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Late-Onset Blount's Disease

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DECLARATION

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PART A

PROTOCOL

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RESEARCH PROPOSAL

LATE-ONSET BLOUNT'S DISEASE

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Introduction

In 1937 WP Blount published a review of tibia vara or osteochondrosis deformans of the proximal tibia¹. Late-onset Blount's disease is varus deformity of the proximal tibia that occurs at or after 6 years old (excluding late-presenting infantile Blount's) and has an associated femoral varus².

Recent recommendations for comprehensive treatment advocate simultaneous tibial and femoral osteotomies (Gordon, Schoenecker 2005)³. We have treated late-onset Blounts with a high tibial osteotomy only.

Materials

We propose to obtain from records at Groote Schuur and Maitland Cottage hospitals the notes and X-rays of all patients treated surgically for late-onset Blount's disease from 1990-2005. A proforma has been designed (see attached) to allow relevant data collection.

By retrospective review of the notes (pre, intra and post operative) and Xrays (mechanical axis antero-posterior and tibial lateral pre-op, post-op at removal of plaster and at final follow-up) we plan to analyse our results using the high tibial osteotomy alone. Surgery involved a barrel vault osteotomy (below the apophysis) correcting the mechanical axis to 5 degrees valgus, rotation and anterior bow.

Methods

Using the proforma data will be collected from the notes and Xrays of the patients. From the notes age at onset and surgery, sex, race, weight (including whether obese or not as defined by the percentile for sex and age) and findings at examination pre and post op will be recorded. All Xrays will be measured using standard techniques described by Paley and Tetsworth. On the AP radiograph mechanical axis (MA), lateral distal femoral angle (LDFA), medial proximal tibial angle (MPTA) and lateral distal tibial angle (LDTA) will be assessed. On the lateral radiograph posterior slope of the tibial plateau will quantify anterior bowing. Known disadvantages of tibial osteotomy alone including dog-leg deformity and joint line obliquity will also be recorded. Results will be assessed as a good result ($0-5^{\circ}$ valgus MA and posterior tibial slope $<20^{\circ}$) or poor result ($>5^{\circ}$ valgus MA or posterior slope $>20^{\circ}$).

References

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PART B

LITERATURE
REVIEW

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Late-onset Blount's disease - Literature review.

Objectives

Tibia vara in childhood was originally described in the medical literature in the 1920's, and later called Blount's disease after a landmark article on the disorder published by W.P. Blount in 1937. The definitions of various forms of the disorder as well as treatment strategies have been evolving since then. The principle modality of treatment however remains a corrective osteotomy of the proximal tibia although techniques of osteotomy and the fixation thereof have varied.

More recent literature has favoured the use of more complex external fixation methods and multiple corrective osteotomies for various aspects of the deformities. In our institution we have 15 years of experience with a relatively cheap and simple treatment method involving a single high tibial osteotomy fixed with Steinmann pins and plaster of paris. In the study presented later in this dissertation we have analysed our results and found them to be comparable to those in international series.

The objective of this literature review is to clarify the definition and classification, epidemiology, etiology, patho-anatomy, clinical and radiographic features and assessment, treatment methods and outcomes of treatment of late-onset Blount's disease. Each of the various techniques of osteotomy described and the methods of fixation will be reviewed and critically analysed. The literature review will also provide insight into the rationale behind our current treatment method as well as into the nature of and reasons for complications encountered.

Literature search strategy

Pubmed and Google Scholar internet databases were used to search for relevant publications on late-onset Blount's disease, including the terms adolescent and juvenile Blount's disease as well as tibia vara. Review articles found on the subject were all analysed and the references for those articles researched. The chapter on the lower extremity by PL. Schoenecker and M. Rich in *Lovell & Winter's Pediatric Orthopaedics, 6th Edition* edited by Morrissy and Weinstein was also reviewed and the relevant references researched.

Articles published in peer reviewed journals with descriptions of surgical techniques or reports on the outcomes of the techniques in clinical settings were included. Also included were articles detailing laboratory studies pertaining to etiology and relevant biomechanics of the disorder.

Not all of the literature reflected a clear distinction between different forms of Blount's disease. Articles published which included the multiple forms of Blount's disease (ie. those including the form presenting in younger children - infantile Blount's) as well as articles specifically reporting treatment methods and outcomes for patients with infantile Blount's as well as late-presenting infantile Blount's were very carefully analysed and only results and other information pertaining specifically to late-onset Blount's disease was extracted. This was done because the pathological process in children with late-presenting infantile Blounts (who are the same age as those with late-onset Blount's) is of a more prolonged and severe nature which requires different and more aggressive treatment. The outcomes in the two groups are therefore not directly comparable. In this study we are specifically analyzing the late-onset group as further subclassified into juvenile late-onset and adolescent late-onset by Thompson and Carter in 1984 which will be clarified and referenced in the summary of the literature below.

Quality Criteria

All articles or chapters included for use in preparation of the summary of the literature as well as ultimately for the manuscript were assessed individually for scientific quality.

There are no Level 1, 2 or 3 clinical outcome studies measuring outcome for treatment of this condition. All of the clinical studies are either Level 4 (Case series reporting outcomes on a group of patients treated by a certain method) or Level 5 (Expert opinion).

Quality of clinical studies used will be discussed individually in the text where required but guidelines for minimum requirements included:

- At least 10 patients included
- Follow-up of at least 2 years or until skeletal maturity
- Adequate pre and post treatment clinical evaluation to allow assessment and grading of outcome
- Pre-op, post-op and follow-up xrays to include at least AP mechanical axis and lateral tibial radiographs to allow accurate assessment of radiological outcome.

Scientific articles on pathology, etiology, gait mechanics and assessment of mechanical alignment of the lower limb were also included. Quality criteria applied included assessment of scientific methodology and relevance to the disorder as applied by the peer reviewed journals in which they were published. No scientific studies extracted during the literature search were excluded on the basis on insufficient quality.

Summary of the literature – Late-onset Blount’s disease

Definition and Classification

Tibia vara localized in the proximal tibial physis and metaphysis due to growth disturbance at the proximal medial tibial physis is known as Blount’s disease in current orthopaedic practice. The condition is named after W.P. Blount who published the seminal article in the English literature in 1937¹ and referred to earlier recognition of the pathology by other authors in smaller series. He added and discussed a further 13 cases of his own.

Despite this being the first combined description of the disorder he already noted two distinct clinical presentations - the infantile form in which the changes in the proximal tibia appear “within the first two years of life” and the adolescent form in which the tibial changes occurred “just before puberty”. This adolescent form later became known as late-onset Blount’s disease.

The classification currently used to define the different subgroups of patients with Blount’s disease is that proposed by Thompson et al. in 1984². In their paper they studied 16 knees in patients with the “adolescent” form of the disease as described originally by Blount. They noted that patients who presented with the condition at or before 10 years of age had a significantly higher risk of recurrence of the deformity after osteotomy. They therefore subdivided all patients with Blount’s disease into three categories – infantile (onset before 6 years old with characteristic radiographic features, the same as the infantile form described in 1937) and late onset (onset at or after 4 years of age) which was subdivided into juvenile late-onset (onset at 4-10 years old) and adolescent late-onset (onset at or after 11 years of age).

