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The stiff total knee arthroplasty: causes, treatment modalities and results

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- It is clear that the stiff total knee arthroplasty (TKA) is a multifactorial entity associated with preoperative, intraoperative and postoperative factors.
- Management of the stiff TKA is best achieved by preventing its occurrence using strategies to control preoperative factors, avoid intraoperative technical errors and perform aggressive, painless postoperative physical medicine and rehabilitation; adequate pain control is paramount in non-invasive management.
- Careful attention to surgical exposure, restoring gap balance, minimizing surgical trauma to the patellar ligament/extensor mechanism, appropriate implant selection, pain control and adequate physical medicine and rehabilitation (physiotherapy, Astym therapy) all serve to reduce its incidence.
- For established stiff TKA, there are multiple treatment options available including mobilization under anaesthesia (MUA), arthroscopic arthrolysis, revision TKA, and combined procedures.

Keywords: postoperative stiffness; total knee arthroplasty; treatment

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Introduction

Total knee arthroplasty (TKA) remains the most reliable and efficacious treatment for patients with osteoarthritis resistant to conservative therapies. The stiff knee is a postoperative complication occurring in 4–16% of patients with TKA,[1–5] and represents a significant cause of morbidity due to pain and restricted function.[6] Risk-reduction strategies and appropriate management options should be identified to deliver optimal care plans for this group. Although there is no consensus in defining the stiff TKA, definitions in the literature refer to flexion limits ranging from 75–90°, flexion contracture greater than 10°, or a combination of the two.[7,8] Multiple modalities have been used to treat the stiff TKA, including manipulation under anaesthesia (MUA), arthroscopic arthrolysis and revision arthroplasty.[9–11] There is no clear management protocol for the treatment of the stiff TKA. This review has two objectives: to define the risk factors for stiff TKA and to review treatment options.

Risk factors

Risk factors for the stiff TKA can be divided into three groups (Table 1): preoperative factors (patient factors); intraoperative factors (surgical technical errors), and postoperative factors (surgical complications).[12]

Preoperative

There are many significant patient factors associated with an increased risk of stiff TKA, including younger age, female gender, higher body mass index (BMI), previous knee surgery, patients with disabilities, diabetes mellitus, pulmonary disease, and depression.[5,13,14] Unfortunately, most of these factors are not modifiable.

There is agreement that the most important risk factor is preoperative range of motion (ROM).[5,6,14,15] However, those with the greatest limitation in ROM preoperatively are found to have the greatest relative improvements.[10,16] Rubinstein and DeHaan found that ROM in patients without preoperative stiffness achieved a slightly reduced ROM of 3° to 118°, compared to an increase of 15° to 109° in those with preoperative stiffness.[10] There is a paucity of studies identifying the impact of improving preoperative ROM as a modifiable risk factor in preventing the stiff TKA.

Although it has been suggested that there are poorer functional outcomes in patients with diabetes,[13] chronic regional pain syndrome (CRPS) and other pathologies such as rheumatoid arthritis and ankylosing spondylitis,[8] Gandhi et al undertook a retrospective, matched, case-control review of 1216 primary TKAs and found no correlation between postoperative stiffness and medical comorbidities, including diabetes. They found a significant correlation between pre and postoperative decreased patellar height and a postoperative stiff TKA.[15]

Table 1. Potential risk factors of a stiff total knee arthroplasty

Preoperative factors
Preoperative stiffness (limited preoperative flexion range)
Low preoperative American Knee Society scores
Young age, female gender, high body mass index (BMI)
Previous knee surgery
Patients with disability (diabetes mellitus, pulmonary disease, depression)
Intraoperative factors
Inappropriate implant selection
Inadequate restoration of gap balance
Surgical trauma to the patella tendon
Implant malalignment
Postoperative factors
Inadequate physical medicine and rehabilitation (physiotherapy) combined with a poorly motivated patient
Inadequate pain control

The term 'arthrofibrosis' has been used as a synonym for the 'stiff knee'. However, it represents an abundance of scar tissue or fibrosis occurring either idiopathically or secondary to a patient's predisposition to it.[16–18] The implication is that arthrofibrosis is a patient risk factor, although as it is only present following surgery and may be considered a postoperative factor.

Knowing the increased risks with preoperative stiff knees enables counselling and consenting of patients prior to surgery, and prompts the surgeon to make intraoperative adjustments to account for this. Modifiable patient factors are currently limited to BMI and can be reduced preoperatively.[19] The effect of improving preoperative ROM on the incidence of stiff TKA should be investigated.

