The Knee 40 (2023) 8–15

Contents lists available at ScienceDirect

The Knee

journal homepage:

Novel Techniques

Supra tubercular tibial osteotomy and gradual correction with Taylor spatial frame for the management of Torsional malalignment syndrome – surgical technique and outcomes

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ARTICLE INFO

Article history:
Received 1 March 2022
Revised 28 September 2022
Accepted 3 November 2022

Keywords:
Torsional
Miserable
Malalignment syndrome
Supratubercular tibial osteotomy
Taylor Spatial Frame

ABSTRACT

Background: Surgical management of Torsional Malalignment Syndrome (TMS) traditionally consists of simultaneous correction of both femoral anteversion and external tibial torsion. We hypothesise that a single supra tubercular osteotomy followed by tibial derotation with Taylor Spatial Frame (TSF) is sufficient to provide significant improvement in both appearance and function.
Method: This is a retrospective single surgeon case series performed at a tertiary referral centre in the UK. Data collected included patient demographics, clinical findings and CT rotational profile measurements. All patients completed pre and post-operative Oxford Knee Score (OKS) and Kujala Anterior Knee Pain Scale (AKPS) functional outcome scores for analysis.
Results: There were 16 osteotomies in 11 patients with complete data sets for analysis performed between 2006 and 2017. Mean age of 16.7 ± 0.8 years. The results show significant improvements in post-operative functional assessment scores, with mean OKS increasing by 18.3 and mean AKPS increasing by 31.4. Average pre-operative thigh-foot angle (TFA) was 44.7°, this was reduced to 12.8° post-operatively, representing an average correction of 31.9°.
Conclusion: The results show that supra tubercular osteotomy, followed by gradual correction with TSF, can be used to provide a significant improvement in both appearance and function for patients suffering from TMS.

1. Introduction

Torsional malalignment syndrome (TMS) presents due to increased femoral anteversion which is accompanied by excessive external tibial torsion, in order to prevent an internally rotated gait pattern and maintain a normal foot progression angle. If existing alone, femoral anteversion may be asymptomatic up to 30°. However, when combined with external tibial torsion, this unique combination of rotational deformities leads to an increase in the Q-angle and subsequent increase in lateral force on the patellae, therefore causing significant patellofemoral joint pain [1].

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https://doi.org/10.1016/j.knee.2022.11.004
0968-0160/

In many cases of TMS, the deformity will naturally correct itself as the patient approaches skeletal maturity. However, this significant malalignment of the extensor mechanism can still cause debilitating patellofemoral joint pain. Conservative management may include rest and activity modification, alongside methods of reducing inflammation, such as cold therapy or non-steroidal anti-inflammatory medications (NSAIDs). Corticosteroid injections and topical NSAIDs may also be useful in alleviating symptoms [2]. In a small amount of cases, where there is a severe anatomical and functional impairment, the problems associated with TMS will persist, and therefore require surgical intervention [3].

TMS is a combination of multiple anatomical deformities, as previously described, and therefore the best approach for the surgical management of this condition is not clearly defined. The majority of reports within the literature reference two osteotomies in each affected limb, performed during the same operative session, with simultaneous correction of both femoral anteversion and external tibial torsion. In order to achieve the desired degree of correction, a concomitant fibular osteotomy is often required in order to mobilise the fibula and facilitate tibial derotation [3,4].

A report published by Meister et al described an alternative method of correction which involves a single tibial derotation osteotomy, performed proximal to the level of the tibial tubercle, parallel to the tibiofemoral joint line. Meister argued that tibial derotation alone could achieve adequate correction of a torsional malalignment deformity, if the goal of treatment is simply the elimination of debilitating symptoms. It is also suggested that the use of a more proximal osteotomy may contribute to a concomitant reduction in Q-angle. The results of the corresponding study supported this argument, as the procedure was able to successfully reduce both tibial torsion and Q-angle to within normal physiological values. However, Meister did concede that further correction may be required in order to treat clinically apparent out-toeing, due to the increased tendency of the quadriceps to pull the tibia into external torsion following surgery [5].