It is critical to differentiate late-onset Blount's disease from late presenting infantile Blount's. In this advanced form of infantile Blount's the patients do indeed present after the age of 6 years but with a history of varus which has been present since infancy which is not the case in late-onset Blount's. The radiographic features of late-presenting infantile Blount's as well as the surgical treatment differ dramatically from those of the late-onset form.

Epidemiology

Late-onset Blount's disease has been shown internationally to be associated with obesity and more common in black, male patients. Bilateral involvement is also common.

Thompson et al.² had 11 of 11 patients black and all were markedly obese with a sex distribution of 2 males to one female and bilateral disease in 5 patients. Wenger et al.³ in 1984 reported a series of 7 adolescent patients of whom all were obese males, 6 were black and 1 white, 2 patients had bilateral disease. Loder et al.⁴ in a study of 15 children had 11 males, 13 black patients and 14 patients were obese. Eight patients had bilateral disease. Kline et al.⁵ had 6 late-onset patients in their study of 14 patients with Blount's disease. Of the 6 there were 5 black patients 4 of whom were morbidly obese and the fifth mildly obese. All 6 were male and 4 had bilateral involvement. Henderson et al.⁶ studied 15 patients all of whom were obese black boys, 6 with bilateral involvement. Coogan et al.⁷ in a study of 8 patients (12 knees) had 6 males and all patients were black and obese. Four had bilateral disease. Gaudinez et al.⁸ studied 11 patients of whom 9 were boys, all obese and 5 had bilateral involvement. Stanitski et al.⁹ had 17 patients, 8 of whom had bilateral disease, all obese and race was not reported. Gordon et al.¹⁰ reported 15 patients with adolescent Blount's. Thirteen were obese and 7 had bilateral disease. Four were so obese that they had sleep apnoea requiring the night-time use of continuous positive airway pressure. Sabharwal et al.¹¹ conducted a Level 2 prognostic study in 2007 to correlate body mass index and radiographic deformity in children with Blount's

disease. In the late-onset group 26 of 28 were obese. Greater malalignment was not seen with increasing body mass index in this group overall but was found to correlate in extremely obese children (body mass index >40).

Late-onset Blount's has also been associated with SUFE (Slipped Upper Femoral Epiphysis)^{12,13,14} and the histopathology of the two conditions is similar as confirmed by Carter et al. in 1988¹² and again in 1990¹³. It has also been associated with idiopathic peroneal spastic flat feet by the same authors as well as by van Huyssteen et al. in 2001¹⁴.

In our study we found two thirds of our patients were female which contradicts these international statistics. Only two thirds of our patients were obese and 60% showed evidence of bilateral involvement (classified as contra-lateral varus malalignment or late-onset Blount's or late-presenting infantile Blount's). Our study had one patient with ipsilateral SUFE and we also had 2 of 36 patients with ipsilateral peroneal spastic flat feet.

Etiology

Increased stresses through the proximal medial tibial physis resulting in retardation or cessation of growth are postulated by many authors to be the primary etiological factor in the development of late-onset Blount's disease. As can be deduced from the epidemiology obesity is largely thought to be the cause of these increased stresses. This is potentiated by the increasingly wide thighs of these patients making it difficult for them to keep their weight-bearing axis over the foot in the stance phase of gait.

There remain however a group of patients with late-onset Blount's disease who are not obese. Sabharwal et al.¹¹ were unable to show a linear correlation between

severity of deformity and body mass index in the late-onset group although they did show it to be present in infantile Blount's.

Cook et al. in 1983¹⁵ performed biomechanical tests on the forces across the medial tibial physis in children. They found that obesity caused forces strong enough to retard growth in the physis. They also found that varus malalignment of 10 degrees or more in children over 5 years old produced "borderline" forces which could retard growth in children of normal weight. Henderson et al.¹⁶ however published a report where there was radiographic evidence proving that no mechanical varus was present in 2 patients who subsequently developed adolescent Blount's disease. Important to note is that both patients were obese.

In 1996 Davids et al.¹⁷ published a dynamic biomechanical analysis which contributed significantly to the understanding of the development of tibia vara without pre-existing varus malalignment in obese children and coined the term "fat thigh gait". In this gait pattern obese patients are unable to place their stance phase foot directly under the centre of their body weight. Varus thrust in the stance phase combined with swing limb circumduction in the simulated fat thigh gait placed the weight bearing line of the stance phase limb medial in the knee resulting in compressive forces across the medial proximal tibial physis sufficient to inhibit physal growth. Gushue et al.¹⁸ in 2003 analysed the gait of normal weight and obese children and confirmed that the overweight group demonstrated a significantly higher peak internal knee abduction moment during early stance.

With the rising incidence of childhood obesity worldwide it has been suggested that the incidence of adolescent Blount's disease is also rising¹¹.

There remains however a distinct group of patients, mainly in the juvenile group (age 4-10 at onset), who develop tibia vara yet are not overweight^{1,4,13,14,16,19}. In this group

it has been postulated that a mild degree of existing physiological varus is unmasked at the pre-adolescent growth spurt and only becomes clinically significant then.

A familial trend has been suggested by many authors^{2-4,6,10-13,19,21} although it remains sporadic and has never been proven as a risk factor for development of Blount's disease. None of our patients reported a positive family history of Blount's disease and it was also not noted in the previous study from the unit¹⁴.

The etiology of Late-Onset Blount's disease therefore, although strongly associated with childhood obesity and mild pre-existing varus malalignment, is not yet fully understood. It is thought that various factors including environmental, humoral and genetic also influence physal growth and may thus play a role¹⁹.

Patho-anatomy

Histological abnormalities in the proximal medial tibial physis and metaphysis were initially noted by Blount in his seminal paper in 1937¹. Wenger et al in 1984³ examined the histopathology of the physis in two patients who underwent correction of their deformity with osteotomies through the growth plate. They found clefts and fissures throughout the hypertrophic and degenerating zones of the physis with marked disorganization of the degenerating zone. Tongues of cartilage were noted extending into the metaphysis. There was loss of orderly cartilage columns and chondrocytes were in disorganized clusters. Metaphyseal bone showed transversely aligned trabeculae forming a transverse plate of bone at the metaphyseal junction representing an arrest line. There was no bony bar across the physis. They postulated repetitive microtrauma as a cause.

Carter et al.¹² subsequently showed marked similarities in the histopathology of the physis of infantile as well as late-onset Blount's disease as well as SUFE which had

earlier been described by Mickelson et al.²⁰ They postulated that abnormal endochondral ossification was caused by compressive and shear forces across the physis.