Intraoperative

Errors in surgical technique are the most frequent cause of postoperative stiff TKA.[8] It is important to restore physiological gap balance and minimize surgical trauma to the lateral retinacula ligament and extensor mechanism as this can increase stiffness. Care must be taken with implant selection as a poorly chosen implant size can restrict joint function. Being aware of these risks and taking care intraoperatively may help to reduce the incidence of stiff TKA.[15] Conversely, inadequate femoral or tibial resection, slope, removal of posterior osteophytes, or inappropriate joint line position can increase its incidence.[6]

Rotational malalignment of prosthetic components, and malalignment in the coronal or sagittal planes may also result in a stiff TKA.[7,12,20] Bédard et al found that all patients from a cohort of 34 stiff TKAs had internal rotation of the femoral or tibial components on computed tomography (CT) scan, which resolved following revision surgery and correction of rotation (confirmed on CT scan).[7] Similar results were achieved by Boldt et al when they looked at 3058 consecutive TKAs of whom 49 developed stiff knees. They found that, in stiff TKAs matched for age, gender and BMI, the femoral component alignment was significantly internally rotated to the surgical transepicondylar axis (TEA).[20] Lee et al confirmed that adequate positioning of the implant, and intraoperative flexion against gravity, are the greatest predictors of postoperative flexion. They found 97% of TKAs had a postoperative flexion within 10° of the intraoperative flexion arc, compared to 55° of the preoperative flexion arc.[21]

There are many ways to interpret the aforementioned findings; those stiff patients were found to have abnormally high internal rotation of the femoral component relative to the TEA. Nonetheless, those patients probably had a reliable 3° external rotation of their femoral component relative to the posterior cruciate ligament (PCL). This is very reproducible with measured resection instrumentation – we therefore cannot talk of malalignment. This therefore means that certain anatomies may not be adequate for a mechanical alignment technique with measured resection. In those cases where the native anatomy is excessively altered, further research is needed. Also, locating the TEA on CT scan is not reliable (intraclass correlation coefficients – ICCs – are low) and the value of those studies is therefore questionable.

A careful assessment of patients with stiff TKAs is mandatory to establish causality. This will help in the planning of correction and improvement. A CT scan can be useful to identify technical errors in surgery, and may assist in the decision to revise. Care must be taken to ensure appropriate preparation, prosthetic selection and implantation to reduce these risks. It is extremely difficult to define what a technical error is even if there were some attempts to define some guidelines.[22] There are almost no studies having assessed the correlation between TKA outcomes and the alteration of the native knee anatomy when performing mechanical alignment (MA)-TKA. All the evidence that has been generated so far about component positioning is extremely questionable.

Technological assistance for precisely implanting TKA (computer-assisted navigation system – CAS, Robotics, patient-specific instrumentation – PSI) has not been a game-changer for TKA outcomes. This means that technical errors in component positioning may not have been the main reason for poor outcomes but rather the MA technique itself.

It is important to emphasize the intrinsic technical limitation of the MA technique. Some authors have shown that 40% of knees cannot be adequately balanced by collateral ligament release when performing measured resection MA-TKA.[23] This is of prime importance as poor TKA outcome may often be the consequence of the non-physiological MA technique.

Postoperative

There are many causes of postoperative stiff TKAs, the most concerning being infection.[3] Although identifying other causes of stiffness (i.e. kinesiophobia) is important,

the consequence of a septic joint is stiffness. Aseptic loosening can have similar symptoms and may require revision.[3] According to Cai et al, the incidence of and risk factors for kinesiophobia after TKA have not been well characterized in the literature. Thus, they investigated the incidence of postoperative kinesiophobia among patients undergoing TKA and to identify the associated risk factors.[24] They found a 24.4% incidence rate of postoperative kinesiophobia was noted in patients following TKA. Older age (most notably ⩾ 76 years old), lower education levels, negative coping styles, greater pain intensity, lower self-efficacy, and less social support were associated with greater odds of developing postoperative kinesiophobia.