There are various methods of fixation which can be employed following acute tibial derotation osteotomy, the least invasive of which is external casting. This method eliminates the need for internal hardware, therefore reducing the risk of complications. However, numerous studies have reported loss of fixation and deformity recurrence when casting is used as a standalone method of fixation. For this reason, many surgeons prefer to use internal fixation to ensure that the correction is maintained [6].

Crossed pins are a relatively simple method of internal fixation, however these are temporary and require protection from external casting. Internal plates and nails offer an advantage in that they are concealed beneath the skin, however they risk complications with wound healing and do not allow for gradual correction which can lead to both under or over correction of the deformity [6].

External fixation has become increasingly popular in recent years, with devices such as the Ilizarov fixator providing strong fixation and allowing gradual correction of multi-planar deformities. The stability of the frame allows early weight-bearing, thus promoting an optimal environment for the formation of new bone. Furthermore, adjustment of the frame is a simple process, allowing a greater margin for error and also providing the option to easily correct any residual deformity [7].

The Taylor Spatial Frame (TSF) was introduced in 1994 by Dr J. Charles Taylor of Memphis USA, as a more advanced alternative to the Ilizarov fixator. The device is an external fixator which works in conjunction with a web-based software, using a virtual hinge to allow gradual correction of multiaxial deformities across all planes simultaneously, using only a single osteotomy [8].

The TSF is more expensive in comparison with alternative methods of fixation, and this has been referenced by several studies as a drawback to using this device. In addition to this, many studies investigating the safety and efficacy of this device describe a "steep learning-curve". Whilst these studies conclude that the TSF can be used to achieve safe and accurate correction of complex deformities, they also stipulate that practice and experience with the device are essential to reduce the number of complications and achieve the most efficient correction possible [9].

Osteotomy performed in close proximity to the knee will always carry an established risk of complication, regardless of the technique used. It has been suggested that the risk of complications may be amplified with a large correctional margin and prolonged operative time, as is often the case when these two procedures are performed during the same operation [10].

In this study we describe a technique in which a single supra tubercular osteotomy of the tibia without a fibula osteotomy is performed, followed by gradual correction with TSF. We hypothesise that this technique is sufficient to provide a significant cosmetic and functional improvement for patients suffering from TMS.

2. Surgical method

The proximal ring is centred on the leg, 2–4 cm above the origin, as determined by anteroposterior X-rays, depending on the level of the knee joint and the tibial tubercle (Figure 1a and 1b). Smooth Ilizarov wires are then inserted, under fluoroscopy guidance, proximal to the tibial plateau, just below the joint line. These wires are positioned at 45-60° angles, relative to each other, in order to achieve an equal span of fixation. The proximal ring is open at the back, allowing unhindered flexion and extension of the knee when the patient is mobile. The distal ring is mounted on the distal tibia in an externally rotated position, complementary to the externally rotated anatomical axis of the tibia. Fixation is achieved with the use of two half-pins, each 6 mm in diameter, and one smooth Ilizarov wire.

The proximal and distal rings are connected by six struts, the starting lengths of which are predetermined by the concomitant computer software. Initially, the struts are attached to the proximal ring in an anti-clockwise fashion, as seen in

Figure 1. 1a and 1b TSF in place prior to osteotomy surgery.

the transverse plane looking down towards the feet. It is important that these struts are arranged correctly in conjunction with the computer software in order to allow proper synchronisation and therefore accurate correction. Following attachment to the proximal ring, the struts are then attached to their corresponding positions on the distal ring.

Once the rings have been correctly positioned and fixed in place, the osteotomy can be performed. For this part of the procedure, the struts are temporarily removed in order to provide unobstructed access to the tibia. The surgeon begins by performing an anterior incision, starting below the joint line and continuing up to the tibial tubercle, before then retracting the patellar tendon. Following periosteal stripping of the proximal tibia, bone levers are placed around the osteotomy site in order to protect the surrounding soft tissues. The osteotomy begins at the medial proximal tibia, superior to the tibial

Figure 2. Osteotomy performed above the level of the tibial tubercle, using a surgical saw.

tubercle, continuing in the transverse plane to exit on the lateral side of the proximal tibia, just above the fibula head, with care being taken not to damage the common peroneal nerve. The initial two-thirds of the osteotomy are performed using a surgical saw, with the final third being completed using osteotomes under fluoroscopy guidance (Figure 2). It is important that the surgical saw is kept cool throughout the procedure in order to prevent thermal necrosis; this cooling is achieved with the use of normal cold saline.