Proximal tibial varus as initially reported by Blount¹ is not the only deformity present in late-onset Blount's disease. The affected growth plate shows histological abnormalities throughout although these are more pronounced in the medial than the lateral physis¹³. In addition to the varus deformity the posterior part of the medial physis is worse affected producing a progressive procurvatum of the proximal tibia^{5,12,10}. There is also internal rotation of the tibia present resulting clinically in in-toeing^{2,3,7,8,9,10,13} as well as reports of limb length inequality due to suppression of growth on the affected side^{2,3,7,8,9,10,13}. Many earlier papers including Schoenecker et al.²¹, Loder et al.⁴, Henderson et al.¹⁶ and Kline et al.⁵ do not mention corrections of the associated deformities of tibial procurvatum and internal rotation.

More recently an association between late-onset Blount's disease and distal femoral varus deformity has been made. Kline et al.⁵ in 1992 reported on 6 patients with adolescent Blount's disease with between 34 and 74% of the the overall varus malalignment of the limb occurring in the distal femur. In 2005 Myers et al.²² found more distal femoral varus with adolescent Blount's than infantile Blount's or a normal database. This is postulated to be due to the increased medial forces in the knees of these patients also affecting the medial distal femoral physis. They did not find distal tibial valgus in their group of patients although this has been well documented by Gordon et al¹⁰. In a subsequent study published in 2006 Gordon et al.²³ demonstrated a significant incidence of distal femoral varus deformity in children with late-onset Blount's disease which contributed on average 30% of the total varus malalignment in these limbs.

Clinical features and assessment

The commonest presentation of late-onset Blount's disease in international literature is an obese black male patient with complaints of bowing, commonly associated with pain or instability which is often bilateral^{2-13,19-21}. In an earlier study from our unit van Huyssteen et al.¹⁴ however showed only 7 of 12 patients were male and 8 of 12 obese which is slightly different to international findings. In the current study of 36 patients there is a reversal of the male predominance and still only 75% of the patients are obese.

The complaint of pain associated with walking is also commonly reported in international literature although in van Huyssteen's earlier study¹⁴ and our recent one none of the patients reported pain. The main complaint is the bowing deformity. It is important also in the history to ascertain at what age the bowing became prominent as this may indicate a possible late-presenting infantile case particularly in the patient under 8-10 years old with marked deformity²⁴.

On clinical examination the gait should be carefully observed for a lateral or varus thrust at the knee in the stance phase on the affected limb. It is critical due to the reported incidence of bilateral involvement to carefully assess the contra-lateral limb for early deformity¹⁰. Careful attention should also be paid to leg-length discrepancy, knee flexion deformity secondary to procurvatum of the proximal tibia, and internal rotation of the tibia as measured by the thigh-foot angle^{10,14,24}.

In order to clinically differentiate late-onset from late-presenting infantile Blount's a Siffert-Katz sign²⁵ is a useful clinical test – in late-onset Blounts the whole medial epiphysis is involved to the same extent whereas in Late-presenting infantile Blount's there is posteromedial depression of the tibial epiphysis^{1,14,24,25}. This results in marked varus instability in the knee when varus stress is applied in 30 degrees of flexion, more so than in extension, as the femoral condyle falls into the postero-

medial depression in late-presenting infantile patients. This sign is negative in patients with late-onset Blount's disease.

Radiological features and assessment

WP Blount noted the radiographic features of late-onset disease in 1937¹ as different to those of the infantile form. He proposed that the changes were most likely due to repetitive trauma and argued that late rickets was not the cause.

Thompson et al.² in the 1984 publication in which they subclassified the late-onset group refined the description of the characteristic radiographic changes. These included a wedge-shaped epiphysis due to medial flattening, irregular thickness of the physis and minimal, if any, increased prominence of the proximal medial metaphysis. This is in stark contrast to the radiographic features of infantile Blount's which include significant narrowing of the medial epiphysis and later joint surface depression as well as beaking of the medial proximal tibial metaphysis as clearly described by Blount¹ and later subclassified by Langenskiold²⁶.

Radiographic assessment of the lower limb for late-onset Blount's has also evolved significantly. Initial studies report only AP knee radiographs¹. In the 1980s most authors used knee radiographs and the tibio-femoral angle to assess varus and procurvatum^{2,3,21}. Thompson in 1990¹³, Loder in 1991⁴ and Hendersen in 1992⁶ described use of the full length AP radiograph of the whole leg for assessment of the mechanical axis rather than relying on the femoro-tibial angle.

In 1992 Paley and Tetsworth^{27,28} published seminal articles on radiographic assessment of lower limb deformity. This has subsequently become the gold standard both for assessment of deformity and planning of deformity correction and is essential reading for anyone involved in the treatment of these patients. It is beyond

the scope of this manuscript to fully expand on the techniques involved but important to note that any studies on the deformities in Blounts disease require very specific radiographic assessment in line with their requirements. These include a full length standing AP of the affected limb to include hip knee and ankle with the patella facing forward, a lateral of the whole tibia and possibly a separate AP of the ankle to assess for distal tibial valgus.

These radiographs are then used to calculate femoral varus (reflected in the lateral distal femoral angle – LDFA – normal range 84-90 degrees), proximal tibial varus (reflected in the medial proximal tibial angle – MPTA – normal 84-90 degrees), tibial procurvatum (reflected in the posterior proximal tibial angle – PPTA – normal 79-84 degrees), distal tibial valgus (reflected in lateral distal tibial angle – LDTA – normal 88-92 degrees) and joint-line congruency (reflected in the joint line congruency angle – JCA – normal 0-2 degrees).

More recent studies have used these views pre-op, post-op and at final follow-up^{7-11,13,14,19,22,24,29,30}. Gordon et al.¹⁰ also highlighted how technically difficult it can be to attain these views in obese tall adolescent patients and offered advice on how to eliminate problems associated. The importance of technically correct radiographic assessment cannot be overstated.

Treatment Methods

Late-onset Blount's disease does not respond to bracing in the early stages as does infantile Blount's^{1,19,21,26} and so this non-operative treatment modality is not appropriate for Late-onset disease³¹. High tibial osteotomy first described by WP Blount¹ is the cornerstone of treatment due to the need for correction of the multiplanar deformity – varus, procurvatum and internal torsion – of the tibia. The methods of osteotomy and fixation thereof have varied tremendously as will be discussed below.

Some authors including Blount^{32,33}, Zuega³⁴, Mielka³⁵ and most recently Park³⁶ have described the use of hemi-epiphyseal stapling for the treatment of tibial varus in late-onset Blount's disease. This is indeed a viable modality but only if the deformity is isolated varus with no procurvatum or internal torsional deformity present. There must also be sufficient growth remaining to allow for correction and careful follow-up to detect and prevent potential complications such as hardware failure or rebound growth³¹. In the earlier study from our unit¹⁴ and the current study we have not had any patients who would have been adequately treated by this method and as such none have been treated with stapling only.

Assymmetric physeal distraction has also been reported as a treatment modality by Ganel et al. in 1997³⁷ but has not been used widely by others. We have no experience with this complex treatment method in our unit.