Idiopathic arthrofibrosis can occur in 3–4% of patients but little is known about the phenomenon. A study in 2010 looked at the histology of periarticular tissue in stiff TKAs and found it to be composed of dense fibroelastic regions. They found that arthrofibrosis can develop into heterotopic ossification (HO). They postulated that these changes may have occurred as a consequence of hypoxia-associated oxidative stress and the resulting mast cell proliferation.[1]

Other postoperative factors include patellar complications, most likely a consequence of technical error, CRPS and HO.[6] Pain control after TKA has been a key concern for orthopaedic surgeons as it can reduce function and adherence to rehabilitation. Effective analgesia can help prevent the occurrence of a stiff TKA. Lavernia et al assessed the effect of a multimodal pain management protocol on the stiff TKA. Patients who underwent primary TKA were selected and divided into two groups. Group A was managed with traditional options, using patient-controlled analgesia and as required opioids. Group B received multimodal pain management and pre-emptive analgesics. The incidence of postoperative MUA for group A and B were 4.75% and 2.24%, respectively. The authors recommend using a multimodal pain management protocol for TKA.[25]

The most important preventative postoperative factor is physiotherapy which, combined with a well-motivated and analgised patient, may serve to reduce the incidence of stiff TKA.[8,15] Adequate physiotherapy can help to reduce the risk of developing arthrofibrosis and HO.[8] Pain can inhibit physical therapy and is a risk factor promoting stiffness.[2] It is suggested that many of the patient factors (mental health, depression, diabetes, high BMI) can affect this particular facet of postoperative rehabilitation as a result of poor compliance with physiotherapy.[13]

Patients must be prepared postoperatively to improve the outcome of their TKA. They need encouragement to complete early, aggressive physical medicine and rehabilitation (physiotherapy) regimes and they should be provided with appropriate analgesia. Care must be taken when managing wounds and assessing patients.

Table 2. Treatment modalities available for the stiff total knee arthroplasty

Physical medicine and rehabilitation (physiotherapy, Astym therapy)
Mobilization under anaesthetic (MUA)
Arthroscopic or open arthrolysis
Revision arthroplasty
Combined procedure (minimally invasive pie-crusting technique combined with arthrolysis)

Treatment modalities

Multiple modalities have been used to treat the stiff TKA (Table 2), ranging from conservative physiotherapy, to simple surgical interventions, to revision surgery.[4,9–11,26–39]

Aggressive physiotherapy alone in the stiff knee has been found to increase ROM by only 5°.[9] If all methods of physiotherapeutic treatment, such as continuous passive motion (CPM),[40] have been exhausted, MUA should be indicated.[40]

Manipulation under anaesthesia (MUA)

The purpose of MUA is to release fibrous bands that occur in the knee following poor rehabilitation and arthrofibrosis. It is performed under general or regional anaesthetic to ensure muscle relaxation.[4,26–32,40–44] Force is also applied to the patella to free adhesions in the suprapatellar pouch.[8] There is strong evidence to show that MUA is the simplest and most effective intervention for established stiff TKA.[2,44] A systematic review by Ghani et al looked at all studies treating stiff TKAs within the first three months of surgery. They showed a significant mean improvement in ROM of 38°, with an average increase in flexion of 29°.[6] Generally, early MUA provides better outcomes, but the procedure remains effective when performed late.[9,42]

According to Pariente et al, MUA is indicated in TKAs with less than 90° ROM after six weeks, with no progression or regression in ROM.[43] They described a modified technique for patients with CRPS symptoms or persistent stiffness after standard manipulation. A retrospective review of 5714 TKAs was conducted to determine the efficacy of the modified technique, which includes: epidural anaesthesia intra and postoperatively, a short hospital stay with the use of CPM and daily physiotherapy. Manipulation using a standard technique was performed on 5.8% of cases and a modified technique on 1.0%. Success was reported in 74% of these, with an additional 6% improving after a repeat manipulation. Component revision was required for 14% of knees to treat persistent arthrofibrosis. Although not without complications, manipulation under epidural anaesthesia represents a viable option for treatment of persistent stiff TKA; 80% of cases achieved successful results.[43]

Ipach et al looked at the effect of MUA and how ROM outcomes were influenced by BMI, number of previous

surgical procedures, pre-MUA ROM and the timing of MUA. There was a statistically significant improvement in flexion directly after MUA, which persisted six weeks later. They found that patients with two or more surgeries prior to TKA had significantly worse results six weeks after MUA in absolute flexion and gain in flexion when compared to patients with fewer procedures. Interestingly, they did not find significant differences between early or late MUA. They noted that stiffer knees with flexion less than 70° showed significantly worse results in absolute flexion six weeks following MUA, but they had still benefitted from statistically improved flexion gains.[40] They concluded that MUA is a good instrument for improving ROM in stiff TKAs, and that, as the time between TKA and MUA seems less important, priority should be given to physiotherapy. MUA in patients with many previous operations and a flexion of less than 70° before MUA is beneficial, but not as effective as in other patients.[40]

Rubinstein and DeHaan analysed a group of patients who required manipulation after TKA to determine whether there was an association between pre-TKA and post-manipulation ROM.[10] Patients with pre-TKA stiffness (average arc of 68°) improved from a pre-manipulation total arc of 94° to 109° while patients without pre-TKA stiffness (average arc of 121°) changed from 83° to 118°. They found that in both groups, the success of TKA can still be maintained despite early motion loss and subsequent manipulation.

