patients presented with a residual knee flexion contracture of >5° at 12 month after surgery (25). Posttraumatic stiffness can be due by intra-articular (inflammation, adhesions, intra-capsular scarring, and bone irregularities after malunion causing impingement) and extra-articular factors (extensor apparatus lesions and fibrosis, and scarring of skin and periarticular soft tissue) (44, 45). Furthermore, prolonged immobilization related to both conservative or surgical treatment, is strictly related to the development of knee stiffness (46). Usually, the sequelae of fractures affect flexion and extension. A trauma causing articular fracture led to arthrofibrosis development with a concomitant quadriceps and hamstring insufficiency with a consequent risk of residual stiffness 1 year after a tibial plateau fracture of 20% (24, 25).

ACL reconstruction (not patient related)

Advanced surgical technique and accelerated rehabilitation protocols have markedly decreased the postoperative stiffness rate after ACL reconstruction from 35% to 4% (47, 48, 49).

The main preoperative risk factors for knee stiffness following ACL reconstruction are preoperative swelling and an limited range of motion (ROM) (8).

However, Magit *et al.* (18) described different factors which can lead to knee stiffness after ACL reconstruction technique. Lateral placement of tibial tunnel has showed to determine impingement with condyle and extension restriction, while anteromedial tunnel can cause flexion lack. Increased graft tension has been also proposed as a cause of excess constrain of knee joint (50). Timing of surgery still presents controversial results, with several studies reporting worst or similar range of motion for acute reconstruction compared to a delayed one (after 3 weeks) (47, 51, 52). One of the cause of extension deficit after ACL reconstruction is the so-called cyclops syndrome (53). Described by Jackson and Schaefer in 1990 as a nodule of fibrous tissue on the anterior

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aspect of the ACL graft, the cyclops lesion causes a loss of terminal extension accompanied by symptoms such as pain and stiffness (53). Eventually, ACL reconstruction can lead to extension loss due to misplacement of tibial tunnel, or it can lead to both extension and flexion loss due to arthrofibrosis development. Paulos *et al.* described the 'Infrapatellar contracture syndrome as complication' after ACL reconstruction, which is a combined reduction of more than 10° in extension and 25° in flexion associated with reduced patellar mobility (54).

Diagnosis

A recent international consensus about knee stiffness has been developed and an investigation algorithm has been described (55). Diagnosis should begin with a careful knee clinical examination. Active and passive knee ROM should be evaluated, and knee stiffness should be classified into flexion, extension, or combined restriction. Patellar mobility, quadriceps strength, extensor apparatus, knee deformities and joint stability should be evaluated in each case. Standard X-rays should be performed routinely to evaluate osteophytes, patellar height and other possible reasons for stiffness. There is no evidence for the routine use of MRI, but it can be useful in case of stiffness after ACL reconstruction for scar tissue evaluation (55).

Treatment modalities

Different treatment modalities can be indicated to treat knee stiffness, including manipulation under anesthesia (MUA), arthroscopic and open surgical release (3, 56).

Manipulation under anesthesia

Manipulation under anesthesia (MUA) has been widely used in the past years to treat native stiff knees. Patient is positioned supine under appropriately anesthesia; hip is than flexed to 90°. A progressive load is applied to the proximal tibia to force knee in flexion, audible scar tissue disruption can occur, at the end the passive range of motion is evaluated and compared to the previous one (57). However, recently it has been less performed due to some problems, such as risk for fractures and tendon rupture. A recent study has been published (58) reporting satisfying results for knee stiffness management in hemophiliacs patients treated with MUA. A mean deformity correction of 22° was achieved with single MUA, but the authors suggested that the treatment can be repeated up to three time until less than 10° flexion contracture is achieved. Complications are associated with MUA such as supracondylar femur fractures and not sufficient improve in ROM gain have been reported (49, 59).