In 1937 Blount¹ described the use of a high tibial osteotomy for correction of the deformity and refers to Langenskiöld's curved osteotomy initially described in 1922 as "ingenious but not always necessary". He used plaster to hold the reduction and does not clarify whether a fibular osteotomy was done in all cases. Some of his post-op radiographs demonstrate a fibular osteotomy and not others. He does describe problems with recurrence of the deformity and difficulty maintaining the corrected position in plaster.

Schoenecker et al. in 1985²¹, Loder et al. in 1991⁴ and van Huyssteen et al. in 2001¹⁴ describe the addition of Steinmann pins to internally fix the osteotomy in the corrected position prior to the application of plaster. This technique is known as limited internal fixation³¹. This is the technique which we have used in our unit from 1990 to 2005 with good results as detailed in the manuscript and as previously reported by van Huyssteen¹⁴. This technique is relatively simple compared to plate fixation and external fixation as well as much cheaper in our environment.

Schoenecker³¹ has referenced Loder et al.⁴ as an example for his statement in his chapter that outcomes of this technique “have all too often been unsatisfactory”. We concede that in the large obese adolescent patient the maintenance of the reduction in plaster is indeed difficult but have shown in the manuscript below that good results are achievable with limited internal fixation.

Rab et al³⁸ described an oblique osteotomy for correction of infantile Blount’s disease to correct all the deformities around a single axis held with a single screw which allows adjustment by manipulation alone. This technique has not been widely used in the treatment of late-onset Blount’s disease.

Acute correction and compression plate fixation of the osteotomy was used by Martin et al.³⁹ for correction of tibia vara of multiple etiologies including 3 patients with adolescent Blount’s. They achieved good results but the small sample size is a weakness of the study. The metaphyseal osteotomy used to correct a physeal deformity results in the need for lateral translation at the osteotomy site²⁷ thus particularly in larger deformities it can be difficult to hold correction with a plate. It also requires greater soft tissue stripping and is associated with plate-specific complications thus has not been widely used as a primary treatment modality particularly for larger deformities or obese patients.

Mono-lateral external fixation using the Orthofix T-Garcke fixator has been described to hold the osteotomy post correction without plaster and simultaneously allow distraction osteogenesis to correct leg length discrepancy. Gaudinez et al.⁸ used the technique in 14 knees and achieved good results with union in an average of 9 weeks. Complications reported included 2 superficial pin tract infections and one transient common peroneal nerve palsy. Advantages listed included ease of application, immediate weight bearing and ease of hardware removal. Disadvantages included difficulty in obtaining adequate AP xrays to assess deformity correction, pin tract infections and the need for high levels of patient compliance. Stanitski et al.⁴⁰ used the technique in 16 tibias and achieve excellent alignment with reported

advantages of functional weightbearing and the use of adjacent joints during treatment. It allows for frontal plane and length adjustment although care must be taken to place the fixator in line with the mechanical axis to avoid causing further angular deformity and translation with lengthening.

The use of circular external fixation has also been reported in the treatment of late-onset Blount's disease. Coogan et al.⁷ reported on 12 tibias treated with this technique which allowed lengthening and weightbearing throughout treatment. They used gradual correction on a hinged Ilizarov type external fixator and corrected the distal tibial valgus with the same frame extended distally in cases where necessary. Advantages listed included the ability to correct deformity in any plane and adjustability allowed for fine tuning. Stanitski et al.⁹ reported 25 tibias in 17 patients treated with this technique also with good results and reported "improved outcomes over traditional methods in these difficult patients". The fixator was on for an average of 19 weeks (Range 12-36 weeks). There was only a single non union and 8 superficial pin tract infections. They also used gradual correction and cited a risk of peroneal nerve palsy with acute correction. More recently the Taylor Spatial Frame (TSF) has allowed correction with a circular fixator and Six-Axis Deformity Analysis as used by Feldman et al. in their series of 13 adolescent patients and six infantile²⁹. They used the TSF in chronic mode for gradual correction and reported 100% good results using Schoenecker's criteria²¹. Reported complications included pin tract infections and a single delayed union requiring 22 weeks in a frame. They also published a comparative study in 2006³⁰ where they compared the patients treated with gradual correction in a TSF to a group treated by acute correction and a different external fixator. They concluded that gradual correction was significantly more accurate.

It must be remembered that distal femoral varus contributes significantly to the deformity in late-onset Blount's disease as discussed under patho-anatomy. Most authors therefore feel that the femoral deformity should be corrected in the femur and not treated by overcorrection of the tibial component of the deformity as this results in an oblique joint line at the knee^{5,7-10,19,22,23,27,29-31}. There are however no

long term outcome studies to show that joint-line obliquity causes problems in later life although it is intuitive that it might. There is significant morbidity associated with femoral correction - usually by distal femoral valgus osteotomy and blade plate if hemi-epiphyseal stapling will not be sufficient due to degree of deformity or duration of growth remaining¹⁰.

Gordon et al.¹⁰ in 2005 published their guidelines for comprehensive treatment of all the deformities in late-onset Blount's disease including distal femoral varus, proximal tibial varus, procurvatum and internal torsion, distal tibial valgus and leg length. In this excellent review they used gradual correction of the proximal tibia with an Ilizarov circular fixator. The distal femur was treated with hemi-epiphysiodesis if possible or valgus osteotomy held with a blade plate if the LDFA was >95 degrees (>5 degrees varus). The distal tibial valgus was treated with gradual correction in a circular fixator or medial hemi-epiphysiodesis if sufficient growth remained and the LDTA showed >5 degrees valgus. Average fixator time was 4.5 months and all patients had superficial pin-tract sepsis. All limbs achieved union and had good results.

The literature thus in summary seems to favour the approach described by Gordon et al¹⁰ although good results have been reported with multiple methods.

We have not encountered distal tibial valgus or had a patient with a leg length discrepancy of >2cm post treatment (see manuscript). We corrected all the deformities in the study through a single high tibial barrel vault osteotomy held with Steinman pins and plaster accepting that in patients with distal femoral varus we will create an oblique joint line. This occurred in 17 of 43 knees with obliquity ranging from 5-15 degrees. As mentioned there is no evidence that this leads to accelerated osteo-arthritis in subsequent years and none of our patients have encountered problems due to joint line obliquity to our knowledge yet. The advantage of our technique is that it is far simpler, quicker and cheaper. We do not have the morbidity associated with simultaneous femoral osteotomy or stapling. Bilateral cases can be

done simultaneously and do not have to be done sequentially with each fixator on for up to 6 months. All limbs were taken out of plaster and the patients mobilized after 6 weeks although in the obese patients they were on bedrest for this time.