MUA is not without problems; a significant complication is supracondylar femur fracture, a rare but devastating complication.[44] Delaying MUA beyond six weeks increases the risk of complications including supracondylar femoral fracture,[6] possibly as a consequence of increasingly developed fibrous bands.[8] Avoidance can be achieved by careful attention to the indications, timing, and technique of manipulation. Risk factors for fracture include prolonged time from arthroplasty to manipulation, arthrofibrosis, radiographic osteopenia, and rheumatoid arthritis. Smith et al suggested an alternative manipulation technique which was found to be a safe and effective technique to manipulate the stiff primary TKA.[44]

MUA is not the solution for all causes of a stiff knee, such as in the case of an overly large femoral component or stiffness as a consequence of quadriceps adhesions. In the latter, patients are at risk of HO if the quadriceps are ruptured following MUA.[42]

According to Fitzsimmons et al, the gains in ROM after MUA and arthroscopic arthrolysis (with or without MUA) are similar.[9] Open arthrolysis seems to have inferior gains in ROM. MUA is more successful in increasing ROM when performed early but may still be effective when performed late. The numbers of clinically important complications after MUA and arthroscopy with or without MUA are similar.[9]

Pariente et al recommended MUA in TKAs with less than 90° ROM after six weeks, with no progression or regression of ROM.[43] They recommended the use of manipulation under epidural anaesthesia for patients with persistent stiffness following manipulation; 80% of these difficult cases achieved successful results.[43] According to Smith et al, MUA risk factors for supracondylar fracture should be borne in mind and include prolonged time from TKA to manipulation, radiographic osteopenia, and rheumatoid arthritis.[44] Table 3 summarizes main data of results of the most important papers reported in recent literature on MUA in the stiff TKA.[4,26–32]

Surgical debridement of adhesions and fibrous tissues (arthrolysis)

Arthrolysis can be achieved arthroscopically or by arthrotomy. Arthroscopic surgery has the benefit of reducing comorbidity and infection risks. Arthroscopic arthrolysis provides good access to the suprapatellar pouch enabling the removal of foreign bodies or removing adhesions.[33–35] It does not provide posterior access, and as such is less effective in correcting extension lag. Most articles cite the benefits of arthrolysis, but there is controversy in the literature. Some studies report that only 43% of cases respond to arthrolysis, and others less still. Furthermore, results have been poor in improving the painful stiff knee and the ideal indication was found to be the painless stiff TKA.[8]

Yercan et al found that arthroscopic arthrolysis improved ROM from 62° to 122°, compared to the open arthrolysis cohort which improved from 66° to 107°.[2] These results were corroborated by Fitzsimmons et al, who found that improvements in ROM for patients undergoing arthroscopic arthrolysis (with or without MUA) had similar gains to those treated with MUA alone.[9] Arthroscopic arthrolysis combined with MUA remained useful in stiff TKAs one year following the primary procedure. In these delayed cases, arthroscopic lysis is more effective than MUA, possibly due to improved access and ability to target the tougher offending tissue.[9]

Fitzsimmons et al found conflicting evidence for open arthrolysis, showing unimpressive ROM gains when compared to arthroscopic arthrolysis or MUA.[9] Mont et al performed exclusively open arthrolysis and intraoperative assessment of the prostheses and found that 17 of the 18 stiff knees had a mean increased range of motion of 31°, though this was in conjunction with a custom intensive postoperative rehabilitation protocol and functional bracing.[45]

With open arthrolysis, there is the added advantage of allowing the surgeon to assess the prosthesis and its orientation intraoperatively.[46] This way, there is an opportunity to exchange the liner, usually downsize it, to facilitate further flexion from mechanical obstruction.[45] The use of such tibial insert exchange technique is

Table 3. Main data and results of the most important papers reported in recent literature on MUA in the stiff TKA