Arthroscopic release

Arthroscopic release involves scar tissue debridement in the suprapatellar pouch, in intercondylar fossa and in medial and lateral gutters. Additional accessory portals can be performed in case of severe flexion contracture to release the posterior compartment of the knee (57). This procedure can be considered in case of MUA failure or stiffness developed and structured since at least 3 months. There are different studies on literature on the efficacy of arthroscopic releases in stiff knee, with good outcomes (60, 61, 62). Particularly, a recent study from Eggeling *et al.* (63) compared mid-term results between very early (<3 months), early (3–6 months) and late (>6 months) arthroscopic release after surgical procedures to treat postoperative knee stiffness. The final ROM after arthrolysis was significantly increased in the group of very early and early arthrolysis while postoperative flexion deficit was higher in the late group. On the other hand, arthroscopic arthrolysis can lead to good results in extension deficit because of the easy access to the suprapatellar pouch enabling the removal of foreign bodies or removing adhesions, while in flexion contracture it can be less effective (12, 64, 65).

Open surgical debridement

Open surgical arthrolysis has been widely used in the past years because it allows also to access the posterior compartment easily compared to arthroscopic releases, even if the indications for these two procedures are similar. A recent study compared open and arthroscopic release in (56), with significant higher success rate for the arthroscopic compared to the open group. The lower success rates related to an open release may be a consequence of the local tissue scare derived from an incision injury. Nowadays arthroscopic approach is the first treatment choice, but open debridement can still be considered for severe stiffness and cases where posterior capsule need to be released. This procedures allow to properly debrief each compartment and can also be useful to perform extra-articular release (57).

TKA in stiff knee

TKA is indicated in patients with advanced knee arthritis to obtain pain relief, knee stability, and correct knee deformities (66) with restoration of good range of motion whenever possible. However, an arthritic stiff knee is a challenging condition and patient should be awarded that postoperative outcomes could be worse compared to other patients, especially regarding ROM. Ritter *et al.* in a study on 4727 knees demonstrated that preoperative ROM is strictly linked with postoperative ROM. Patients with a preoperative flexion <77° showed a postoperative mean flexion of 93°. This condition appears to be even worst in valgus stiff knee (67).

TKA in stiff knee can be challenging for the surgeon. Implant's choice and knee exposure are the first

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steps. In some cases, additional release and extensive approach can be considered. A stepwise approach and careful preoperative planning are mandatory to obtain long-term satisfactory outcomes.

Implant choice

Careful preoperative planning is mandatory in TKA, especially in cases of a stiff knee. Particularly, it is important to address possible intra-operative difficulties, including the need for an increased constraint. In native stiff knee, posterior cruciate ligament is usually sacrificed, and a posterior stabilized insert can be enough to achieve good stability. However, in case of moderate to severe stiffness, if major releases must be performed to achieve good exposure and gaps, higher constraint implants (condylar constrained) can be needed due to residual instabilities. Posterior stabilized implants showed at satisfactory results in term of ROM improvement and functional score in Boettner cohort (68). No specific studies exist in varus–valgus constrained (VVC) TKA for stiff knees. However, when used in primary TKA for fixed valgus deformities reported, excellent results at long term follow-up have been reported, but with low survivorship compared to primary especially in young patients (69, 70).

Skin incision

Skin incision can be an issue in native stiff knee, especially if previous surgeries have been performed. In presence of different skin incisions, do not forget the safety criteria such as: using the most lateral incision, keep a minimum distance of 7 cm between two incision and at least 60° between the incision and scars to avoid lesions to tissue blood supply (71). Due to knee stiffness, exposure of the knee joint can be challenging with standard parapatellar approach. For these reasons, especially in those patients with preoperative ROM less than 90° and severe stiffness, some extensile approaches can be considered.

Preliminary intraoperative maneuver to improve range of motion

Quadriceps pie-crusting and Tarabichi maneuver have been described in literature to overcome anterior stiffness when approaching a stiff knee. These procedures can be performed as preliminary options to properly expose the knee avoiding the use of extensile approaches (22, 72, 73).

