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ORIGINAL STUDY

Temporary screw epiphysiodesis for ankle valgus in children

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The aim of this case series was to assess clinical outcomes and achievable correction grades following temporary percutaneous medial malleolar screw epiphysiodesis.

A retrospective chart review of 16 consecutive children with ankle valgus (23 ankles) treated with medial malleolar screw epiphysiodesis in one single institution was performed. Tibiotalar angle, fibular station, and the lateral distal tibial angle were measured before screw epiphysiodesis, and before and after hardware removal.

Mean mechanical and anatomical lateral distal tibial angles were significantly improved by epiphysiodesis (75.6° to 85.2° and 75.7° to 85.3°, respectively, p < 0.005). Similarly, mean tibiotalar angle was significantly improved by screw epiphysiodesis when comparing to the last follow-up before screw removal (5.8° to 14.2°, p < 0.005). We observed a slight rebound following screw removal.

Temporary medial malleolar screw epiphysiodesis is an effective method to treat ankle valgus in children.

Level of Evidence: Level 4

Keywords: Screw epiphysiodesis ; ankle valgus.

INTRODUCTION

Ankle valgus is defined as an eversion of the calcaneus relatively to the tibia resulting in foot pronation and sometimes lateral translocation of the talus *(4)*. This deformity is rare in children and different etiologies including multiple exostoses, Ollier's disease, Larsen's syndrome, type 1 neurofibromatosis, and neurological disorders have been implicated *(1)*. Ankle valgus generally leads to gait instability, pain, and problems wearing shoes. Treatment options consist of supramalleolar osteotomy and medial malleolar screw epiphysiodesis. While supramalleolar osteotomy reflects an invasive procedure requiring hospitalization, immobilisation and delayed weight bearing, medial malleolar screw epiphysiodesis offers a less invasive therapy with satisfactory outcomes *(16,9)*. Screw epiphysiodesis was first described by Métaizeau in 1998 *(11)*.

The aim of the present study was to assess the correction of ankle valgus following temporary

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screw ephiphysiodesis using a transphyseal medial malleolar screw. Mechanical and anatomical lateral distal tibial angle (LDTA), tibiotalar angle and fibular station were hence assessed before screw epiphysiodesis, as well as before and after implant removal.

PATIENTS AND METHODS

In the current study 23 ankles in 16 patients (7 females and 9 males), who underwent temporary epiphysiodesis using a transphyseal medial malleolar screw between 2010 and 2014 at one single institution in Zurich, Switzerland, were included. All included patients were diagnosed with ankle valgus as confirmed by clinical exam and radiographs. Patients' charts including their pre-, postoperative and follow-up x-ray images were retrospectively reviewed. Angles were digitally measured using the picture archiving and communication system (PACS) by two independent observers (SG and SL).

All patients underwent screw removal during the study period and follow-up radiological images were available. Two patients received additional distal tibial osteotomy during screw removal.

In total 10 left-sided (43,5%) and 13 right-sided (56,5%) screw epiphysiodeses were performed. Seven (30%) patients had bilateral surgery. Mean patients' age at first surgery was 12 years (ranging from 8.6 to 16.3 years). Mean patients' body mass index (BMI) was 18.41 kg/m2 (ranging from 14.8 to 23.2 kg/m2). Screw removal was carried out 16 months after epiphysiodesis on average (ranging from 3 to 31 months). Last follow-up before removal was carried out following 14.1 months (ranging from 3 to 31 months) after implantation, respectively 1,7 months (0 - 11 months) before screw removal. Follow-up after screw removal was carried out 6.7 months (2 - 22 months) thereafter (Table I). Of note, in 20 of 23 screw implantations and in 22 of 23 implant removals, additional surgical procedures not aiming at correcting a valgus deformity of the ankle were performed.

No complications (such as wound infections, non-healing wounds, implant failures, screw dislocations, etc.) occurred following screw implantation or removal, respectively. Hence no re-operation due to complications was necessary.

Table I. — Patients' data

Total number (n) of extremities	23
Total number (n) of patients	16
Unilateral/Bilateral	9/7
Gender (Male/Female)	9/7
Laterality (Left/Right)	10/13
Age at epiphysiodesis [months]	145 (132.2 - 157.5)
Age at screw removal [months]	161.4 (149.6 - 173.2)
Mean time screw in situ [months]	16 (12.7 - 19.3)

Values are given as absolute values or as mean with 95% Confidence Intervals in brackets

Several patients had concomitant diseases, including clubfoot (one patient), myelomeningocele (three patients), Down Syndrome (one patient), dysmorphia syndrome (one patient), cerebral palsy (one patient), and Pseudoachondroplasia (one patient).