Authors	Year	Results	Comments
Ipach et al[4]	2011	One thousand three hundred and forty-four elective intra-articular surgeries (no trauma cases) were performed. Fifty-two of them underwent MUA because of postoperative knee stiffness with a flexion less than 90°. The prevalence for stiffness after primary TKA was 4.54%, for revision knee procedures 5.11%, and for other forms of intra-articular surgery 1.29%. Flexion was statistically significantly improved directly after MUA in the group after primary TKA with a mean gain of 35°, in the group with revision procedures of 41° and in the group with other forms of intra-articular surgery of 24°. Patients with more than two previous operations showed significantly worse results. No statistically significant difference was seen according to time (>/< 30 days) of MUA.	MUA is a valuable technique to increase ROM after TKA in patients with stiff knees, for 'revision knees' and all other patients with reduced flexion after different forms of intra-articular knee surgical procedures (excluding trauma cases). The results were similar for early and delayed MUA relative to the last surgery. The patients can therefore undergo conservative treatment (e.g. physiotherapy) before the MUA without the risk of poorer outcome. The results after MUA in patients with many previous operations were significantly worse and so an open/arthroscopic arthrolysis should be discussed earlier for this subgroup.
Pivec et al[26]	2013	A systematic review of the literature was performed to identify studies that reported the clinical outcomes and measured ROM for patients undergoing MUA. Fourteen studies (913 patients) reported ROM results following MUA at up to 10-year follow-up. The mean premanipulation and final ROM were 66° and 99°, respectively. Compared with preoperative ROM, the gains in the ROM arc at 1-, 5-, and 10-year follow-up were 30°, 33°, and 33°, respectively. Complications were rare with only two reported periprosthetic fractures, resulting in an incidence of 0.2%.	MUA for a stiff primary TKA is an efficacious procedure to restore ROM. The risk of periprosthetic fracture is low, making MUA a safe option for improving knee ROM.
Choi et al[27]	2014	One hundred and thirty-six out of 143 patients (95 %) improved mean ROM from pre-MUA 62° to final ROM 101°. Flexion ⩾ 90° was achieved in 74% (106/143) of patients. Regional anaesthesia was identified as a predictor of successful MUA outcome.	Although the proportion of patients regaining flexion ⩾ 90° following MUA was less than those patients with simple overall ROM increase, the functional flexion ⩾ 90° was achieved in the vast majority of patients with stiff TKA following MUA.
Issa et al[28]	2014	Early manipulation within 12 weeks of performing the TKA had a higher mean flexion gain (36°), higher final ROM (119°) and higher knee society score (89 points) compared to those performed after 12 weeks which were 17°, 95° and 84 points respectively.	NA
Choi et al[29]	2015	The authors reviewed 15 patients who underwent repeated MUA after failure of initial MUA for stiff TKA. A final ROM of less than 90° was considered a failed manipulation (failure group) and a final ROM of 90° or more was considered a successful manipulation (success group). Average pre-repeated MUA ROM (72°) immediately improved to 112° in the operating room, and final ROM was 89°, an overall gain of 17°. However, despite this overall ROM increase, a successful final ROM (90° or more) was achieved in approximately half of patients (7 of 13; 54%). There were no significant differences in demographics between the success and failure groups, except that there was significantly less pre-TKA ROM in the failure group. There were no complications related to either the first or the repeated MUA procedures.	The findings of this study suggested that repeated MUA can improve overall ROM for stiff TKA. The success rate of repeated MUA was less than that of primary MUA; however, it was a useful treatment modality for stiff TKA. Decreased pre-TKA ROM appeared to be associated with poor outcomes after repeated MUA.
Mamarelis et al[30]	2015	Early manipulation within 12 weeks has a better outcome than those performed after 12 weeks.	There may still be a benefit of MUA until 26 weeks after which open arthrolysis may be needed to improve ROM.
Vanlommel et al[31]	2017	Three factors, pre-TKA flexion type of prosthesis and interval between TKA procedure and manipulation under anaesthesia, were found to have impact on flexion after TKA and MUA were identified.	Results must be expected to be inferior in patients with low flexion before TKA procedure or with a long interval (> 12 weeks) between the TKA procedure and the manipulation under anaesthesia.
Kornuijt et al[32]	2018	MUA was an effective treatment option with evidence suggesting better outcomes if performed within the first three months after TKA.	NA

Note. MUA, manipulation under anaesthesia; TKA, total knee arthroplasty; ROM, range of motion; NA, not available.