Quadriceps pie-crusting has been reported in only few studies (72, 73). Burge (72) described a blade-based technique reporting a 45° improvement at final follow-up. Zhang *et al.* (73) with a 18 gauge needle pie crusting reported a mean knee flexion improvement of 35° at 1 year in 16 TKA. Knee Society score (KSS) reported significant improvement at 1 year. This technique is performed with the knee at maximum flexion. First puncture is located in the distal and lateral part of the vastus intermedius tendon about 5 cm from the superior pole of the patella and a series of puncture (10-20 per level) are performed from lateral to medial and from distal to proximal (at 1 cm intervals). Same authors also described a percutaneous technique in stiff TKA providing satisfactory clinical results (74).

Tarabichi maneuver is usually performed to improve exposure during a standard subvastus approach. The underlying supra-patellar pouch is identified, and any adhering bands or fibrotic tissue are removed by hand. This provides direct access to the deep interface between the quadriceps muscle and the anterior surface of the femur, allowing the release to be carried in a stepwise fashion where the knee is flexed. The release is progressed further proximally until a ROM of over 130° is obtained. Their results showed 88% of patients achieving excellent ROM (flexion more than 125 degrees) 3-month after surgery (22).

Extensile approaches

First extensile approach described by Insall (75) is the quadricep snip, which involves an enlarged medial parapatellar approach. Typically, the tendon incision extends from the medial–distal to the lateral–proximal direction with a 45° angle. This technique does not require a restricted postoperative regimen. However, it allows for an improved knee exposure, but it is often not enough to obtain good exposure in severe stiff knees. A recent study evaluated quadriceps snip in 29 knees at 3 years of follow-up. Mean ROM improved from 20° preoperatively to 91° postoperatively. Mean KSS clinical score increased from 48 to 83 postoperatively. Extensor lag was a rare but possible complication occurring in 3 out of 29 cases (76). This procedure cannot be enough for an optimal exposure; in these cases a conversion to V-Y quadricepsplasty can be considered.

The V-Y quadricepsplasty was first described by Coonse and Adams (77) as the V-Y quadriceps turndown and subsequently modified by Insall (75). It consists of a 45° tenotomy of quadriceps tendon from the medial-proximal to lateral-distal creating an inverted V triangular flap, which includes the patella. The patella is then turned down to expose the knee. After the procedure the quadriceps is repaired with possibility to performed some lengthening of the quadriceps converting the V into a and inverted Y repair if needed (78). Postoperative protocols must be modified to permit extensor apparatus healing, using a brace locked in extension for the first six weeks. The maximum ROM allowed should be driven by the maximum passive flexion angle obtained intraoperatively. The brace is then locked in extension for ambulation (79), weight bearing is allowed only in full extension. However,

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different complications such as residual extension lag and patella baja have been shown after this extensile approach (80). Scott *et al.* reported a modified V-Y quadricepsplasty in seven ankylosed knees. The ROM improved from a mean preoperative of 26–75° postoperatively with a mean extensor lag of 8° (81). Trousdale reported a significant weakness of 42% at speed tests when compared with normal matched population of a V-Y turndown was performed (78).

Tibial tubercle osteotomy (TTO) is probably the most widely performed extensive approach. The osteotomy is typically 7–10 cm in length and 1 cm thick to avoid fragment fracture and to allow better healing. The osteotomy should be performed from medial to lateral maintaining a lateral hinge while elevating the tibial tubercle. The TTO allows for a perfect visualization, and position of the tibial tubercle can also be slightly modified at the end of the procedure to correct a patella alta or baja. Once TKA is implanted, the osteotomy is fixed with screws or cerclages. Postoperative protocol is slightly different compared to a standard TKA, with ROM limitation up to 90° of flexion for 4–6 weeks, and patients have weightbearing as tolerated with a knee brace locked in extension for 4 weeks (82). A recent systematic review reported a complication rate of 3.8–20% performing TTO during TKA (83). Other studies reported an average nonunion rate of 10% (84, 85, 86). Recently an analysis on 135 knees with a minimum follow-up of 2 years reported a complication rate of 15% with 5% of nonunion but a very low rate of extensor deficit (2%) and satisfactory subjective and objective outcomes (87).