Outcomes of treatment

Schoenecker et al. in 1985²¹ used criteria to grade the results of treatment for Blount's disease but the paper included both the infantile and adolescent forms. These criteria have however remained the standard used by authors^{3,4,9,14} until last used by Feldman et al.²⁹ in 2003. Other authors report their results as angular outcomes but do not use criteria to grade them good, fair or poor. We used Schoenecker's criteria to grade our results. A good result is a pain free limb with no radiographic abnormalities and a mechanical axis within 5 degrees of neutral. A fair result is occasional pain with a mechanical axis as in the good group. A poor result is one with a mechanical axis more than 5 degrees of varus or valgus, pain limiting activity or joint line incongruity or osteophytes. We added a residual PPTA of less than 70 degrees as an indicator of a poor result as we feel that this is the limit of acceptable procurvatum.

Later recurrence of the varus deformity remains a problem in the treatment of late-onset Blount's and is particularly prevalent in the juvenile type as noted by Thompson² with a 50% recurrence rate in the Juvenile group sparking the need for subclassification of late-onset Blount's. Recurrence has also been noted by Schoenecker²¹, Thompson¹³ (with a 25% recurrence rate in the juvenile group in a subsequent study), Henderson¹⁶, and Sabharwal¹⁹.

The higher risk of recurrence observed in the juvenile group is thought to be due to ongoing growth inhibition in an abnormal medial proximal tibial physis in a child with more years of growth remaining than in the adolescent group. We have subsequently changed our goals for correction slightly in the Juvenile group by over-

correcting to a mechanical axis of between 5 and 10 degrees of valgus to accommodate ongoing growth inhibition at the proximal medial tibial physis.

Identification of gaps or needs for further research

Due to the multitude of treatment options available and the spectrum of severity of deformity and associated deformities which can present to the treating surgeon it is very difficult to set up randomized controlled trials comparing one treatment modality to another. No two patients are the same weight, size, shape and with the same combination of deformities. The preference, skills and experience of the surgeon with the various different modalities will also influence both choice of treatment method and the outcome.

We can however establish better guidelines of what constitutes a good vs. a poor result.

Long term outcome studies on patient with oblique joint lines are needed to assess whether or not it is critical to correct this deformity. Recurrence remains an issue - even a perfect correction of all the deformities can recur to an unacceptable result if the effect of ongoing growth inhibition is not quantifiable and predictable – further analysis of patients with recurrence and the rate of angular change with years of growth remaining would be a good start.

Inherent difficulties with ascertaining accurate measurement of correction on the table in obese legs continue to plague surgeons who aim for acute correction. Using the electrocautery cord for alignment in an obese patient is a crude blunt instrument at best. All of our poor results not due to juvenile recurrence were due to inaccuracy of correction at the time of surgery. Sabharwal et al.⁴¹ showed that this method is useful only in patients with a normal body mass index, <2cm of mechanical axis deviation and <3 degrees of joint line convergence angle on the standing AP radiograph. They cautioned that the results be used with caution in obese patients or those with pathological knee joint laxity or residual mechanical axis deviation. Saleh et al.⁴² developed a grid with wires to be used to accurately align the tibial

mechanical axis. A longer grid has since been made too allow a wire to run from the hip to the ankle to more accurately assess mechanical axis intra-op but needs to be verified. We have developed a simple Y-shaped metal rod to be used in a similar fashion and set at 10 degrees to allow the alignment to be more accurately set in theatre at between 0-10 degrees . We plan to analyse the results using this method compared to those with the electrocautery cord.

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PART C

MANUSCRIPT

This manuscript will be submitted to the South African Orthopaedic Journal. The format and referencing style is as according to the Instructions for Authors of the journal.

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Late-onset Blount's disease

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Declaration:

The contents of this article is the sole work of the authors.

No benefits of any form have been or are to be received from a commercial party related directly or indirectly to the subject of this article.

The research has been approved by the Research Ethics Committee, Health Sciences Faculty, University of Cape Town (REF:349/2008)

Late-onset Blount's disease

Abstract

Background:

Late-onset Blount's disease is subdivided by age at onset into juvenile (4-10years) and adolescent (≥ 11 years) Blount's. Recent literature recommends the use of external fixation with gradual correction of tibial varus and simultaneous correction of associated femoral varus.

Methods:

We retrospectively reviewed 36 patients (43 knees) treated from 1990-2005. Pre-operatively, post-operatively and at follow-up patients were assessed clinically and radiographically. Surgery involved a tibial barrel-vault osteotomy alone acutely correcting all the deformities. Fixation was with Steinmann pins and plaster.

Results:

Of 36 patients (43 knees), 22 were female and 65% obese. Seventeen knees were juvenile and 26 adolescent. Pre-operative mechanical axis ranged from 8-55° varus. Seventeen of the 43 knees (40%) had significant femoral varus (lateral distal femoral angle $>95^\circ$). At an average follow-up of 4 years (38 knees to maturity), 33 knees (77%) had a good result. Poor results were due to inaccuracy of intra-operative determination of alignment and in 3 juvenile knees the varus recurred after initial correction to 0-4° valgus only.

Conclusion:

Tibial osteotomy alone with limited internal fixation can achieve good results in late-onset Blount's. In juvenile knees overcorrection to 5-10° mechanical valgus accommodates recurrence secondary to persistent growth inhibition.

Introduction

Proximal tibia vara in childhood is due to growth disturbance of the proximal medial tibial physis. The condition was critically analyzed by WP Blount in 1937¹ who was the first to sub-classify the condition into 2 broad groups - an infantile form with changes appearing “in the first year or two of life” and an adolescent form with the deformity occurring “just before puberty”.

This late-onset form of the disease was later sub-classified by Thompson et al.² into a juvenile form with onset at 4-10 years and a “true” adolescent form with an onset at or after 11 years of age. Both differed from the infantile form in radiological appearance with less pronounced radiographic changes. These are medial epiphyseal wedging, medial physeal irregularity and minimal increased prominence of the proximal medial tibial metaphysis. The juvenile group was categorized as a separate entity due to the high rate of recurrence of the varus deformity following surgical correction.

Late-onset Blount’s disease classically occurs in obese patients with characteristically wide thighs, with M:F ratio of 4:1 and 90% of patients are black^{2,3,4,5,6,7,8,9,10}. There is a well documented association with slipped upper femoral epiphysis (SUFE)^{11,12,13}.

Late-onset Blount’s disease has been noted to have an association with concurrent distal femoral varus with a reported incidence of 19-60%^{13,14,15,16,17}. This is in contrast to the distal femoral valgus reported in infantile Blount’s¹⁴. It is postulated that the medial femoral physis also suffers growth inhibition due to the high loads through the medial knee joint particularly in older obese patients with a “fat thigh gait”^{9,18,19}.

The treatment of late-onset tibia vara has evolved over time, although the mainstay remains high tibial osteotomy as it was when Blount published his review in 1937¹. Lateral tibial hemi-epiphysiodesis has also been used as a treatment modality^{20,21,22} but does not address the associated internal rotation or procurvatum deformities commonly associated with late-onset Blount’s disease.