Patient's bone age was assessed according to the 'Greulich and Pyle method' based on x-rays of the left hand, fingers, and wrist that are compared to the bones of a standard atlas.

The present study was approved by the local ethics committee. Informed consent was obtained from all patients' parents or legal representatives.

Four different outcomes were assessed in the present study: Mechanical (i) and anatomical (ii) lateral distal tibial angle (LDTA), tibio-talar angle (iii), and fibular station (iv).

Lateral distal tibial angle describes the angle between mechanical or anatomical axis of tibia and tibial plafond with a norm of 89 +/- 3 degrees. (11) Hence valgus deformity was diagnosed when LDTA was < 86° *(7)*.

Tibiotalar angle describes the angle between anatomical axis of tibia and tangential line to the talar dome minus 90 degrees. Hereby a tibiotalar angle of >10° was considered to be a valgus deformity *(2)*. Fibular station in relation to the distal tibio-talar joint was assessed in weight-bearing antero-posterior radiographs according to Malthora's classification *(10)*.

Digital measurements were executed using the build-in PACS viewing system SECTRA Workstation IDS7 (16.2.30.2401, 2015, Sectra AB, Linköping, Sweden). All radiographic measurements were performed twice independently by two authors (SL and SG). Differences in measurements of mechanical and anatomical LDTA greater than 5 degrees were re-evaluated by both authors and resulted in independent re-measurements.

Ankle valgus was documented with long radiographs (overall lower extremity) as well as anteroposterior view radiographs of knee to foot and foot with ankle preoperatively, prior to screw removal, and at follow-up after screw removal. Mechanical LDTA, anatomical LDTA , tibio-talar angle, and fibular station were measured for all these radiographs.

Surgery was performed by four orthopedics surgeons or under their direct supervision. A small incision over the tip of the medial malleolus was performed. An unthreaded K-wire was inserted under fluoroscopic control. Finally, a cannulated 4.0 mm (in diameter) screw was placed over the wire, and the wound was closed.

Patients were allowed to bear weight fully immediately after both surgeries (epiphysiodesis and implant removal), but were offered crutches for pain reduction if needed.

Descriptive statistics and statistical analysis were performed using Graphpad Prism® (GraphPad Software Inc., La Jolla, CA) and SPSS (Version 22, IBM Corp., Armonk, NY). P-values of 0.05 or less were considered statistically significant. Results are given as mean with 95% confidence intervals. Statistical tests included ANOVA with post-hoc Dunnett's Multiple Comparison Test (for parametric data), and Kruskal-Wallis test with post-hoc Dunn's Multiple Comparison Test (for non-parametric data).

Bivariate correlations were computed using Pearson product-moment correlation coefficient. Interobserver reliability was computed using Cohen's K for nominal variables and ICC (Intraclass Correlation Coefficient) for metric parameters. Correlations were performed by linear regression analysis.

RESULTS

Mean mechanical and anatomical LTDA were significantly ($p < 0.001$) improved on last follow-up before implant removal (85.2° and 85.3° on average, respectively) when compared to values prior epiphysiodesis (75.6° and 75.7° on average, respectively). After screw removal values for angles decreased to 82.5° and 82.9° on average (excluding two patients with additional osteotomy during implant removal), but still showed significant improvement compared to initial angles (Figure 1a and 1b).

Similarly, mean tibiotalar angle was significantly ($p<0.001$) larger (14.2°) before screw epiphysiodesis when comparing to the last follow-up before screw removal (5.8°) (Figure 1c).

Mean degree of angle correction with screw in situ was 1.17°/month in mechanical axis, 1.19°/month in anatomical axis and -0.5°/month in tibiotalar angle.

Excluding two patients receiving additional osteotomy during implant removal, we observed a mean rebound of angles after screw removal of -2.7° in mechanical axis, -2.4° in anatomical axis and 3.0° in tibiotalar angle. Rebound seemed to be greater in younger children (figures 2a-d). Whereas simple linear regression analysis did not show a correlation between rebound and patient's age (anatomical LDTA: $r2 = 0.039$, $p = 0.39$; mechanical LDTA: $r2 = 0.085$, $p = 0.2$) (figures 2a-b).