In this method, fibular osteotomy is not required as the osteotomy is performed superior to the fibula head. Once the osteotomy is complete, the struts are reattached and partial distraction is performed, with the patient still on the operating table, in order to ensure that the bone is fully separated at the osteotomy site (Figure 3).

This method does not involve correction of femoral anteversion, instead we hope to demonstrate that correcting the tibial deformity alone will lead to a reduction in the abnormal force placed on the patella, thereby relieving the symptoms of patellofemoral joint pain.

Initially the frame adjustments facilitate distraction at the osteotomy site by 8–10 mm, this distraction is then followed by gradual derotation to reduce the external tibial torsion to within normal population parameters, usually 10°. The average rate of correction is roughly 1 mm per day. Patients are instructed to complete one full turn each day, according to their predetermined schedule. During the adjustment period, patients are followed up on a weekly basis and radiographic assessment is carried out in order to assess patient progress and identify any errors or complications which may have arisen. Weight bearing is encouraged in order to increase blood flow to the osteotomy site and promote bone and soft tissue healing (Figure 4). Regular flexion and extension of the knee joint is also encouraged to prevent stiffening of the joint, and therefore shorten overall recovery time.

Once correction is obtained, further adjustment is required in order to reverse the previous distraction and compress the bone at the osteotomy site. The frame remains in place for 3–4 months, with follow-up frequency reducing to a monthly basis, until there is evidence of bone healing on radiographic films.

3. Materials and methods

This is a retrospective, single surgeon case series of supra tubercular osteotomy, followed by gradual tibial derotation with TSF, for the management of TMS.

Data was collected on all consecutive patients undergoing the supra tubercular osteotomy at a dedicated tertiary referral hospital in the UK. Data collected included patient demographics, clinical rotational profile measurement, CT rotational profile measurements and functional outcome scores.

Patients were excluded from the study if there was any evidence of underlying dysplasia of the patellofemoral joint or lateral patellar subluxation on full extension.

Rotational deformity was assessed clinically using the transmalleolar axis (TMA) and thigh-foot angle (TFA). To achieve the most accurate possible measurements prior to surgery, rotational deformity was assessed radiologically using transverse sections on CT. This was achieved through the use of Reikeras and Hoiseth's method, which involved calculating the angular difference between two reference lines. The proximal reference line was drawn across the dorsal aspect of the tibial condyles, with the distal line bisecting the centres of the medial and lateral malleoli [11].

Pre-operative CT measurement of femoral anteversion was achieved using the method first described by Weiner et al. [12] Post-operative measurement was not required given that this technique does not involve correction of the femoral deformity.

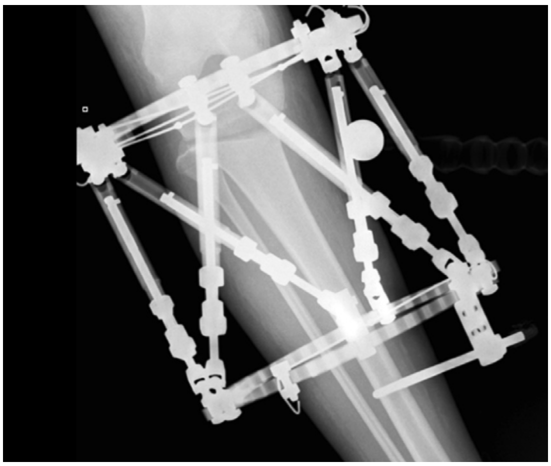

Figure 3. Immediate post-operative radiograph showing TSF placement on the affected limb.