controversial. Babis et al found that, despite a 20° ROM gain, the mean final flexion was 58° and concluded that tibial insert exchange did not help in their series of seven knees.[46] This contrasts with Keeney et al who performed a limited approach for 12 cases by downsizing the tibial insert. The motion arc improved by 25° compared to the 11 patients who underwent comprehensive revision gaining a mean increase of 18°.[47]

Ghani et al, in their systematic review, found that the average improvement in ROM for arthroscopic arthrolysis was 36°, but they could not find the significance of these results as p-values were not included. Of the 195 patients in the systematic review, only seven were considered failures, and there were very few complications.[6] Open arthrolysis had similar efficacy with a mean improvement of 39°. Table 4 summarizes the main data from the most important papers reported in recent literature on arthroscopic lysis of adhesions in the stiff TKA.[33–35]

Revision arthroplasty

If other interventions fail to improve stiffness, revision surgery is the next option. It is still important to isolate the cause, otherwise revision may only provide modest improvements.[3,36–38] Keeney et al suggested that revision

Table 4. Main data of results of the most important papers reported in recent literature on arthroscopic lysis of adhesions in the stiff TKA

Author	Year	Results	Comments
Schwarzkopf et al[33]	2013	Average ROM increased from 75° preoperatively to 98° postoperatively. The authors found an association between preoperative knee score and change in ROM between pre-arthroscopic lysis and ROM at final follow-up. When the authors examined the relationship between patient BMI and change in ROM, they found that patients with a BMI higher than 30 kg/m^2 had a change of 26° compared with patients with a BMI lower than 30 kg/m^2, who had a change of only 8°. A strong association was found between patient height and change in ROM and final ROM achieved. The authors found an association between patient height, BMI, and preoperative knee score and the improvement achieved after arthroscopic lysis of adhesions following TKA.	The current study's results are comparable with those of published results. The authors recommended arthroscopic lysis of adhesions as a treatment option for stiff knees after TKA that fails after at least three months of nonoperative treatment.
Tjoumakaris et al[34]	2014	Pre- to postoperative increase in ROM was significant (average, 62° preoperatively to 98° postoperatively). Average preoperative extension deficit was 16°, which was reduced to 4° at final follow-up. This value was also found to be statistically significant. With regard to ultimate flexion attained, average preoperative flexion was 79°, which was improved to 103° at final follow-up.	Patients can reliably expect an improvement after arthroscopic lysis of adhesions for a stiff TKA using an arthroscopic approach; however, patients achieved approximately half of the improvement that was obtained at the time of surgery.
Bodendorfer et al[35]	2017	The mean time from TKA to LOA was 117 days, with a mean follow-up of 449 days. Mean improvements in ROM flexion contracture, flexion, and arc were 6°, 29°, and 35°, respectively. ROM improved for 17 of 18 patients. The WOMAC was completed by 15 of 18 patients, with a mean improvement in scores of 32%; all 15 patients with available WOMAC scores improved. Pain score improved by a mean of 2.17, with 14 of 18 patients reporting decreased pain. Improvements in flexion contracture, flexion, ROM arc, WOMAC scores, and pain were all statistically significant.	Age, weight, BMI, and time to LOA were found to be statistically significant predictors of outcome. Finally, pre-TKA and pre-LOA ROM parameters were found to be statistically significant predictors of post-LOA ROM outcomes.

Note. TKA, total knee arthroplasty; ROM, range of motion; BMI, body mass index; LOA, lysis of adhesions; WOMAC, Western Ontario and McMaster Universities Osteoarthritis Index.

surgery should be limited to patients with severely restricted motion and extensive flexion contractures. They found that in these cases the postoperative improvements are likely to be limited as a consequence of the severity of stiffness.[47]

Kim et al studied the effects of revision surgery and the postoperative risk for stiff knee. They found that a poor pre-revision ROM, and short duration between primary and revision surgery were higher risk factors for recurrent stiffness.[14] Kasmire et al found similar results, and that a high BMI is a modifiable predictor of stiffness following revision. They found that revision improved functional and clinical scores.[19] Christensen et al quantified the improvement in a consecutive series of 11 stiff TKAs undergoing revision whereby the average ROM increased from 39.7° to 83.2°.[48]

Two factors have been identified as indicators for successful revision in stiff TKA: patellar problems[2] and malpositioned components.[7] Bédard found that revision surgery for internally rotated tibial or femoral components resulted in improved flexion arcs from 61° to 98°.[7] There is a paucity of data concerning which components to revise; the general consensus seems to promote revision of the component responsible for stiffness.[20] Although the systematic review by Ghani et al did not comment on the extent of revision in each article, they found that, of all the interventions, revision TKA had the lowest mean ROM improvement,[6] but this may be a testament to the resistant nature of the stiffness, or a consequence of further scarring and fibrosis.

