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Tension band plating in growth modulation : A review of current evidences

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Tension band plating (TBF) has been pitted as the best method for correcting the angular deformities and limb length discrepancies (LLD) in growing children. In this review we examined the superiority of the tension band plating over other methods of growth modulation, in terms of safety and efficacy. As per the current literature, in angular deformities TBP has similar correction rates with lesser complications. However in LLD the results are less promising.

Keywords :

INTRODUCTION

Physeal growth manipulation can correct the angular deformity in growing children in a less invasive way (*14*). An ideal implant for growth modulation should be effective in restraining physeal growth without causing permanent damage, easy to apply and remove and produce minimal complications. In 1949 Blount first used staples for temporary hemiepiphysisodesis (*6*). Though, staples proved to be an effective tool for temporary growth modulation, concerns remained regarding implant extrusion, breakage, migration and permanent growth arrest (*6,14,39*). In 1998 Metaizeau described percutaneous epiphysiodesis using transphyseal screws (PETS). However the difficulties of accurate placement, removal and implant breakage remained (*24,31*). To overcome these difficulties Dr Stevens devised a new construct of extraperiosteal plate with 2 nonlocking screws. The plate would act like a tension band device and being extraperiosteal, it would provide larger fulcrum for correction with minimal risk of physeal bar formation (*43*). The relative ease of application and removal, secure fixation and low incidence of complications reported in earlier clinical studies led to proliferation of its use. The indications were extended to younger children, limb length discrepancies, fixed knee flexion deformities and deformities of ankle and hip (*25,35,43,44,46*). As the use of tension band plate (TBP) increased clinical failures and complications were also reported (*7,10,21,34,35,40,41*). So there arises a need to review the available evidences regarding the efficacy of TBP and to find out whether it provides a real benefit over other methods of growth modulation. The purpose of this review was to evaluate the present evidence in literature regarding implant design, application and removal, follow up, effectiveness and complications of the tension band plating.

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MATERIALS AND METHODS

We did a "PubMed" search in March 2014 using the following key words : tension band plate, 8 plate, hemiepiphysiodesis, epiphysiodesis, guided growth, growth modulation. A total of 40 full text original articles and 4 abstracts published from 2007 to 2014 were identified for review. Eight of these were experimental studies and 36 were clinical studies which reported on results of growth modulation using TBP. Among the experimental studies, 1 paper studied the mechanical strength of TBP in bone model (*49*) and rest compared TBP with staples in animal models (*9,16,18,19,23,37,38*). Among the clinical papers, there was 1 randomized control trial between TBP and staples (*17*), 9 case control studies (*2,7,13,20,22,28,45, 48,50*), 20 case series (*3,4,5,8,11,12,15,21,25,29,32,34,35,36, 40,41,43,44,47,51*), 5 case reports (*1,26,30,33,46*) and 1 survey of implant failure (*10*). Four of the case series had < 8 cases (*11,29,34,47*). We have included all the studies irrespective of the number of cases, which included case reports also.

A total of 585 patients have been reported. Among them, 372 patients were treated for knee coronal deformities (21 series and 3 case reports) (*1,3,5,7,8,11,12,17,20,22,30,32, 34,36,40,41,43,45,46,47,51*), 39 patients for knee fixed flexion deformities (4 series) (*2,25,29,36*), 54 patients for angular deformities of ankle (2 series and 2 reports) (*8,13,33,44*), 120 patients for limb length discrepancies (6 series and 1 report) (*4,15,26,28,35,36,48*) and 3 patients for coxa vara (1 series) (*46*). Of the 372 patients with knee coronal deformity, details of the site of fixation were available in 228 patients with 419 segments being operated upon. Additionally, 24 segments operated for knee coronal deformities without the details of number of patients were also included for evaluation (*50*).

In terms of etiology, the patient population was uniform in only 10 studies, with Blount's disease in 5 studies (*1,30,34,40,41*), idiopathic genu valgum in 2 studies (*17,20*) and chondrodysplasia (*46*), fibular hemimelia (*11*) and Cozen's phenomenon (*47*) in 1 study each. The remaining 26 studies had patient groups of varied etiology.