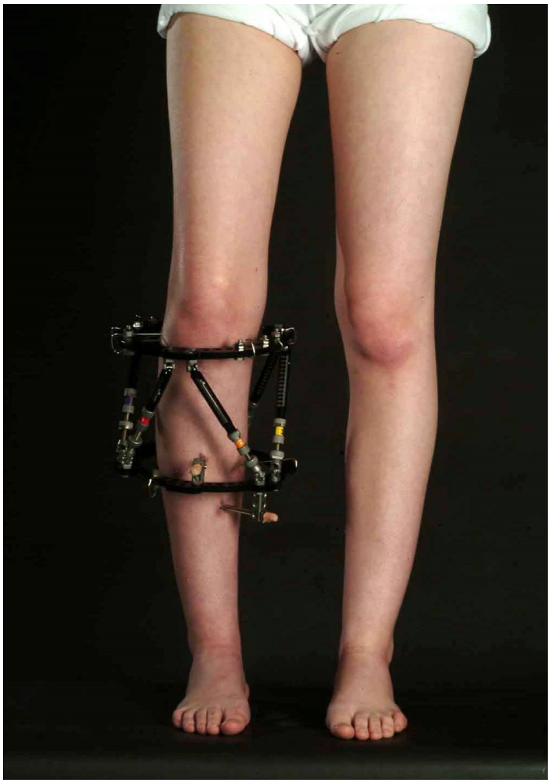

Figure 4. Clinical photograph with TSF in situ during gradual correction of deformity.

Patients were asked to complete the Oxford Knee Score (OKS) and the Kujala Anterior Knee Pain Scale (AKPS), to provide a subjective functional evaluation of their condition both pre and post operatively.

4. Results

There were 16 osteotomies performed in 11 patients included for analysis, four male and seven female, mean age at surgery was 16.8 ± 4.2 years (range 14–29).

Mean follow-up time was 24.2 months (range 20.5–34.5). On pre-operative clinical assessment, mean TFA was 44.7° ± 7.2° (range 35-60°). Mean pre-operative CT measurement of femoral anteversion was 26.1° ± 15.5° (range −9-41°), normal range for this measurement is 8-14°. Pre-operative CT measurement of external tibial torsion was 55.5° ± 6.6° (range 44-68°). Mean pre-operative OKS was 23.9 ± 6.0 (range 15–34) and mean pre-operative Kujala AKPS was 56.7 ± 3.6 (range 51–64).

In all cases, TFA was successfully reduced to within normal population parameters, −5-30°. Mean post-operative TFA was 12.8° ± 4.1° (range 10-20°), versus a mean pre-operative value of 44.7° ± 7.2° (range 35-60°). This represents an average degree of correction of 31.9° ± 9.8° (range 15-50°) (Table 1).

On post-operative functional assessment, an increase in OKS was reported for 14/16 (87.5 %) tibias, with 2/16 (12.5 %) cases reporting no change in OKS. Mean post-operative OKS was 42.1 ± 8.5 (range 20–48), versus a mean pre-operative score of 23.9 ± 6.0 (range 15–34) representing a mean improvement of 18.3 ± 11.2 (range 0–33). An increase in Kujala AKPS score was observed in 15/16 (93.8 %) cases, with 1/16 (6.2 %) cases reporting a decrease in score post-operatively, by a value of two. Mean post- operative score was 88.1 ± 14.7 (range 54–100), compared with a mean pre-operative score of 56.7 ± 3.6 (range 51–64), corresponding to a mean improvement of 31.4 ± 15.6 (range −2–49) (Table 2).

Post-operative complications were reported in 4 (25 %) cases. One patient suffered a complete injury to the common peroneal nerve (CPN), which required treatment with a nerve graft. This occurred after the CPN inadvertently came into contact with the saw blade during completion of the osteotomy at the level of the fibula head. Although this is a serious complication, we believe this can be avoided through careful retractor placement to protect the common peroneal nerve, as well completing the osteotomy with osteotomes at this site. Another patient required frame adjustment under general anaesthetic. There was one case of early patellofemoral osteoarthritis, this occurred 57 months after surgery and was thought to be as a result of the underlying chondral damage which was present prior to the osteotomy, as opposed to a complication of the procedure itself. Further surgical intervention was not required in this case. Superficial pin-tract infections were

Table 1
Table showing the baseline demographics of the patients.