Histogram of fibular station distribution was not significantly different before surgery versus before and after screw removal. The percentage of patients with a normal fibular station of zero was almost doubled after epiphysiodesis (9/23 = 39%) as compared to prior to surgery (5/23 = 22%) (no statistical test applied) (Figure 1d).

Fibular station at different measuring points was neither significantly correlated to mechanical or anatomical axis prior surgery (both $p = 0.1$) nor post surgery ($p = 0.49$ resp. $p = 0.34$) or at follow-up after screw removal concerning mechanical axis ($p = 0.08$). After screw removal, fibular station was significantly correlated negatively to anatomical axis (correlation coefficient -0.44, $p = 0.04$).

No other variables (including age at epiphysiodesis, height, weight, sex, surgeon performing

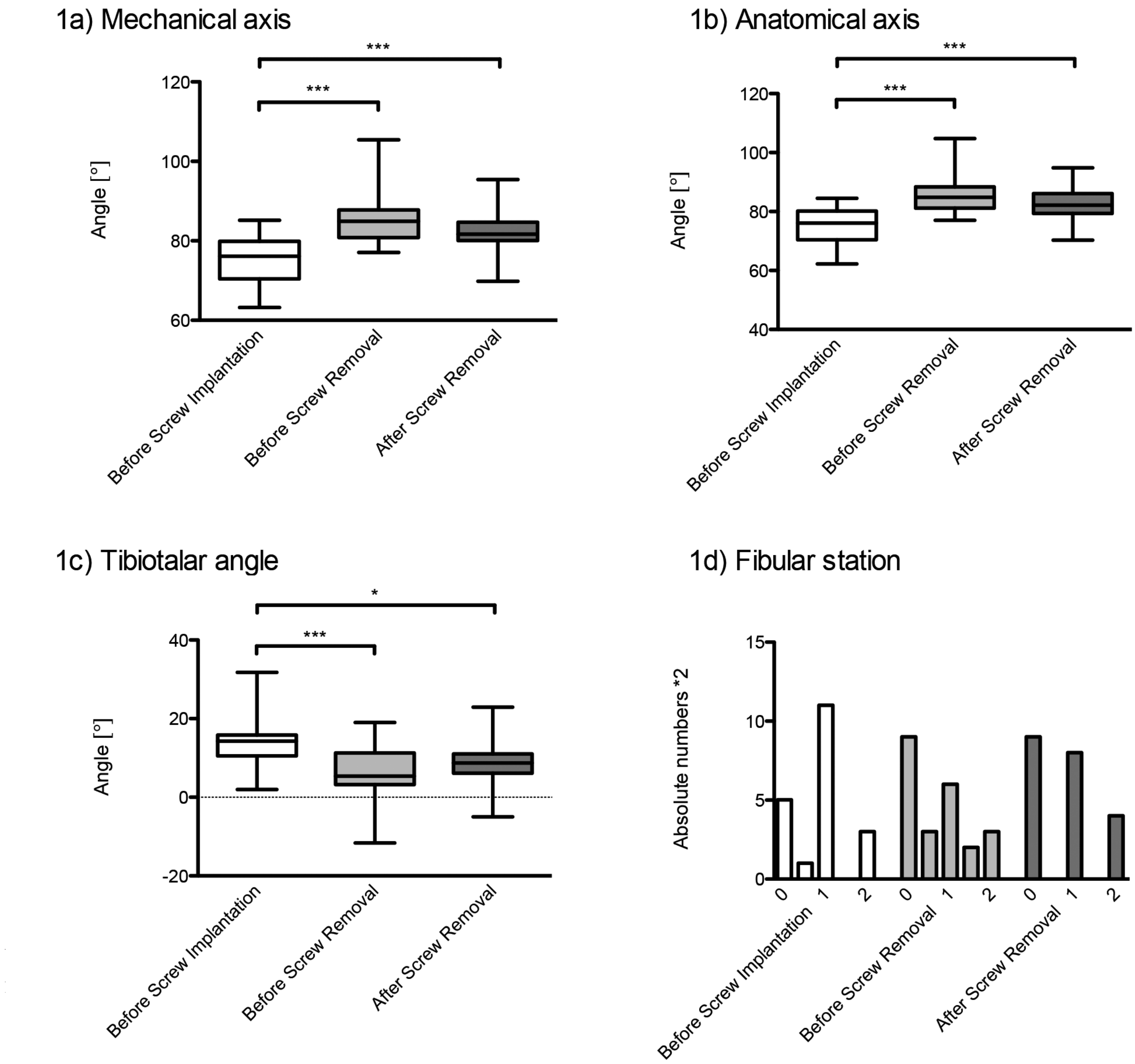

Fig. 1. – *Figure 1 - Mechanical axis, anatomical axis, tibiotalar angle, and fibular station over time.*
Figure 1a-c: Boxplots of mechanical axis (1a), anatomical axis (1b), and tibiotalar angle (1c) before screw implanation (white), before screw removal (light grey), and after implant removal (dark grey (2 values with simultaneous osteotomy removed)) (solid line = median, box limits = 25th and 75th percentiles, whiskers = maximum or minimum observations). Figure 1d: Histogram of fibular station ranging from 0 to 2 before screw implantation (white), before screw removal (light grey), and after implant removal (dark grey (2 values with simultaneous osteotomy removed)) (shown is the mean of assessed values by two independent authors (SL and SG); disagreement among authors could led to values of 1.5 and 2.5).

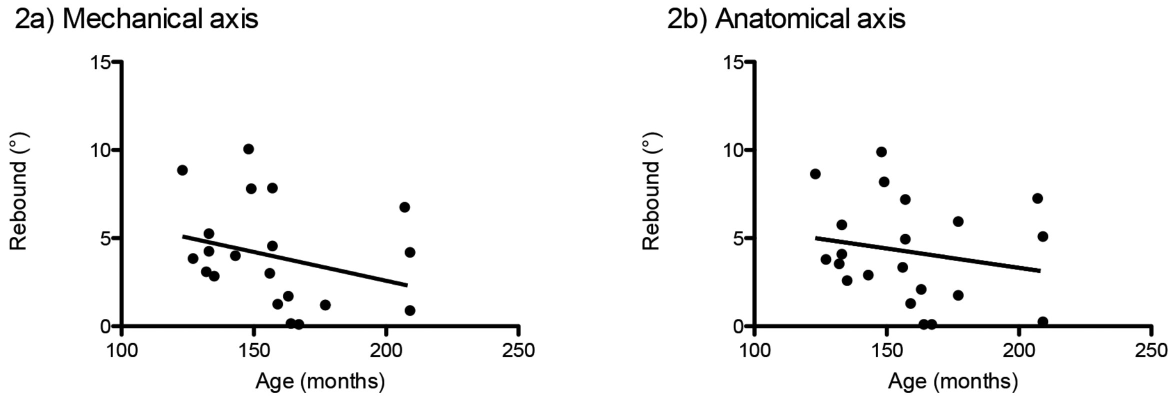

***Fig. 2.** – Rebound following screw removal according to patient's age.*
Figure 2a-b: Linear regression analysis modeling the relationship between rebound of angles (y-axis) (2a: mechanical axis; 2b: anatomical axis) and patient's age (x-axis).

DISCUSSION

