Supramalleolar derotation osteotomy of the tibia, with T plate fixation

TECHNIQUE AND RESULTS IN PATIENTS WITH NEUROMUSCULAR DISEASE

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Torsional deformities of the tibia are common in children, but in the majority both the torsion and the associated disturbance of gait resolve without intervention. There are, however, a significant number of children and adults with neuromuscular disease who present with pathological tibial torsion, which may require surgical correction.

We conducted a prospective study in two centres, to investigate the outcome of supramalleolar derotation osteotomy of the tibia, using internal fixation with the AO-ASIF T plate. A range of outcome variables was collected, prospectively, for 57 patients (91 osteotomies), including thigh foot angle, foot progression angle, post-operative complications and serial radiographs. Correction of thigh foot angle and foot progression angle was satisfactory in all patients. Three major complications were recorded; one aseptic nonunion, one fracture through the osteotomy site after removal of the plate and one distal tibial growth arrest.

We found that supramalleolar derotation osteotomy of the tibia, with AO-ASIF T plate fixation is an effective method for the correction of torsional deformities of the tibia and the associated disturbances of gait in children and adults with neuromuscular disease, with a 5.3% risk of major complications.

Torsional malalignment in the legs is common and usually self-limiting.¹⁻⁴ Medial tibial torsion is usually physiological,⁵ whereas lateral tibial torsion is much more likely to be acquired and is usually seen in patients with neuromuscular disease, such as cerebral palsy and myelomeningocele.^{6,7} The effects of abnormal tibial torsion may be cosmetic and functional. The majority of patients present with excessive in-toeing or out-toeing and may also complain of tripping, leg pain, poor endurance or brace intolerance. There are many causes of gait disturbance apart from tibial deformity especially in children with cerebral palsy and myelomeningocele.⁶⁻⁹ In patients with neuromuscular disease, torsional deformity of the tibia may cause functional impairment, sometimes referred to as 'lever arm dysfunction'.

When there is malalignment of the foot in relation to the line of gait, the ability to generate an effective extensor moment at the knee level in mid-stance is decreased.⁶ In addition, deviation of the foot may reduce the efficiency of the muscle-tendon units, especially the ankle plantar flexors decreasing their ability to impart power to the gait cycle and to control

forward progression of the tibia during second rocker. This may result in excessive dorsiflexion of the ankle during the stance phase, excessive knee and hip flexion and crouch gait.⁶ Excessive lateral tibial torsion has been associated with abnormal internal varus knee moments and an increased risk of degenerative disease in patients with myelomeningocele.^{10,11} There is no evidence that non-operative management alters the natural history of pathological tibial torsion and the only effective treatment is surgical.¹⁻⁵

Proximal tibial osteotomy has a high complication rate, including compartment syndromes and nerve palsies.¹² It should be reserved for the correction of genu varum and genu valgum. A recent report recommends the distal tibia as the ideal site for correction of torsional deformity.¹³ Other areas of controversy are the need for fibular osteotomy and the type of fixation.^{13,14} Crossed Kirschner wire fixation has been recommended.¹²⁻¹⁴ Internal fixation with straight compression plates and with a single staple have also been reported.^{9,15} We report the results of the use of the AO-ASIF T plate for internal fixation in derotation osteotomy of the distal tibia in a prospective cohort study.

Figure 1a – Drawing showing the skin incisions over the distal fibula and tibia. The distal tibia is exposed through a 4- to 5-cm incision medial to the tibialis anterior in incision 1. The distal fibula is exposed through a 2.5 cm longitudinal incision 3 to 4 cm above the distal fibular growth plate in incision 2. Figure 1b – Drawing showing the fibular osteotomy for internal rotation. The oblique osteotomy is positioned 2 to 3 cm above the physis to allow internal rotation of the ankle and foot. Figure 1c – Drawing showing the position of the T plate above the growth plate before and after de-rotation of the distal tibia, ankle and foot.

Patients and Methods

Two surgical centres were involved in the study, the Association for the Assistance of Crippled Children, São Paulo, and the Royal Children's Hospital, Melbourne. Patients with an in-toe or out-toe gait due to pathological tibial torsion, were considered for supramalleolar osteotomy. Between January 1995 and March 2000, 91 tibial derotation osteotomies were undertaken in 57 patients with neuromuscular disease. There were 30 men and boys and 27 women and girls with mean age 13.5 years (4 to 36). The mean follow-up was 44 months (24 to 80). The diagnoses were cerebral palsy in 47 patients and myelomeningocele in ten.