Baseline demographics	Value
Age	16.8 ± 4.2
TFA	44.7° ± 7.2°
Pre-op CT Femoral anteversion	26.1° ± 15.5°
Pre-op CT external tibial torsion	55.5° ± 6.6°

Table 2
Table showing the improvements in pre and post-operative functional outcome scores.

	Pre-op	Post-op	P-value
OKS	23.9 ± 6.0	42.1 ± 8.5	< 0.05
Kujala AKPS	56.7 ± 3.6	88.1 ± 14.7	< 0.05

observed in the majority of patients, and one case of complex regional pain syndrome (CRPS) was observed. No cases of compartment syndrome were observed in this study.

5. Discussion

This study describes the surgical technique and clinical outcomes in which TMS can be effectively and accurately treated using a single supra tubercle osteotomy of the tibia with gradual correction using a TSF. The described technique eliminates the need for additional femoral and fibular osteotomies [10].

In all cases the TFA was successfully reduced to within normal population parameters. In addition to this, our results show that this procedure can be used to provide a significant improvement in functionality, with significant improvements noted in both the OKS and the Kujala AKPS. Although this method does little to correct the femoral anteversion, we have demonstrated that correction of the tibial deformity alone is enough to rebalance the distribution of forces around the knee joint, therefore reducing the abnormal force on the patella and relieving symptoms of patellofemoral joint pain. This clearly is advantageous as it reduces the potential increased morbidity and complications associated with performing osteotomies in both the femur and tibia.

External fixation with TSF allows early weight-bearing, thus increasing blood flow to the osteotomy site and creating a more favourable environment for the formation of new bone and soft tissue healing [13]. In addition to this, by working in conjunction with computer software, the frame can provide accurate and efficient correction, minimising the risk to the surrounding soft tissues [9].

Realignment in this way aims to correct the biomechanics of the knee joint as well as correcting the cosmetic deformity. Derotation of the tibia shifts the tibial tubercle in line with the patella, therefore reducing the Q-angle and improving patellar tracking within the trochlea groove. By decreasing the Q-angle, this procedure aims to equalise the distribution of forces around the patellofemoral joint, reducing the amount of lateral force on the patella and relieving symptoms of anterior knee pain [14].

Surgical management of TMS is scarcely described within the literature. Broadly speaking, published methods consist of either single or multi-level osteotomies and acute corrections in both the tibia and femur, with different surgeons opting to perform these osteotomies at varying levels throughout the limb. It is often the case that more than one osteotomy is required in order to achieve complete correction [15].

Zargarbashi et al surveyed 40 orthopaedic surgeons at Tehran University of Medical Sciences in an attempt to evaluate the various methods and approaches for the surgical management of TMS. They found 92 % of paediatric orthopaedic surgeons and 71 % of general orthopaedic surgeons surveyed voted in favour of combined femoral and tibial osteotomies. The remaining 8 % of paediatric orthopaedic surgeons opted for a single femoral osteotomy, with the remaining general orthopaedic surgeons favouring either a single tibial osteotomy or non-surgical approach [15].

A study published by Delgado et al in 1996 looked to compare the efficacy of single and multi-level osteotomies for the treatment of TMS. The study included nine patients, three girls and six boys, aged between 10 and 18 years. Of the 13 extremities included in the study; seven received combined femoral and tibial osteotomies, whilst six underwent only a singular tibial osteotomy. In eight out of 13 cases, the tibial osteotomy was performed proximally. Of these eight cases, five involved an osteotomy performed proximal to the tibial tubercle. In the remaining three cases, the osteotomies were performed distal to the tibial tubercle. There were an additional five cases in which the tibial osteotomy was performed distally [4].

All procedures were performed successfully with complete union achieved in all cases and no significant complications. All nine patients reported a significant decrease in anterior knee pain with a subsequent increase in function. In addition to this, all patients noticed a significant improvement in the appearance of the extremities. The average degree of femoral rotational correction was 25°, decreasing from 80° preoperatively to 55° postoperatively. Mean external tibial rotation, as determined by thigh-foot angle, decreased from 42° to 20° [4].