Several techniques exist for the correction of ankle valgus in children, including medial malleolar screw epiphysiodesis, surgical osteotomy, and guided growth with medial tension plate banding across the physis. Surgical osteotomy is the most invasive of these three techniques, and is more commonly used as salvage therapy when a minimally invasive approach has failed to provide adequate correction of the valgus deformity. Both screw epiphysiodesis and medial tension band techniques work on the same principle of mechanically limiting axial growth on the medial side of the physis, and both techniques allow for full weight bearing immediately after the procedure, an advantage over osteotomy. One possible advantage of screw epiphysiodesis over the tension band technique is a more rapid rate of correction, estimated by one comparative study to be over 50% faster *(15)* though this difference did not reach statistical significance in this study with a p = 0.057. The complications of both of these techniques are generally minor (such as bony overgrowth of the screw head leading to difficult extrication, broken hardware, infection), but seem more common with the screw epiphysiolysis technique *(15)*. Another advantage of the medial tension band technique is that it leaves the physis undisturbed, which could theoretically reduce the probability of permanent physial arrest and over-correction of the deformity, although none of the case series we reviewed reported instances of this complication.

The aim of the present study was to assess the efficacy of transphyseal medial malleolar screw epiphysiodesis to treat ankle valgus in a case series of children and to compare our experience to the existing literature.

Screw epiphysiodesis yielded in satisfactory (i.e. correction of lateral distal tibial angle up to 89° +/- 3° and tibiotalar angle under 10°) results in 14 patients (21 ankles), whereas fibular station non-significantly changed over time *(2,8)*. An inadequate outcome necessitating additional tibia osteotomy was necessary in 2 patients (2 ankles (8.7%)) at the time of implant removal.