Pro and cons of each technique are reported in Table 2.

Stepwise approach to flexion contracture

Different authors proposed a stepwise algorithmic approaches to address flexion contracture during TKA (88, 89, 90, 91). Bellemans *et al.* in 2006 (17) evaluated 2898 primary TKA with a preoperative flexion contracture of minimum 5°. Patients were grouped into mild (<5°), moderate (5–15°) and severe (>15°) flexion contracture. The first step described by the authors included standard bone resection, osteophyte removal, and eventually an additional 2 mm distal femur resection to enlarge extension space

Figure 2

Tarabichi maneuver.

if needed. The second step was performed in moderate contractures (15-30°) and it included a transverse posterior capsule release lateral and/or medial plus a subperiosteal release of the medial and/or lateral head of the gastrocnemius from the femur. The third and fourth steps were usually performed in severe flexion contracture, and they included, respectively, an increased distal femoral cut by 4 mm and a biceps tenotomy to obtain more motion in flexion. In the study the authors concluded that the first two steps were enough to obtain full extension in 100% of mild cases, 87% of moderate and 48% in severe. Adding the third step leads to a deformity correction rate of 76% in case of severe flexion contracture. There were two cases of peroneal nerve palsy, and both of them occurred in patient with a biceps femoral release. Berend *et al.* (91) also provided a stepwise approach to flexion contracture. Their study includes 52 knees with a fixed flexion contracture >20°. First, osteophyte removal and soft tissue release was performed. If it was not enough, 2 mm increased distal femoral resection was performed. If correction is not obtained PCL can be released as step 3. In step 4, an additional 2 mm distal femoral cut can be performed, while step 5 described in this technique includes additional soft tissue release such as hamstring tenotomy. Two previous articles studied the effect of distal femoral bone resection on fixed flexion deformity with controversial results. Bengs *et al.* showed a mean 9° flexion correction per 2 mm of additional distal femoral resection. Conversely, Smith described only 1.8° of correction

Table 2 Extensile approaches: pro and cons.

	Pros	Cons
Quadriceps snip	No different postoperative protocol Extensible to VY	Not optimal exposure
V-Y quadricepsplasty	Optimal exposure	Different postoperative protocol Extensor lag
Tibial tubercle osteotomy	Optimal exposure Realignment extensor mechanism	Different postoperative protocol Nonunion Knee pain in kneeling

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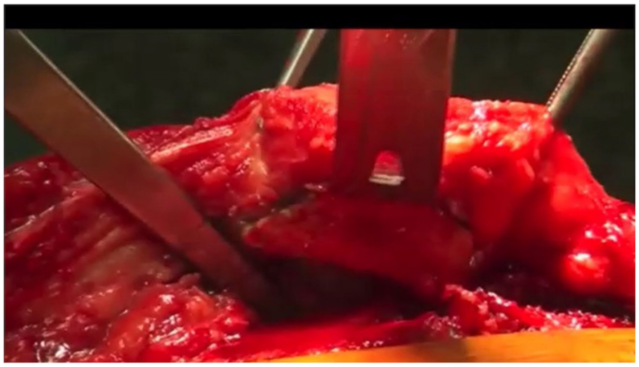

Figure 3

Patellar precut.

for each mm of distal cut if bone resection alone is used to correct fixed flexion. Furthermore, different authors suggested that increasing distal femoral bone resection up to 8 mm changes the joint line, leading to a reduction in knee function score, range of motion and increased anterior pain rates (92, 93, 94, 95).