Methods of fixation of the osteotomy however have changed, from plaster of paris (POP) alone¹ to include limited internal fixation with Steinmann pins^{4,13,23} or stable internal fixation with compression plates²⁴. Due to the difficulties associated with obesity in late-onset Blount's disease external fixators have become a popular fixation method, including monolateral^{7,25} and circular fixators^{6,8,15}. Gradual correction with a circular fixator has become increasingly popular and authors report that a more accurate correction is achieved than with acute correction^{26,27}.

Recently authors have also recommended simultaneous correction of distal femoral varus if $>5^\circ$ outside the normal range^{6,15,25}. This is achieved by simultaneous distal femoral valgus osteotomy held with a blade plate or lateral distal femoral hemiepiphysiodesis if sufficient growth potential remains. The reason for the simultaneous femoral correction is to prevent knee joint line obliquity which occurs when both tibial and femoral mechanical varus are corrected by tibial osteotomy alone^{28,29}. In some advanced cases of adolescent late-onset Blount's disease distal tibial valgus also occurs^{15,17}. It has been recommended that this deformity also be simultaneously corrected by distal tibial osteotomy¹⁵ which is held with an extension of the tibial circular external fixator.

Whatever method is used the treatment of the obese patient with late-onset Blount's remains a challenge due to difficulties with obtaining correct intra-operative mechanical axis radiographs^{28,30}, surgical difficulties and fixation difficulties and the literature reflects a high percentage of fair and poor results^{4,5,12,13,23,25}.

We have treated all patients with late-onset Blount's disease between 1990 and 2005 with acute correction by means of high tibial barrel vault osteotomy alone held with Steinman pins and plaster. We did not correct concomitant femoral varus. We corrected the overall varus alignment of the lower limb by overcorrecting the tibia.

The aim of this study was to assess the clinical and radiological outcome of patients treated for late-onset Blount's disease by this method and to identify and quantify potential problems including adequacy of correction of the deformity, joint line

obliquity and recurrence of the deformity. We also analysed the demographics of late-onset Blount's disease in our population.

Materials and Methods

We retrospectively reviewed 36 patients (43 knees) treated for late-onset Blount's disease from 1990-2005. All patients were assessed both clinically and radiographically pre-operatively, post-operatively at removal of plaster and at final follow-up of at least two years or at skeletal maturity.

The duration since the onset of the genu varum and obesity and the presence of pain were noted.

Clinical examination at presentation included the body weight, the presence or absence of a varus or lateral thrust at the knee with walking, intercondylar distance, intoeing (measured by the thigh foot angle), leg length discrepancy and the presence/absence of a Siffert-Katz sign³¹ (increased deformity demonstrated with varus stress in flexion as is common in Infantile Blount's).

Pre-operative radiographic examination included a mechanical axis antero-posterior (AP) standing radiograph of the whole limb to include the hip and ankle with the patella pointing forward and a lateral radiograph of the whole tibia. These radiographs were assessed according to the methods of Paley and Tetsworth^{28,2829}. On the AP full length radiograph the mechanical axis (MA - normal 0°; range 5° varus – 5° valgus), lateral distal femoral angle (LDFA - normal 87°; range 85-90°), medial proximal tibial angle (MPTA - normal 87°; range 85-90°) and lateral distal tibial angle (LDTA - normal 89°; range 86-92°) were measured. On the lateral tibial radiograph the posterior proximal tibial angle (PPTA – normal 81°; range 77-84°) quantified the procurvatum.

The surgical technique used was the same in all cases. Through a mid-fibular incision an oblique osteotomy of the fibula and a prophylactic fasciotomy of the lateral compartment was completed. Through a second mid-tibial incision a

prophylactic anterior compartment fasciotomy was performed. This was followed by a low energy tibial barrel vault osteotomy just below the apophysis. Through this osteotomy the mechanical axis of the limb was corrected to 0-5° valgus using intra-operative fluoroscopy with the electrocautery cord, the internal tibial torsion to 15° of external tibial torsion and the procurvatum to a PPTA of 80°. No patient had a distal femoral or distal tibial osteotomy. The corrected barrel vault osteotomy was held with 2 to 3 crossed 2.4mm Steinmann pins and the leg immobilized in an above knee plaster of paris for 6 weeks.

Radiographs taken immediately post operatively, at union and at final follow-up were measured as described above.

At final follow-up the patients were subjectively assessed for pain and satisfaction with the cosmetic result. Objectively each leg was clinically assessed for mechanical axis, leg length discrepancy, thigh foot angle and heel angle.

Patients were followed up for 2-8 years (average 4 years) and 38 of the 43 knees were followed up to physeal closure (either secondary to maturity or epiphysiodesis in the case of the 7 patients with contralateral late presenting infantile Blount's). Results were graded using criteria similar to Schoenecker et al²³ (Table I).

Results

Of the 36 patients 22 were female (M:F 2:3). Two thirds (24) of our patients were obese (predicted weight for age > 95th percentile). Of the 43 knees 17 knees were in juvenile patients and 26 knees were in adolescent patients. All patients had intoeing (internal rotation on thigh foot angle: average 10°; range 0-25°) (Figure 1 a and b).

Twenty two of our 36 patients (61%) had some form of bilateral genu varum: 7 patients had bilateral late-onset Blount's disease, 7 patients had contra-lateral late presenting infantile Blount's and a further 8 patients had contra lateral genu varum of <5° which did not warrant corrective osteotomy.

Ten patients had associated pathologies: 7 (20%) contralateral late presenting infantile Blount's, 2 (5,5%) idiopathic peroneal spastic flat feet and 1 (3%) SUFE.

Pre-operative radiographs revealed that overall mechanical varus ranged from 8-55°. Significant femoral varus was defined as $>5^\circ$ outside the normal range (LDFA $> 95^\circ$) as this is the severity of deformity which is addressed by those authors who recommend simultaneous femoral varus correction^{6,15,25}. Distal femoral varus occurred in 17 of 43 knees (40%). Femoral varus ranged from 2-12° and this quantifies the potential joint line obliquity for this group of patients who were treated to correct overall mechanical varus with tibial osteotomy alone. Of the patients with distal femoral varus deformity 88% were obese compared to patients without distal femoral varus of whom only 42% were obese. Of the adolescent patients 50 % had distal femoral varus while only 25% of the juvenile patients had femoral varus deformity.

Thirty three knees (77%) had good results (Figure 2 a-c) and there were 10 poor results (Table I).

No ankle valgus occurred in this study. At the time of final follow-up all patients had thigh foot angles between 10-15° external rotation and heel angles of 5-10° valgus. No patient had a leg length discrepancy of $>2\text{cm}$.

Seven of the poor results were attributable to not getting accurate deformity correction at surgery and three due to recurrence in juvenile patients. Five of the ten knees with poor results required re-operation – 2 knees for over-correction to $>10^\circ$ mechanical valgus and three juvenile knees which were initially only corrected to between 0-4° valgus and recurred to $>5^\circ$ varus (due to ongoing growth disturbance at the abnormal proximal medial tibial physis) (Figure 3 a-c). The 5 knees with poor results who did not have further surgery included 4 knees with undercorrection to between 6° and 10° mechanical varus and 1 with undercorrection of procurvatum to a PPTA $< 70^\circ$. These 5 patients were satisfied with their outcome and refused further corrective surgery despite the residual mechanical axis deviation.