The age of these two patients (needing additional tibia osteotomy) was 15 10/12, and 12 4/12 years respectively. The older patient was male without any concomitant diseases, the younger patient was female with cerebral palsy. It might be assumed that failure of temporary screw epiphysiodesis occurred due to late screw implantation with little epiphyseal growth and correction potential remaining.

No complications after surgery, neither following screw epiphysiodesis, nor past implant removal occurred. Mean degree of angle correction with screw in situ was 1.17°/month in mechanical axis,

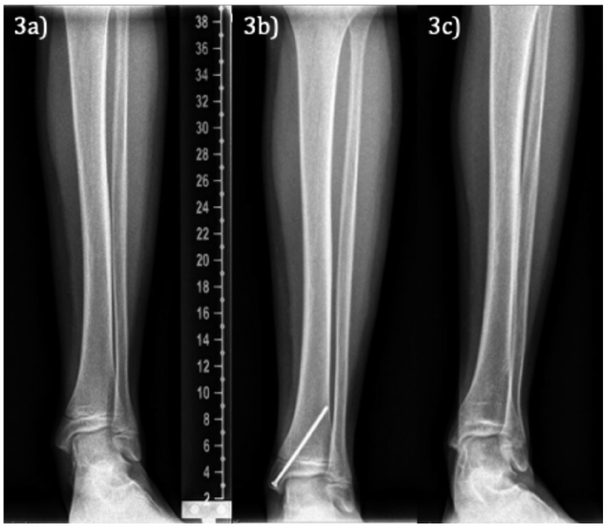

Fig. 3. – *Anteroposterior radiographs of a representative patient undergoing screw epiphysiodesis.*
Figure 3a-c: Anteroposterior view of a lower limb radiograph before screw implantation (3a), after screw implantation (3b), and after screw removal (3c). The scale on picture 3a is given in centimeters.

1.19°/month in anatomical axis and -0.5°/month in tibiotalar angle matching with previous reports showing corrections in tibiotalar angle of -0.63°, and -0.59° per month, respectively *(3, 7,13)*. Mean rebound of angles after screw removal was -2.7° in mechanical LDTA, -2.4° in anatomical LDTA, and 3.0° in tibiotalar angle over 9 months on average (ranging from 2 - 22 months). Rebound of more than five degrees occurred in 6 patients regarding the mechanical (28,6%) and 8 patients regarding the anatomical LDTA (38.1%), respectively (excluding the two distal tibia osteotomies), which is in line with previous studies showing a rebound > 5° in up to 43 % of treated patients.(13, 19) The rebound effect seemed to be more pronounced in younger children, as expected. A slight overcorrection is hence intended following screw epiphysiodesis *(3,17)*. An adequate temporal planning including the patient's growth potential, as well as regular radiologic controls are crucial to achieve a reasonable correction of ankle valgus *(6,14,18)*. Patients in the present study were 12.1 years on average at epiphysiodesis, and repeated radiologic controls were performed.

Screw epiphysiodesis has to be performed while the physis is open enabling sufficient correction potential due to remaining bone growth. While bone age may be assessed according to the 'Greulich and Pyle method' based on x-rays of the left hand, fingers, and wrist that are compared to the bones of a standard atlas, the remaining growth potential of the distal tibia may be calculated using the normogram of 'Green and Anderson' assuming that distal tibia contributes to 40 per cent of total tibial growth *(15)*. Bone age and the remaining growth potential were assessed accordingly in the present study.

One can predict that 10 degrees of tibiotalar valgus deformity can be corrected by preventing 1 cm of medial epiphyseal growth, allowing for the optimal age of epiphysiodesis to be determined *(1)*.

To date, not many reports assessing the outcome after temporary percutaneous medial malleolar screw epiphysiodesis are published. Furthermore, most reports focus on mechanical and anatomical LDTA, tibiotalar angle, or fibular station, but do not report all these outcomes togeter *(1,13,16)*. The present case series adds another 23 ankles to the current published literature and documents mechanical and anatomical LDTA, tibiotalar angle, and fibular station as outcomes.

A main limitation of the present study clearly reflects its retrospective study design together with the relatively small number of included patients making this study prone to bias. Furthermore, in two patients simultaneous distal tibial osteotomy was performed while screw removal. Post removal radiographs were hence confounded by the osteotomy and could not be included in the analysis. Slight leg-rotation/angulation on the taken radiographs could further have confounded the angle measurements.

CONCLUSIONS

Taken together, temporary screw epiphysiodesis reflects an easy and safe method to treat ankle valgus in children with open epiphyseal fusions.

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