RESULTS

Implant design

Of the 36 clinical studies, 23 papers had specified the type of TBP construct used. The most commonly used TBP construct was 2 holed nonlocking titanium plate along with fully threaded 4.5 mm cannulated screws by Orthofix (Verona, Italy or McKinney, USA). It was used in 20 studies. This standard construct proposed by Dr Stevens was widely used with high rates of success and minimal complications (*43*). However in Blount's disease and obese children, modifications of this standard construct have been attempted to minimize the construct failures. Solid titanium screws, stainless steel implants and use of two plates per hemiepiphysis have been proposed to strengthen the construct (*10,40,41*). Experimental studies have shown that solid titanium screws are 65-100% stronger as compared to the cannulated ones. Similarly solid stainless steel screws have been shown to be 96% stronger than the titanium cannulated screws and 20% stronger than the solid titanium screws (*49*). One author had also used the 2 holed DCP with 4.5 or 6.5 mm cortical screws for exchange after failure of the Orthofix screws in patients with Blount's disease (*40*).

Among the remaining 3 studies, one study used a 3.5 mm alloy steel construct. The authors stated that these plates were of lower profile and have less chance of prominence even in patients with low subcutaneous fat. Additional benefit of the steel implants was the lower cost as compared to the titanium (*36*). Another study used a 3.5 mm 2 holed reconstruction plates along with solid 4 mm cannulated screws. Though the correction rates were good, there was 10% implant failure which occurred even in idiopathic and nonobese patients. The low elasticity of the reconstruction plate constructs might have predisposed to implant failure when the physeal growth continued beyond maximum screw divergence (*3*). The last study used Pediplate, a 4.5 mm stainless steel construct by OrthoPediatrics (Warsaw, USA) (*30*). Other available constructs were those with partially threaded screws and a 4 holed construct. The partially threaded screw construct had been abandoned by the initial authors themselves due to its high risk of implant pullout and difficulty in explantation (*43*).

Procedure

Surgical procedure has been well described by the initial authors and most studies have religiously followed the same. The TBP is placed through a 2-3 cm skin incision in a submuscular supraperiosteal plane, protecting the overlying structures like saphenous nerve, saphenous vein and pes anserinus. Preservation of the periosteum and periosteal vessels is mandatory during this procedure. The guide wire with cannulated system helps in accurate placement of screws avoiding the physis (*43*). The physeal anatomy varies considerably with age. A fair knowledge of these anatomic variations along with close up radiographs apart from scanogram will help in avoiding any inadvertent injury to the physis (*27*). Coaptation of the plate to the bone and secure fixation is crucial for TBP to act (*10,43*). In cases of screw loosening, an exchange with longer screw can help in better fixation. Though animal studies failed to prove any impact of screw length on rate of correction, some authors were concerned regarding the possible growth inhibition of entire physis due to very long screws (*5,37,50*).

In coronal deformities of knee, a single plate (single tether) was used per hemiepiphysis and was typically placed on or slightly behind the mid-sagittal plane (*38,43*). Only one study (11 patients) used 2 plates per hemipeiphysis (*20*). For fixed flexion deformities of knee, 2 plates were placed, one on each side of the anterior articular surface of distal femur in intracapsular, extraarticular region (*25*). One study (4 patients) attempted correction of oblique plane deformity using a single plate applied in anterolateral/anteromedial location (*29*). One study reported correction of knee angular deformities in amputees. The authors suggested careful evaluation of the deformity and individualization of the plate placement according to the joint line obliquity and rotational malalignment (*21*).

When surgical procedure was compared with other methods of growth modulation, two studies (51 patients) have shown that, the implantation and explantation of staples required more time than TBP and also needed a bigger incision (*17,22*). Though smaller incision was used for PETS the technical difficulty in accurate placement and possibility of permanent physeal damage was a cause of concern (*24,31,42*).

Follow up

Considerable variation was seen among the studies regarding the follow up interval and evaluation method used during follow up. Only 6 studies mentioned about the follow up interval which ranging from 3-6 months. A more frequent follow up was recommended for younger children and after distal femoral plating (*3,5,7,11,12,34*). In case of coronal deformities, 15 studies performed scanogram at each follow up (*3,5,8,11,12,17,21,32,34,40,41,45,46,47,50*), while in 4 series, only clinical evaluation was done and scanogram was performed only at the final follow up (*7,20,22,50*). Proper positioning of the limb during scanogram was advocated to avoid inaccuracies in measurement of tibiofemoral angle. Standing foot prints were used in one study to reproduce the limb position during the scanograms (*17*). Mean axis deviation (MAD) was the most commonly used radiological parameter (11 studies) (*8,17,21,32,34,41,43,45,46,47,51*), followed by anatomical angles (10 studies) (*8,17,20,22,32,41,43,45,47,51*) and tibiofemoral angle (5 studies) (*7,11,12,47,51*). The end point of correction was not clearly defined in most papers. While 3 studies preferred overcorrection (*8,41,43,51*), 2 studies removed TBP after neutralization of axis (*7,22*). In cases of fixed knee sagittal deformities clinically measured angle was preferred criteria for evaluation, with end point of correction aimed at deformity < 10° (*2*).