Analysis of the radiographic measurements of the patients with good results (Table II) show that although the overall mechanical varus of 8-55° has been corrected to within 5° of neutral the average MPTA is 94° reflecting tibial valgus. This is due to both the femoral and tibial contributions to the overall mechanical varus being corrected through a tibial osteotomy alone and is a reflection of the average distal femoral varus (LDFA 93°). When the patients with femoral varus are excluded, the average post op MPTA is normal at 88° (Table III).

Discussion

The pathology of Blount's disease is growth inhibition of the medial proximal tibial physis due to abnormal endochondral ossification^{3,10,11,13}. The etiology however remains unknown and is probably multifactorial¹⁰. Davids et al.¹⁸ postulated that obese adolescents had a "fat thigh gait" and difficulty adducting the hip in stance as well as swing limb circumduction. This results in increased forces across the medial side of the knee causing physeal growth inhibition.

Demographic data from the United States show 90% black patients, 75% male and >90% obese. Although 90% of the patients in our study were black, the male:female ratio was 2:3 and only two thirds of the patients were obese. The "fat thigh gait" theory alone does not explain late-onset Blount's disease in patients of normal weight and in the 39% of patients in our study who did not have any form of bilateral involvement. The theory however is supported by the distribution of the femoral varus which occurred in 40% of the knees in our study. Older or adolescent patients (50% femoral varus) and overweight patients (88% femoral varus) were twice as likely to develop femoral varus when compared to juvenile (25%) or normal weight (42%) patients.

Three classical pathologies that occur in overweight black children are Blount's disease, SUFE and idiopathic peroneal spastic flat feet. SUFE has a similar histopathology of the growth plate to Blount's and the association with Blount's has been well documented^{10,11,12}. Idiopathic peroneal spastic flat feet which occurred in two patients in our study have not previously been described in Blount's.

Over the last 20 years the treatment of late-onset Blount's disease has evolved away from the more traditional high tibial osteotomy alone held with limited internal fixation. This is due to a number of reasons including difficulties with managing the often very obese patient in plaster and achieving exact correction of the deformity under fluoroscopy. The literature reflects an evolution of the surgical technique towards more complicated modalities such as internal fixation with plates and external fixation with mono-lateral and ring fixators.

Acute correction and compression plate fixation of the osteotomy was used by Martin et al.²⁴ for correction of tibia vara of multiple etiologies including 3 patients with adolescent Blount's. They achieved good results but the small sample size is a weakness of the study. The metaphyseal osteotomy used to correct a physeal deformity results in the need for lateral translation at the osteotomy site^{28,29} thus particularly in larger deformities it can be difficult to hold correction with a plate. It also requires greater soft tissue stripping and is associated with plate-specific complications thus has not been widely used as a primary treatment modality particularly for larger deformities or obese patients.

Mono-lateral external fixation using the Orthofix T-Garcke fixator has been described to hold the osteotomy post correction without plaster and simultaneously allow distraction osteogenesis to correct leg length discrepancy. Gaudinez et al.⁷ used the technique in 14 knees and achieved good results with union in an average of 9 weeks. Complications reported included 2 superficial pin tract infections and one transient common peroneal nerve palsy. Advantages listed included ease of application, immediate weight bearing and ease of hardware removal. Disadvantages included difficulty in obtaining adequate AP radiographs to assess deformity correction, pin tract infections and the need for high levels of patient compliance. Stanitski et al.²⁵ used the technique in 16 tibias and achieve excellent alignment with reported advantages of functional weightbearing and the use of adjacent joints during treatment. It allows for frontal plane and length adjustment although care must be taken to place the fixator in line with the mechanical axis to avoid causing further angular deformity and translation with lengthening.

The use of circular external fixation has also been reported in the treatment of late-onset Blount's disease. Coogan et al.⁶ reported on 12 tibias treated with this technique which allowed lengthening and weightbearing throughout treatment. They used gradual correction on a hinged Ilizarov type external fixator and corrected the distal tibial valgus with the same frame extended distally in cases where necessary. Advantages listed included the ability to correct deformity in any plane and adjustability allowed for fine tuning. Stanitski et al.⁸ reported 25 tibias in 17 patients treated with this technique also with good results and reported "improved outcomes over traditional methods in these difficult patients". The fixator was on for an average of 19 weeks (Range 12-36 weeks). There was only a single non-union and 8 superficial pin tract infections. They also used gradual correction and cited a risk of peroneal nerve palsy with acute correction. More recently the Taylor Spatial Frame (TSF) has allowed correction with a circular fixator and Six-Axis Deformity Analysis as used by Feldman et al. in their series of 13 adolescent patients and six Infants²⁶. They used the TSF in chronic mode for gradual correction and reported 100% good results using Schoenecker's criteria²³. Reported complications included pin tract infections and a single delayed union requiring 22 weeks in a frame. They also published a comparative study in 2006²⁷ where they compared the patients treated with gradual correction in a TSF to a group treated by acute correction and a different external fixator. They concluded that gradual correction was significantly more accurate.

Problems with achieving accurate intra-operative measurement of the degree of correction combined with advancing technology have more recently sparked a trend for gradual rather than acute correction to allow the final position to be fine-tuned even out of theatre. Using the electrocautery cord for alignment in an obese patient is a crude blunt instrument at best. All of our poor results not due to juvenile recurrence were due to inaccuracy of correction at the time of surgery. Sabharwal et al.³⁰ showed that this method is useful only in patients with a normal body mass index, <2 cm of mechanical axis deviation and <3° of joint line convergence angle on the standing AP radiograph. They cautioned that the results be used with caution in obese patients or those with pathological knee joint laxity or substantial residual mechanical axis deviation. Saleh et al.³² developed a grid with wires to be used to accurately align the tibial mechanical axis. A longer grid has since been made too

allow a wire to run from the hip to the ankle to more accurately assess mechanical axis intra-operatively but needs to be verified.

There is also a greater recognition of the contribution of distal femoral varus deformity to the overall varus deformity around the knee. This has resulted in an increased drive to simultaneously correct the deformities in both the femur and the tibia when present in order to prevent joint line obliquity. There are however as yet no long term follow-up studies into adulthood as to whether the resultant joint line obliquity causes long term problems. Gordon et al.¹⁶ demonstrated a significant incidence of distal femoral varus deformity in children with late-onset Blount's disease which contributed on average 30% of the total varus malalignment in these limbs. In our study the femoral varus which was not corrected by femoral osteotomy when the LDFA was $>95^\circ$ as it would have been using the comprehensive approach of Gordon et al¹⁵. This led to 17 knees having joint line obliquity of between 2 and 12° and only time will tell whether this will indeed lead to accelerated degeneration in these knees in the future. It may well be that in these obese patients who cannot normally adduct their legs in the stance phase that the joint line is parallel to the floor in stance although not perpendicular to the mechanical axis.