The clinical parameters recorded were the rotational profile of the hip, femoral anteversion, thigh-foot angle and foot progression angle. Thigh-foot angles were measured using a goniometer, with the patient prone and careful attention to detail.^{1,5,6} Foot progression angles were estimated clinically and from video recordings of gait.

The distance between the tibial osteotomy and the growth plate or ankle joint, and the displacement and angulation of the distal fragment, in both the coronal and sagittal planes, were measured and recorded from standardised radiographs. Sequential plain radiographs were obtained and reviewed for all patients in order to determine the time to union and for possible loss of position after resumption of weight-bearing. Complications were classified as major, if they required additional surgery, led to impairment of the final outcome or caused a major delay in rehabilitation. Complications were classified as minor if they resolved quickly with local treatment and did not impair the final outcome.

The data from each centre were analysed separately and later combined when no significant differences between the two sets of data were found in the principal outcome measures.

Operative technique. The operative technique was identical in both centres apart from the frequency of fibular osteotomy.

The patient lies supine on the operating table. Any significant rotational deformity of the ipsilateral femur is cor-

rected first, either at the same or previous operating session. A mid-thigh pneumatic tourniquet is used. The knee must be visible and easily flexed and extended during the operation. The distal fibula is exposed (Fig. 1a) and an oblique osteotomy performed 2 to 3 cm above the physis (Fig. 1b). The direction of the osteotomy is anterosuperior to posteroinferior when an internal rotation osteotomy of the tibia is to be performed and *vice versa* for an external rotation osteotomy.

The distal tibia is exposed through a separate vertical incision 1 cm medial to the tibialis anterior tendon (Fig. 1a) and an anterior compartment fasciotomy performed. The distal tibia is exposed sub-periosteally and the level of the distal tibial physis confirmed by intra-operative fluoroscopy. An AO-ASIF small fragment T plate is used as a template as well as for final fixation. The T plate is malleable and must be bent to match the contour of the curve of the distal tibia which varies according to the age and maturity of the patient. The transverse limb of the T plate is temporarily screwed to the tibia just above the physis with the vertical limb lateral to the mid-line when correcting external rotation (Fig. 1c) and *vice versa* for internal rotation. The level of the horizontal osteotomy is marked just below the first screw hole in the vertical limb of the T plate which is then removed. K-wires may be inserted above and below the level of the osteotomy to allow accurate measurement of the amount of rotation required. The osteotomy is performed with a broad oscillating saw and osteotome. The transverse limb of the T plate is reattached with screws, the distal fragment rotated to the correct position and then the vertical limb of the T plate is attached under compression. The final position is checked by fluoroscopy. The wound is closed after releasing the tourniquet and the leg immobilised in a well padded below-knee plaster.

Weight-bearing for transfers is permitted as soon as the post-operative swelling has resolved. Three weeks post-operatively the plaster is changed, radiographs taken, and the patient is casted for an ankle foot orthosis (AFO). A new plaster is applied and full weight-bearing encouraged.

Fig. 2a

Fig. 2b

Radiographs of a four-year-old six weeks after right internal rotation supermalleolar osteotomy of the distal tibia with the T plate fixation a) AP and b) lateral views. Note that there is good callus at the fibular osteotomy site, but the callus is sparse at the tibial osteotomy although the line of the osteotomy is now difficult to see.

Fig. 3a

Fig. 3b

Radiographs of a young adult following internal rotation osteotomy of the distal tibia a) AP and b) lateral views. The T plate is positioned 1 cm above the joint line, the osteotomy is parallel to the ankle joint and 90° to the tibial diaphysis on the AP view. Two to 3 mm of apparent medial displacement can be seen after internal rotation. The elliptical cross section of the distal tibia results from an obligatory mismatch in size between the proximal and distal fragments.

Table I. Details of the 57 patients who underwent supramalleolar derotation osteotomy of the tibia with T plate fixation

	Melbourne	São Paulo
Patients	28	29
Men	16	14
Women	12	15
Age (yrs)		
Mean	13.2	13.6
Range	4 to 36	7 to 17
Diagnosis		
Cerebral palsy	18	29
Myelomeningocele	10	
Osteotomies	48	43
Internal	42	43
External	6	

This second plaster is removed six weeks after operation, further check radiographs obtained and AFO's fitted. Callus formation may be sparse and unimpressive (Fig. 2). The patient should be carefully monitored for signs of non-union such as pain or fracture of the plate.