Release of PCL has controversial evidence among literature. Some authors suggest that PCL release can cause a larger flexion space in comparison to the extension space of about 2 mm. Consequently, this exacerbates the discrepancy between the flexion and extension gaps present in cases of flexion contracture with an increased lateral flexion gap compared to the medial causing a coronal instability at 90° of flexion (96, 97).

Author's preferred technique

Skin incision is performed following the safety criteria if previous scar are presents. A medial parapatellar approach is often performed. If joint exposure is not

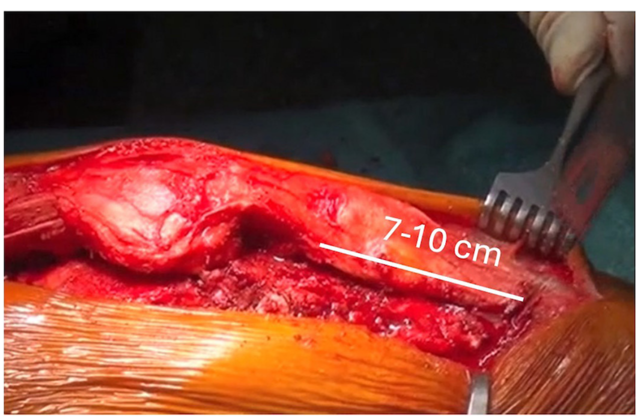

Figure 4

Tibial tubercle osteotomy.

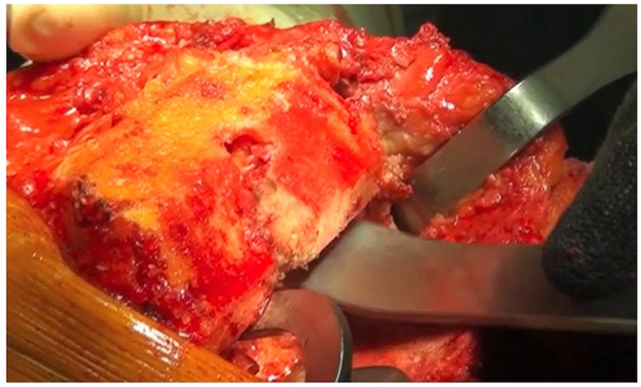

Figure 5

Posterior osteophyte removal.

possible because of extensor apparatus stiffness, anterior osteophytes removal to separate patella from femur is performed. Patellar tendon in then careful released without damaging it to dislocate the patella. To properly release the anterior compartment, suprapatellar pouch soft tissue debridement is performed as described by Tarabichi (Fig. 2). If stiffness persists and patella dislocation is not possible, a thin patellar precut is performed (Fig. 3) to gain more space, measuring patellar thickness and avoiding over-resection. If proper exposure is not obtained, the author's preferred extensile approach is tibial tubercle osteotomy. Tibial tubercle osteotomy is performed 7–10 cm in length and 1 cm in thickness from medial to lateral preserving the lateral hinge (Fig. 4).

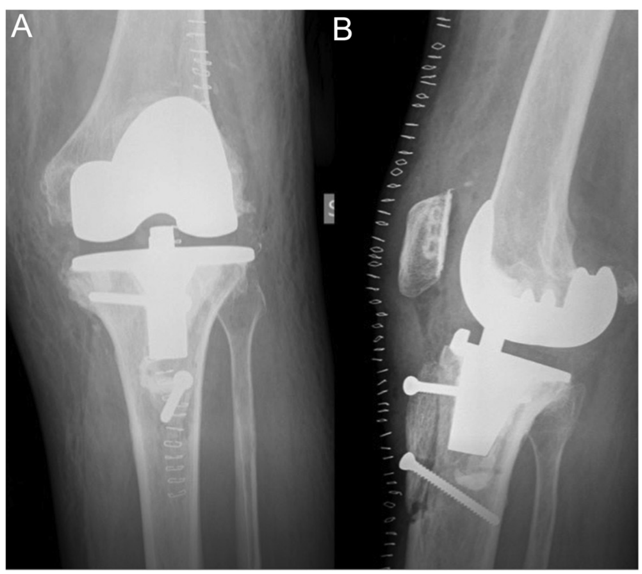

Figure 6

Postoperative X-rays with a posterior-stabilized implant and a tibial tubercle osteotomy stabilized with screws (A, antero-posterior view; B, lateral view).