In a previously mentioned study, conducted by Meister et al, six patients suffering from TMS underwent proximal tibial derotation osteotomy to correct external tibial torsion. The aim of surgery was to reduce the external tibial torsion to a more physiological alignment of 20°. Subjective evaluation returned one excellent score, five good and one fair, whilst functional evaluation identified three excellent and four good. The average degree of correction was 19.7° and the average degree of external tibial torsion post-operatively was 19.7° [5].

Fouilleron et al published a case series analysing 36 knees, in 29 patients, between 1995 and 2006. All patients had confirmed patellar instability or patellofemoral pain syndrome. The working hypothesis was that "isolated tibial derotation osteotomies could relieve patellofemoral pain and instability even in cases of combined femorotibial rotation abnormalities" [16]. 27 patients were either 'satisfied' or 'very satisfied' at clinical follow-up. These subjective evaluations also correlated with the results of The Lille Patellofemoral Score evaluation, which showed a significant improvement from 54.8 to 85.2. Mean post-operative tibial torsion was 8.6°, reflecting a mean decrease of 25.2°. A comparison was also made between cases with a coexisting femoral anteversion of 20° or more, and those without, this showed no significant differences between both subjective and functional scores. There was a significant improvement in patellofemoral pain, with 95 % of patients reporting moderate to severe pain pre-operatively whilst post-operatively 78 % of patients had slight or no pain [16].

The methods described in these studies differ from ours slightly in that the osteotomies were performed at varying levels throughout the tibia, whilst all osteotomies described in our study were performed at the same level, above the tibial tubercle. In addition to this, these studies reference a series of acute corrections with internal fixation, as opposed to the gradual correction referenced within our methodology. However, the findings of this studies somewhat support our research and reinforce the suggestion that effective management of TMS can be achieved through a single tibial osteotomy [4–5,16]. There is also a difference in the choice of fixation used with few studies describing the use of the TSF.

Performing the osteotomy above the level of the tibial tubercle may carry a greater risk of complication, due to being in closer proximity to the knee. Complications were reported in 4 (25 %) cases in our study, a similar rate to that which is seen most commonly in the literature. Willey et al reported 37.1 % complication rate [9]. A retrospective case analysis conducted by Krengel and Staheli reported complications 25 % complication rate of proximal tibial osteotomy patients. They had 2 common peroneal nerve palsies and 2 compartment syndromes [17]. Walton et al performed 43 proximal tibial derotation osteotomies in 24 patients for the correction of internal tibial torsion, with an observed complication rate of 9 %. He reported one common peroneal nerve palsy [18]. Fouilleron et al reported on one common peroneal nerve palsy [15]. Whilst the complication rate noted in our study is comparable with other studies within the literature, we must concede that 25 % is not insignificant. However, given that our study describes a novel surgical technique with a complex method of fixation, we believe that this complication rate can be reduced through further practice and experience using this surgical technique alongside the TSF.

This study does have limitations, the retrospective nature of the study means there could be gaps in our data, however due to the prospective database kept by the senior author we believe our dataset to be complete. Mean follow-up time for patients in our study was 24.2 months. In order to properly assess the safety and efficacy of our method, it would be valuable to obtain a more long-term assessment of patient satisfaction to evaluate whether or not this improvement in functional scores was maintained. Any patients experiencing a relapse in symptoms due to significant femoral anteversion may ultimately require an additional procedure to correct this co-existing deformity. In addition to this, a validated scoring system, such as the SF-36 or EQ-5D, could also be utilised to investigate the wider impact that this surgery may have had on individual patients' quality of life [19].

6. Conclusion

The results of our study do suggest that a single supratubercular osteotomy, followed by gradual correction with TSF, can be used as an effective method of reducing the degree of clinically assessed external tibial torsion, whilst also providing a marked improvement in symptoms of anterior knee pain.

Ethical considerations

This is a retrospective case analysis. All data collected formed part of routine diagnosis and management of this condition.

The programme was set up as a treatment programme, not a study or research project.

The study looks at outcomes for patients undergoing a treatment intervention, and this was done internally as part of an evaluation to try to improve quality of care.

Therefore, we did not need to seek ethical approval for this project.

Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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