Results

Six tibiae had an external derotation osteotomy for medial torsion (in-toe gait) and 85 tibiae had an internal derotation osteotomy for the correction of out-toe gait (Table I). Osteotomy of the fibula was carried out in all patients treated in Melbourne and in seven treated in São Paulo.

In patients with myelomeningocele, tibial osteotomy was an isolated procedure. In children with cerebral palsy, the tibial osteotomy was in the context of multilevel surgery, with a mean of 6.6 (4 to 14) procedures per child.

There were three major complications in the 57 patients (5.3%): one aseptic nonunion, one fracture through the osteotomy site following removal of the plate and one distal tibial growth arrest. The patient with aseptic nonunion presented with pain at the osteotomy site three months post-operatively. Radiographs revealed that the plate had broken at the junction of the horizontal and vertical limbs. It was removed and after revision plating and bone grafting, the osteotomies of both tibia and fibula united without loss of position with a good clinical result. Another patient had the plate removed seven months after the operation and one week later presented with swelling and pain at the osteotomy site. Radiographs showed widening of the osteotomy line suggestive of a fracture. A weight-bearing cast was applied and the osteotomy healed four weeks later, without loss of correction. In another patient, the distal tibia was thin and difficulty was encountered in recognising the perichondrial ring and distal tibial physis. Two of the distal fixation screws were inadvertently placed across the physis. Despite immediate removal of the plate and screws, distal tibial growth arrest occurred 12 months later. Contralateral, proximal tibial epiphysodesis was undertaken two years later.

Four minor complications occurred. Two patients had minor malalignment on the post-operative anteroposterior (AP) radiograph and there were two superficial wound problems. One child had a superficial wound infection (penicillin sensitive *Staphylococcus aureus*) and one adult had delayed wound healing. Both were managed by dressings and oral antibiotics and resolved uneventfully.

Radiographic review indicated a mean distance of the tibial osteotomy above the growth plate or ankle of 22.8

Table II. Change in foot progression angles in the 57 patients who underwent 91 supramalleolar derotation osteotomies of the tibia

Pathology (osteotomy type)	Number of operations	Foot progression angle* (°)	
		Pre-operative	Post-operative
Mean medial tibial torsion, an external rotation osteotomy	6	-27 (9)	5 (7)
Range		-15 to -45	0 to +20
Mean lateral tibial torsion, an internal rotation osteotomy	85	+38 (10)	+7 (8)
Range		+30 to +55	0 to +25

*-, internal foot progression angles; +, external foot progression angles

mm (15 to 30). Most radiographs showed slight medialisation of the distal fragment, with a mean of 2.3 mm (0 to 4) (Fig. 3). Two patients had a mild angular deformity in the coronal plane, one of 4° valgus and the other of 6° valgus. Both occurred after external derotation osteotomy. These deformities were not clinically significant. There were no angular deformities in the sagittal plane. Synostosis between the tibial and fibular osteotomy sites was not observed.

After a mean derotation of 26° (15 to 45), in the external rotation osteotomy group, the thigh-foot angle was corrected from a mean of 22° internal to a mean of 7° external. After a mean derotation of 29° (20 to 45) in the internal rotation osteotomy group, the thigh-foot angle was corrected from a mean of 37° external to a mean of 8° external. The changes in foot progression angle are shown in Table II.

Significant improvements were noted in a number of parameters of gait in the patients who had gait analysis, including kinematic and kinetic parameters at the knee and ankle. These were significantly influenced by the concomitant operations and we have, therefore, not reported them as a direct result of the tibial derotation osteotomies.

Discussion

Previous studies have suggested that the optimum site for a pure rotation osteotomy of the lower limb is the supramalleolar area of the distal tibia. Proximal tibial osteotomy carries a high risk of peroneal nerve palsy and compartment syndrome and should be reserved for correction of genu varum or genu valgum. Kregel and Staheli¹² reported a major complication rate of 13% after proximal tibial osteotomy, including a peroneal nerve palsy rate of 5%. They reported no major complications after distal tibial osteotomy. Although distal tibial osteotomy is undoubtedly safer than proximal osteotomy, the complication rate remains significant, for an operation in which, for some patients, cosmesis is an important indication for surgery. McNichol et al¹⁵ reported a major complication rate of 10% and a residual deformity rate of 5% after distal tibial osteotomy. Dodgin et al¹³ reported a 4.8% complication rate in a series of 63 distal tibial osteotomies, using a technique similar to our study, apart from the fixation technique. They used percutaneous crossed K-wires, a method

reported in several previous studies.^{12-14,16} The major complication rate in our series was 5.3% and in two patients this was related to failure to select the optimum level for the osteotomy and application of the fixation device. Prior to these complications we only used fluoroscopy to check the position of the implant at the end of the operation. We now use it much earlier in the operation in order to identify the correct position for the implant and the osteotomy. If the fixation is too distal, the risk of growth arrest is increased. If it is too proximal, the biological and biomechanical benefits of a metaphyseal osteotomy may be lost.