Efficacy

The overall success rate of TBP has been satisfactory in correction of angular deformities. Among the coronal deformities of knee, 320 of 365 patients (87.6%) achieved desired correction. The success rates ranged from 74-100%, excepting the studies comprising only of Blount's disease (*3,7,17,22,43,45,47,51*). Rate of correction (ROC) was stated in 9 studies (Table I). Six studies used the anatomical angle for calculation of ROC and the mean ROC ranged from 0.41° to 2.0°/month (*5,8,20,40,41,50*). One study used FTA with mean ROC 1.43°/month for idiopathic and 0.38°/month for pathological deformities (*7*). MAD was used by 2 authors and the ROC was1.3-1.7 mm/month (*21,51*). Overall, the ROC was higher in femoral plating, and idiopathic deformities (*7,8,41*). Among the skeletal dysplasias, multiple epiphyseal dysplasias showed better correction rates while spondylometaphyseal dysplasia

Table I. — Rate of correction sated in various studies

Author	*Year*	*Parameter*	*Rate of correction/month*
Coronal deformities of knee			
Burghardt	2010	AA	Femur -0.65°, proximal tibia -0.58°
Ballal	2010	AA	Femur -0.7°, tibia -0.5°
Guzman	2011	AA	1 TBP[#] -0.56°, 2TBP[##] -0.74°
Scott[@]	2012	AA	Tibia -0.84, femur -2.0
Schroerlucke[@]	2009	AA	Tibia -0.41°
Weimann	2009	AA	TBP -0.92°, staple- 0.79°
Boreo	2011	FTA	Idiopathic -1.43°, pathologic -0.38°
Yilmaz	2013	MAD	Varus -1.5 mm, valgus -1.8 mm
Gyr	2013	MAD	1.3 mm
Ankle valgus			
Stevens	2011	LDTA	0.6°
Driscoll	2013	LDTA	TBP -0.36°, PETS -0.55°
Fixed flexion deformities of knee			
Al-Aubaidi	2012	FD	Staple -0.3, TBP -0.5°
MacWilliams	2011	FD	1.0°
Limb length discrepancies			
Lykissas	2013	LLD	TBP -0.9 mm, staple -1.0 mm, PETS -0.5 mm
Baliga	2013	LLD	0.8 mm
Stewart	2013	LLD	0.5 mm

AA, anatomical angle ; MAD,mean axis deviation ; FTA, femorotibial angle ; TBP, tension band plate ; PETS, percutaneous epiphysiodesis using transphyseal screws ; # 1 TBP per hemiepiphysis ; ## 2TBP per hemiepiphysis ; LDTA, lateral distal tibial angle.

and Moroquio's syndrome showed poorer correction rates (*51*). Application of 2 plates per hemi-epiphysis showed higher ROC than single plate, but the difference was not significant (*20*). Stevens had proposed that the TBP would provide 30% better correction than PETS or staples due to peripheral fulcrum (*43*). However, none of the clinical or experimental comparative studies showed any significant difference between staples and TBP, even though patients in the TBP groups were younger (*9,17,22,23,19,38,50*).

In fixed knee flexion deformity, anterior tension band plating of distal femoral physis corrected 26 of 39 patients (66.7%). Though both staples and TBP were equally successful in correcting the deformity, ROC in TBP (0.5°-1.4°/month) was higher than in staples (0.3°/months). The authors suggested that residual patella alta after correction of FKFD with TBP, needs no treatment (*2,25,29*). The ROC in ankle valgus was 0.36-0.6°/month with TBP and comparable to that of PETS (0.52-0.59°/month) (*13,44*).

The reported efficacy of TBP in LLD was not uniform. The mean LLD decreased in 5 studies. Lykissas compared TBP, staples and PETS in LLD and found that there was no difference between them in terms of correction (*4,15,28,35,48*). However Pendleton *et al* found that, 6 of 34 patients had an increase in LLD despite having TBP in place (*35*). Radiosteometric analysis by Pedersen showed that TBP was not effective in completely blocking the longitudinal growth of physis (*26*). Stewart *et al* observed that cessation of growth took much longer time after dual 8 plate and none of the patients had implant removal before skeletal maturity. Thus the resumption of growth after implant removal was mostly theoretical (*48*). In an experimental study,

Table II. — Complications

Complication	Total number
Surgery related	
Pain	9
Effusion	1
Infection	12
Stiffness	1
Implant related	
Loosening	1
Migration	3
Back out	2
Implant failure	89*
Fracture	1
Growth related	
Over correction	9
Rebound phenomenon	17
Additional deformity	4

* Includes 24 failures reported by the clinical studies and 65 failure reported by the survey.