Recurrence of varus deformity in patients with juvenile Blount's disease after adequate corrective osteotomy is a well recognized problem with rates between 25 and 50% reported^{2,5,12,15}. Our study was no exception. Three of 17 juvenile knees (18%) required re-operation due to recurrence following initial correction to $<5^\circ$ varus. No juvenile knees which were initially corrected to between 5 and 10° of mechanical valgus recurred. We therefore recommend that patients <11 years old at surgery be corrected to 5-10° of mechanical valgus to accommodate recurrence of the varus deformity due to ongoing growth inhibition at the proximal medial tibial physis.

Advantages of our technique include that it is relatively simple to perform and equipment costs are minimal. It also requires relatively less surgical time and bilateral cases can be done at the same surgical sitting. Post operatively patients can be mobilized without the need for further plaster or bracing at 6 weeks.

Disadvantages include large heavy plasters and that the position obtained in theatre

cannot be adjusted without re-operation. Unfortunately in bilateral cases the patients must have bedrest for 6 weeks.

It is important to note that seven of our ten poor results could have been avoided with better assessment of intra-operative deformity at surgery. It is critical that the correct position is obtained if acute correction is the method used. The ability to fine tune the osteotomy position post-op with gradual correction could be valuable in these cases.

A limitation of this study is that 5 knees were not followed to maturity. The paper also has the bias of a retrospective study. Since the completion of this study the degree and incidence of obesity has increased significantly. The maximum weight of a patient in our study was 114kg while the study of Gordon et al.¹⁵ reported a mean weight of 112kg with a maximum of 178kg! In these very obese adolescent patients we are now using a monolateral Orthofix fixator while we still use the technique described in this study for juvenile patients and patients that are not morbidly obese. We are studying a new method of assessing intra-operative alignment.

In conclusion the relatively cheap and simple treatment option of high tibial osteotomy alone held with Steinman pins and plaster can achieve good results in the treatment of late-onset Blount's disease.

Tables

Table I: Grading of results

| | |
|---|---|
| Good result n=33 | Poor result n=10 |
| No pain | Pain |
| Mechanical axis $\leq 5^\circ$ varus/valgus | Mechanical axis $>5^\circ$ varus/valgus |
| PPTA $70-90^\circ$ | PPTA $<70^\circ$ |

Table II: Analysis of all good results - n=33

| | Pre - operative | Follow-up | Normal |
|------------------------|------------------------|----------------------|---------------|
| Mechanical axis | 8-55° varus | 5° varus - 5° valgus | 0° |
| LDFA | 87-102° | 87-102° (93°) | 87° |
| MPTA | 58-83° | 87-104° (94°) | 87° |
| LDTA | 85-90° | 85-90° | 89° |
| PPTA | 50-86° | 70-90° 79° | 79° |

Table III: Analysis of good results with no femoral varus (LDFA $<95^\circ$) - n=21

| | Pre - operative | Follow-up | Normal |
|-------------|------------------------|------------------|---------------|
| LDFA | 87-90° | 87-90° (88.5)° | 87° |
| MPTA | 58-83° | 84-92° (88.5)° | 87° |

Legends to Illustrations

Figure 1

- a) 13 year old overweight boy with adolescent late-onset Blount's disease
- b) Thigh foot angle measured 0° (normal range $10-15^{\circ}$ external rotation)

Figure 2

- a) AP full length standing mechanical axis radiograph of a 12 year old girl with adolescent late-onset Blount's. Mechanical axis is 30° varus, LDFA 90° , MPTA 75° , LDTA 90°
- b) Follow-up at maturity shows neutral mechanical axis
- c) Lateral post-op radiograph of the tibia showing PPTA 80°

Figure 3

- a) AP full length mechanical axis radiograph of left leg of a 9 year old girl with juvenile late-onset Blount's disease
- b) Post-operative correction to a neutral mechanical axis
- c) 2 years post-operatively the deformity has recurred

Illustrations

Figure 1.



Figure 2.



Figure 3.



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PART D

SUPPORTING DOCUMENTS

University of Cape Town

PROFORMA

LATE-ONSET BLOUNT'S DISEASE 2008

NAME: _____ NUMBER : _____ TEL NO. : _____
 ADDRESS: _____
 DOB: _____ AGE AT SURGERY: _____ RACE/SEX: _____
 WEIGHT & DURATION: _____ PERCENTILE: _____ %
 DATE OF SURGERY: _____ DATE/DURATION AT FOLLOWUP: _____

| PRE - OP | POST-OP – POP REMOVAL | FINAL FOLLOW-UP |
|----------------------------|-----------------------|-----------------------|
| Symptoms | | Symptoms |
| - Cosmesis Duration | | - Cosmesis |
| - Pain Duration | | - Pain |
| | | |
| Examination | | Examination |
| - Varus thrust | | - LLD |
| - Siffert-Katz | | - Mech Axis |
| - Intercondylar dist. | | - Intercondylar dist. |
| - Thigh-foot angle | | - Thigh-foot angle |
| - Foot | | - Foot |
| - LLD | | |
| | | |
| XRy | XRy | XRy |
| - Knee | - Knee | - Knee |
| - Mech axis | - Mech axis | - Mech axis |
| - MAD | - MAD | - MAD |
| - LFA | - LFA | - LFA |
| - MTA | - MTA | - MTA |
| - JLCA | - JLCA | - JLCA |
| - Post. Slope | - Post. Slope | - Post. Slope |
| - Ankle | - Ankle | - Ankle |
| -LDTA | -LDTA | -LDTA |
| | | |
| | Joint line obliquity | Joint line obliquity |
| | Dogleg | Dogleg |

OPERATIVE TECHNIQUE:
RESULTS AND COMMENTS:

ETHICS APPROVAL LETTER

UNIVERSITY OF CAPE TOWN



Health Sciences Faculty
Research Ethics Committee
Room E52-24 Groote Schuur Hospital Old Main Building
Observatory 7925
Telephone [021] 406 6338 • Facsimile [021] 406 6411
e-mail: lamces.cmjedi@uct.ac.za

29 September 2008

REC REF: 349/2008

Dr CD White
Orthopaedics
H49 OMB

Dear Dr White

PROJECT TITLE: LATE-ONSET BLOUNT'S DISEASE

Thank you for submitting your study to the Research Ethics Committee for review.

It is a pleasure to inform you that the Ethics Committee has **formally approved** the above-mentioned study.

Approval is granted for one year till the 5th October 2009.

Please submit an annual progress report if the research continues beyond the expiry date. Please submit a brief summary of findings if you complete the study within the approval period so that we can close our file.

Please note that the ongoing ethical conduct of the study remains the responsibility of the principal investigator.

Please quote the REC. REF in all your correspondence.

Yours sincerely

PROFESSOR M BLOCKMAN
CHAIRPERSON, HSE HUMAN ETHICS

Federal Wide Assurance Number: FWA00001637.
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cmjedi

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