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Table 3 Main results of recent literature on TKA in native stiff Knee.

Reference	Patients and FUP	Mean FUP	Results	Complications
Boettner *et al.* (68)	98 TKA with a preoperative ROM <80°	53 months	Mean ROM increased preoperatively from 67° to 114° postoperatively. Mean flexion contracture decreased from 14° to 1°. The mean KSS improved from 34 to 88 and the KSS Functional Score from 43 to 86.	Seven knees (7%) required MUA and none of the knees had flexion instability.
Purudappa *et al.* (103)	30 TKA with a preoperative ROM between 15° and 90°	2 years	Mean ROM improved from 75° preoperatively to 108° postoperatively. KSS functional from 58.5 to 93.83 postoperatively. WOMAC from 76.73 to 7.63 postoperatively	1 superficial wound infection
Debette *et al.* (104)	304 TKA with preoperative flexion <90° or a flexion contracture >20°	5 years	ROM improved of 39° in the flexion contraction group and 32° in the flexion deficit group. KSS in the flexion contraction group improved from 65 to 87 and the functional score from 51 to 77. In the flexion deficit group, the knee score improved from 33 to 86 and the functional score from 48 to 72.	Intraoperative complications rate was relatively higher in the flexion deficit group with 11 cases or 4.6%. In flexion contracture group intraoperative complication were 2. Postoperative complications were 40 in the flexion deficit group and 4 for the flexion contracture group.
Kim *et al.* (102)	86 TKA with a mean preoperative ROM of 40°	Minimum 5 years	Preoperative ROM improved to a mean 102°. The mean HSS gain from 42 to 84 postoperatively. The mean KSS arise from 11 to 90 postoperatively, while the Knee functional score get from 42 to 84 points, respectively. WOMAC scores moved from 73 to 34 postoperatively.	12 knees (14%) experienced complications: 5 skin necrosis; 3 PJI ; 2 periprosthetic fractures; 2 quadriceps tendon rupture.
Berend *et al.* (91)	52 TKA with a preoperative fixed flexion contracture >20°	3 years	The average preoperative ROM of 90° improved to 112° postoperatively. The average preoperative KSS of 32 points improved to 90 postoperatively. 94% of knees achieved less than 10° contracture	Five of the 52 knees (10%) underwent subsequent procedures: 3 MUA for unacceptable postoperative motion; 1 PJI; 1 constrain change for instability
Rajgopal *et al.* (105)	84 TKA with a preoperative native knee ROM < 20°	Minimum 4 years	Mean postoperative ROM was 75°, with a mean gain of 61°. Mean postoperative knee score was 75.2 with a gain of 14.6. The mean functional score was 84.7, with a gain of 26.8	3 skin necrosis; 2 wound infections; 3 peroneal nerve palsy; 1 Heterotopic ossifications
McAuley *et al.* (101)	27 TKA in 21 patients with a preoperative mean ROM of 30°	6 years	Mean postoperative ROM was 74° with a mean gain of 44°. 18 of the 21 patients (86%) reported improved in quality of life, function, and pain	An overall complication rate of 41% (11 of 27) was seen with a revision rate of 5 of 27 (18.5%)

FUP, follow-up; HSS, Hospital for Special Surgery knee score; KSS, Knee Society score; MUA, manipulation under anesthesia; ROM, range of motion; TKA, total knee arthroplasty; WOMAC, Western Ontario and McMaster Universities Osteoarthritis Index.