Multiple modalities have been used to treat the stiff TKA, including MUA, arthroscopic and open arthrolysis, liner exchange, single component revision and whole revision.[9–11] Unfortunately, there is a lack of clarity in the literature concerning modifiable risk factors and treatment of a stiff TKA.

A significant correlation between internal femoral component rotation and chronic arthrofibrosis has been reported as a risk factor following mobile-bearing arthroplasty.[7] CT scanning of patients with stiff TKAs before surgical intervention to identify the presence of internally rotated components is recommended;[20] although the stiff TKA is multifactorial, careful intraoperative attention to surgical exposure, restoring gap balance, minimizing surgical trauma to the patellar ligament/extensor mechanism, appropriate implant selection, and physical medicine and rehabilitation (physiotherapy) combined with a well-motivated patient may all serve to reduce the incidence of stiff TKA. Table 5 summarizes the main data from the most important papers reported in recent literature on revision arthroplasty in the stiff TKA.[36–38]

Combined procedures

In 2015, Chen et al reported the results of 13 patients undergoing minimally invasive pie-crusting technique of the medial collateral ligament combined with arthrolysis for the treatment of the stiff knee.[39] At 10 months mean follow-up, the mean maximum flexion augmented from 37° preoperatively to 52° after arthrolysis, and 108° after pie-crusting. At the final follow-up, mean

Table 5. Main data of results of the most important papers reported in recent literature on revision arthroplasty in the stiff TKA

Authors	Year	Results	Comments
Heesterbeek et al[36]	2016	A group of 40 patients with a preoperative ROM ⩽ 70° and a minimum of two-year follow-up after total system revision (Genesis or Legion stemmed condylar implant) was evaluated. ROM, KSS and VAS pain scores improved significantly: median ROM at two years 85° and median gain 25°. Median VAS satisfaction was 53.5 points. Seventeen patients reported at least one complication, including one re-revision. Six patients underwent manipulation under anaesthesia, and five were referred to the pain clinic.	TKA revision in patients with severe stiffness resulted in a moderate but significant improved clinical outcome after two years. Accompanying abnormalities such as component malposition, aseptic loosening or instability did not influence clinical outcome.
Donaldson et al[37]	2016	These authors presented the results of revision surgery for stiff TKA in 48 cases. The mean age at revision surgery was 65 years. At a mean follow up of 60 months there was a mean improvement in arc of movement of 45°. Mean flexion improved from 55° to 90° and the mean flexion contracture decreased from 12° to 3.5°. The mean WOMAC scores improved for pain, stiffness and function. In patients with extreme stiffness these authors described a novel technique, which we have called the 'sloppy' revision. This entailed downsizing the polyethylene insert by 4 mm and using a more constrained liner to retain stability.	Whilst revision surgery is technically demanding, improvements in ROM and outcome can be achieved, particularly when the revision is within two years of the primary surgery.
van Rensch et al[38]	2019	A group of 38 patients with a hinged-type revision TKA (Waldemar Link or RT-Plus) and preoperative ROM ⩽ 70° were selected from a prospectively collected database. There was a significant increase in ROM and KSS. VAS pain scores did not differ significantly. The median ROM at two years was 90° with a median gain of 45°. Median VAS pain was 28.5 points and median VAS satisfaction was 72 points at two years. Twelve patients suffered a complication. Recurrent stiff knee was the most frequently reported complication (five patients).	Hinged-type revision TKA following a severely stiff TKA renders a significant, although moderate, clinical improvement at two years.

Note. TKA, total knee arthroplasty; ROM, range of motion; KSS, Knee Society score; VAS, visual analogue scale; WOMAC, Western Ontario and McMaster Universities Osteoarthritis Index.

maximum flexion was 105°. According to the Judet evaluation system, 10 patients got an excellent result and three a good result. No major complications were encountered. The percutaneous technique of pie-crusting seemed to be a simple, minimally invasive and effective treatment for knee stiffness.[39]