Evidence from previous studies suggests that internal fixation is better than casting alone. This is the first study in which plate fixation has been used. The complication rate was very similar to that of Dodgin et al.¹³ The main advantages of plate fixation are that a below-knee plaster can be used and much earlier weight-bearing permitted than after K-wire fixation. This is very important for young adults, who comprised a significant proportion of our study cohort. The principal disadvantage is that it requires a second operation for removal of the plate.

We agree with Dodgin et al,¹³ that the literature is inconclusive on the need for concomitant fibular osteotomy.^{13,14} In our series fibular osteotomy was undertaken routinely in Melbourne, but only in seven patients in São Paulo, with no difference in the results. This suggests that when external tibial torsion is <30°, fibular osteotomy may not be essential. In the patients treated in Melbourne, fibular osteotomy facilitated derotation of the tibia and did not lead to any complications. We had no delayed unions of the fibular osteotomy and no cross unions between the tibial and fibular osteotomies.

In children with myelomeningocele, pathological tibial torsion is usually medial in the younger child (Fig. 4) and lateral in the older child. Tibial osteotomy using other techniques has been associated with very high complication rates including infection, nonunion and loss of correction.^{7,8} We had one minor complication, a superficial infection with *Staph. aureus*, but no major complications in 16 osteotomies in ten children with myelomeningocele.

The two patients who had a superficial infection and a delay in wound healing both had very large corrections (40° and 45°) and marked swelling after surgery. The safe upper limit for a rotational osteotomy in the distal tibia is proba-

Fig. 4a

Fig. 4b

Photographs of the patients whose radiographs are shown in Figure 2 with L5 myelomeningocele and bilateral asymmetrical medial tibial torsion a) before and b) after bilateral supramalleolar osteotomies with T plate fixation. The thigh foot angles were corrected only to neutral because these patients tend to develop progressive lateral tibial torsion during growth.

Fig. 5a

Fig. 5b

Photographs of an eight-year-old boy with asymmetric spastic diplegia and severe right external tibia torsion a) pre-operatively the foot progression angle was 45° external b) post-operatively the angle was corrected to 15° external.

bly about 40°. For more severe deformities and greater rotational corrections, slow correction with a circular frame may be a better option.¹⁷

The principal indication for rotational osteotomy of the tibia in this and previous studies was excessive lateral tibial torsion in patients with cerebral palsy^{6,9} (Fig. 5). The cause of lateral torsion of the tibia in cerebral palsy is probably the abnormal biomechanical environment during growth. The age at which excessive torsion is recognised and at which surgery is recommended suggests that the torsion is

acquired gradually.¹⁸ Excessive laterally directed torsional moments, transmitted from toe drag to the distal tibia, because of poor foot clearance, may be contributory.

Early rehabilitation is required and prolonged periods of immobilisation in a cast and/or an inability to weight-bear are undesirable. The concept of internal fixation of the distal tibial osteotomy is attractive if it provides precise control and early mobilisation. The malleable T plate does not in itself afford rigid internal fixation. It controls rotation. The broad horizontal osteotomy and the intact soft-

tissue envelope provide stability. Weight-bearing may commence before bony union in contrast to when percutaneous K-wires or casting alone are used.

No loss of position was seen in our series, a problem encountered in some other series not using a secure fixation system.⁸

The age range of patients in our series was much wider than in previous reports. In particular, eight osteotomies were undertaken in skeletally mature patients aged between 18 and 36 years. All united without complications.

Derotation osteotomy of the tibia and fibula in the supramalleolar area, combined with T plate fixation, is an effective procedure for the correction of torsional abnormalities of the tibia associated with an in-toe or out-toe gait. It allows early mobilisation and a high rate of union, with an acceptable complication rate in patients with neuromuscular disease, including adolescents and young adults.

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