After obtaining at least 90° of flexion a stepwise approach is then performed to manage stiffness. First, all the femoral and tibial osteophytes are removed to identified bony landmarks. Mechanical alignment is usually the preferred alignment technique in stiff knees. The distal femoral and proximal tibial cut are performed according to mechanical alignment principles, and alignment and extension gap are evaluated. Femoral sizing and rotation are then decided; in this phase flexion gap is assessed using a Minus spacer. At this point, if the extension gap is thigh compared to the flexion one, a 2 mm distal femoral recut is performed. If both the flexion and extension gap are tight, a 2 mm proximal tibial cut can be performed to obtain symmetric gaps. If proper flexion and extension gaps are obtained, femoral cuts are then completed carefully to avoid notching and protecting collateral ligaments with retractors.

Using laminar spreaders, lateral or medial posterior osteophytes are removed with an osteotome (Fig. 5). After cuts are completed, flexion and extension gap are evaluated again. In moderate posterior contracture is still present, posterior capsule release, PCL release and posterior condyle subperiosteal release are performed. In case of severe posterior stiffness, posterior transverse capsule sectioning and hamstring release can be also included in release strategy. Once gaps and ROM have been accomplished a posterior stabilized implant is usually preferred. In case of unstable condition after

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release a VVC implant must be available for implant. After implantation is completed, patellar malpositioning is evaluated and TTO is fixed into the desired place, considering tracking and patella height, with two screws or metallic cerclage (Fig. 6).

Evidence about TKA in native stiff knee

There is consensus on the role of preoperative ROM on the postoperative ROM which can be achieved after a TKA in stiff knees (98, 99, 100). However, different studies reported an average of 40° of ROM improvement. McAuley *et al.* reported in 27 knees at 6 years of follow-up mean ROM improvement of 44° with 86% of patients declaring improved in quality of life, function, and pain (101). Kim *et al.* showed a mean 60° ROM improvement postoperatively, with significant KSS and WOMAC improvements (102). Boettner *et al.* retrospectively evaluated 98 stiff knees undergoing a PS TKA with a 2 mm increased flexion gap. At a mean follow-up of 53 months mean ROM improved from 119° to 123°, mean KSS functional score improved from 52 to 95 (68). Despite fair clinical and patient reported outcomes, complication rates tend to be high in stiff knees undergoing TKA. Ranges reported in literature varied from 7% (68) up to 41% (101). Also revision rate can be high, as reported by McAuley *et al.* in their case series with 18.5% revision rate (Table 3).

Conclusion

Native stiff knee is a rare but invalidating condition. To properly approach these cases it is mandatory to distinguish between stiff knee (less than 50° ROM) and ankylotic knee (less than 30° of ROM). Stiff knee can be clinically classified into three conditions: flexion contracture, extension contracture and combined. Different risk factors have been described and grouped into patient's related (such as hemophilia, diabetes, female sex, high BMI and depression) and patient's unrelated (such as infections, trauma and previous surgery). Different treatment modalities have been proposed for native stiff knee. However, considering that it is frequently associated to sever arthritis, TKA can be a valid option in painful stiff knees. TKA in stiff knee is a demanding procedure. Extensive approaches, such as quadriceps snip, VY quadricepsplasty and TTO, may be needed to obtain adequate visualization. A stepwise approach is then useful to obtain adequate tissue release avoiding knee instabilities. Improvement in ROM and clinical outcome in stiff knees are lower than standard TKA with higher complication rate.

In summary, the intricate nature of knee stiffness necessitates a customized approach to ensure successful management and achieve satisfying outcomes.

ICMJE Conflict of Interest Statement
The authors declare that there is no conflict of interest that could be perceived as prejudicing the impartiality of this instructional lecture.

Funding Statement
This instructional lecture did not receive any specific grant from any funding agency in the public, commercial or not-for-profit sector.

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