Comparative studies

MUA versus low stretch device

In 2013 Witvrouw et al compared MUA versus use of a low stretch device in 64 patients with poor ROM after TKA.[49] The outcomes of this study demonstrated that the stretch technique had equal or better results concerning ROM and function compared to MUA. The stretch technique achieved this without requiring the patient to undergo in-hospital treatment or anaesthesia, limiting the cost and the risk of adverse events. The outcomes of this study showed that stretching is a valuable method for treating joint contractures of the knee. Therefore, the use of this stretching technique may be an excellent first choice of treatment modality in patients with slow progress of knee flexion or persistent knee stiffness after TKA, prior to MUA or arthroscopic arthrolysis of adhesions.[49]

The low load progressive stretch utilized by Witvrouw et al was applied by an orthosis.[49] The orthosis used was the computer-controlled motion technology device (computer-controlled motion technology, Antwerp, Belgium). The device consists of a made-to-measure knee brace with a foot orthosis adjustable for inversion/eversion. The brace can be adjusted between 0° and 110°. The brace is custom-designed for each patient. The total orthosis is fixed to the computer-controlled motion device. This device exists of a controller and a linear console that can be programmed with different parameters: ROM, speed, force and time. There are also many safety features to make sure that the patient is safe at all times. The computer-controlled motion technology controls the amount of resistance to stretch. This means that the maximal amount of resistance is pre-set in the computer by the practitioner. The orthosis performs repetitive stretching by moving over a pre-set ROM. However, the orthosis will only move to the limits of the pre-set ROM if this can be done with less resistance from the tissue (or the patient) than the pre-set amount of resistance. If the maximal amount of resistance by the tissue or the patient is reached, the orthosis will stop the movement in that direction and start the movement in the other direction. In this way, the applied force of the stretch is determined by the resistance of the joint. As a result, the computer-controlled motion technology minimizes the risk of overstretching and damage to the tissue. The use of cyclic stretching causes less pain during stretching, while a continuous and static form of stretching may be uncomfortable to the patient. In the study by Witvrouw et al, patients were instructed to use the computer-controlled motion machine for at least 1 hour and 20 minutes per day for six weeks. Applying the computer-controlled motion therapy four times a day for 20 minutes was advocated, with an interval of at least 1 hour between sessions. In addition to the computer-controlled

motion therapy, all patients from the computer-controlled motion group received the same physiotherapy programme as the patients in the MUA group with the same frequency and intensity (e.g. daily physiotherapy the first two weeks and twice a week the following four weeks).[49]

Hinged versus constrained condylar knee (CCK) revision arthroplasty

In 2018 Hermans et al compared a rotating hinged design (RHD) with constrained condylar knee (CCK) revision arthroplasty for the stiff TKAs of 40 patients.[50] Preoperative data were similar for RHD and CCK-type implants except for knee pain score, which was significantly worse for the RHD group. At two years of follow-up, compared to CCK, the RHD group demonstrated significantly better postoperative results for knee function scores, knee function improvement, knee pain improvement, greater maximal flexion (99.9° vs 81.4°), better maximal extension (–1.9° vs –6.2°), greater flexion gain (35.8° vs 14.2°), and greater extension gain (8.6° vs 2.0°). The findings of this study showed that that revision arthroplasty of the stiff knee using a rotating hinged device can provide excellent results in selected cases. To date, this is the first report to analyse the differences in results between revision TKA for idiopathic arthrofibrosis using a hinged or a constrained condylar knee device.

Conclusions

The stiff TKA is a common problem that should be avoided by reducing risk factors. Prevention is better than cure. Patient factors must be considered and adjusted for, surgery must be careful and precise, and rehabilitation must be swift and effective. The value of adequate analgesia to facilitate physical medicine and rehabilitation (physiotherapy) must not be overlooked. Should the stiffness still occur, it is important to identify and address the cause. CT scans are useful in determining the position of prostheses. Assuming there is no mechanical obstruction, stiffness can be improved with conservative measures in the first instance, followed by MUA at least three weeks following surgery. If there are modest improvements, or short-term gains, a second MUA, or progression to arthroscopic arthrolysis of adhesions, or open arthrolysis with liner exchange can help. Arthroscopic arthrolysis would be better suited to early stiff TKAs and knees where the cause is unlikely to be mechanical. Arthroscopy combined with MUA can be useful one year following primary surgery. Open arthrolysis is used in delayed stiff TKA treatment, or for cases where a liner exchange or detailed analysis of components is required. Finally, revision arthroplasty is reserved for resistant cases or where stiffness is due to malalignment of components. As a general rule, early MUA seems to have the best improvements in ROM, as it is known that MUA is more successful less than three months postoperatively, but should still be considered if required later.

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