Goyeneche observed that staples were more effective than TBP in blocking the longitudinal growth of physis at least in initial period (*19*).

Complications

Broadly, complications in TBP could be categorized into three types : surgery related (joint effusion, stiffness and knee pain, infection), implant related (extrusion, migration, implant failure and fracture), growth related (over correction, rebound phenomenon, additional deformity and physeal arrest) (*49*). The total number of complications in the available literature are given in Table II. Complications such as knee effusion, stiffness and infection were more commonly reported with distal femur plating (*2,22,28,29,41*). The tenacious grasp of TBP has significantly reduced the implant related complications, such as loosening, back out and migration which were commonly associated with staples. Failure of screw was a new complication associated with TBP and was reported in 89 cases, predominantly involving the metaphyseal screws in Blount's disease (85.4%). Abnormal physeal anatomy, chondrocyte disorganization and misalignment along with cyclical loading by physeal motion were implicated for these failures (*10,40,41*).

Nine patients had clinically significant over corrections and 17 had rebound phenomena. These growth related complications remained an enigma and continued to occur even with TBP although to a lesser extent (*7,13,17,18,43,50*). In a comparative study, the rate of rebound growth was 0.1°/month with TBP and 0.2°/month with PETS (*13*). There were only 2 physeal arrests reported, 1 due to screw migration and 1 due to infection (*33,41*). Total 4 cases developed additional deformity, which included 2 genu recurvatum (after hemiepiphysiodesis) and 2 genu varum (after epiphysiodesis) due to malpositioning of TBP. So the importance of accurate positioning of TBP cannot be overemphasized (*20,35*).

DISCUSSION

Within a short period after its introduction, undoubtedly TBP has surpassed staples and its enthusiastic use continues in growth modulation. The scope for growth modulation has expanded beyond knee deformities and newer indications are being explored (*25,35,43,44,46*).

The present literature supports that, TBP can effectively correct the coronal knee deformities with similar success rates and lesser complications than staple or PETS (*14,17,22,47,50*). However in cases of Blount's disease, failure of implant and failure of correction still remains a concern (*10,40,41*). Role of TBP in angular deformities due to physeal arrest is still uncertain as none of the studies have included such cases. Theoretically TBP may help in preventing the progression of the deformity and minimize the magnitude of further surgical correction. In cases of FKFD and ankle valgus, the rates of correction by TBP were similar to staples and PETS respectively. However the results must be interpreted with caution considering the smaller number of reported cases (*2,13,25,29,44*). In cases of LLD, the results of epiphysiodesis by TBP remained inconclusive (*4,26,28,35,48*).

Among those who reported failure of correction, 15 patients in 4 studies have reported progression of the deformity or discrepancy even after tension band plating (*8,26,34,35*). Though none of these authors explained the possible cause of this phenomenon, in an experimental study Goyeneche noted an initial delay in action of TBP. This was possibly due to the plate screw toggle and intrinsic elasticity of the titanium plates (*19*). This latency can significantly alter the outcome in children nearing maturity with lesser remaining growth. A rigid fixation like staples or PETS would act as an immediate restraint to the physis and probably be more beneficial in such patients. Considering the ease and reversibility, some authors have used TBP in very young children including toddlers (*7,22,32,36,46*). We feel that growth modulation at such a young age should be considered only when the physiological correction is expected to be inadequate. The 4.5 mm screw construct in the smaller bones of young children may pose a theoretical risk of iatrogenic fracture (*2*). This is more so important in correction of FKFD where 2 plates are being used.

The lack of uniformity in terms of patient characteristics, smaller studies, lack of long term follow ups after implant removal and variation of evaluation parameters, makes the comparison among the studies difficult. Despite these limitations, the present review concludes that in comparison to other devices, TBP has significantly lower complications and is more surgeon friendly, but offers no advantage in terms of rate of correction or efficacy. Future studies comparing the results of TBP, staples and PETS in uniform patient groups and studies with follow up till skeletal maturity will help in better understanding and planning.

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