Acta Orthopaedica et Traumatologica Turcica xxx (2016) 1–5

Contents lists available at ScienceDirect

Acta Orthopaedica et Traumatologica Turcica

journal homepage: https://www.elsevier.com/locate/aott

Is there a correlation between the change in the interscrew angle of the eight-plate and the delta joint orientation angles?

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ARTICLE INFO

Article history:
Received 3 March 2016
Received in revised form
21 April 2016
Accepted 28 May 2016
Available online xxx

Keywords:
Hemiepiphysiodesis
Eight-plate
Correlation
Screw divergence
Joint orientation angle
Interscrew angle

ABSTRACT

Objectives: It is known that the screws of the eight-plate hemiepiphysiodesis construct diverge as growth occurs through the physis. Our objective was to investigate whether there is a correlation between the amount of change of the joint orientation angle (JOA) and that of the interscrew angle (ISA) of the eight-plate hemiepiphysiodesis construct before and after correction.
Patients and methods: After the institutional review board approval, medical charts and X-rays of all patients operated for either genu valgum or genu varum with eight-plate hemiepiphysiodesis were analyzed retrospectively. All consecutive patients at various ages with miscellaneous diagnoses were included. JOA and ISA were measured before and after correction. After review of the X-rays, statistical analyses were performed which included Pearson correlation coefficient and regression analyses.
Results: There were 53 segments of 30 patients included in the study. Eighteen were males, and 12 were females. Mean age at surgery was 9.1 (range 3–17). Mean follow-up time was 21.5 (range, 7–46) months. The diagnoses were diverse. A strong correlation was found between the delta JOA (d-JOA) and delta ISA (d-ISA) of the eight-plate hemiepiphysiodesis construct ($r = 0.759$ (0.615–0.854, 95%CI), $p < 0.001$). This correlation was independent of the age and gender of the patient.
Conclusions: There is a strong correlation between the d-ISA and the d-JOA. The d-ISA follows the d-JOA at a predictable amount through formulas which regression analysis yielded. This study confirms the clinical observation of the diverging angle between the screws is in correlation with the correction of the JOA.
Level of evidence: Level IV, Therapeutic study.

Introduction

The eight-plate is a tension-band plate and screws construct. It involves a two-hole titanium plate with a figure of eight configuration used with two nonlocking 4.5 mm cannulated cortical screws. It shows its effect by limiting the growth of the hemiphysis over which it is applied, and as the contralateral side of the physis continues to grow and expand, the screws of the eight-plate construct diverge.[1] Since it was introduced to the literature by Stevens[2] it has become popular in deformity correction in the growing skeleton. The surgeons using this implant observe that the screws diverge as the correction takes place.[2] Divergence of the screws represent growth in the related physis.[2–4] However it has not been studied before whether this divergence of the screws correlates with the amount of correction that takes place in the individual bone segment, femur or tibia. One of the problems that arises in the follow-up of patients who undergo eight-plate hemiepiphysiodesis is that in order to assess the degree of correction the surgeon needs to see the X-rays of the entire individual bone segment; such as AP femur or AP tibia, or the entire lower extremity. At times, those X-rays might be missing the femoral head for the femur, or ankle for the tibia. Sometimes the patients live in areas with limited resources, and would be asked to travel back and forth in order to get proper X-rays. An alternative to that could be not taking X-rays and following patients with clinical judgment, however that could yield imprecise results. The rationale behind this study was that if there is a close enough correlation between

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Peer review under responsibility of Turkish Association of Orthopaedics and Traumatology.

http://dx.doi.org/10.1016/j.aott.2016.05.005

Please cite this article in press as: Marangoz S, et al., Is there a correlation between the change in the interscrew angle of the eight-plate and the delta joint orientation angles?, Acta Orthop Traumatol Turc (2016), http://dx.doi.org/10.1016/j.aott.2016.05.005

the change in the joint orientation angle (JOA) and the change in the interscrew angle (ISA), the patients could be instructed to have only an AP knee X-ray taken instead of a full-length individual bone X-ray until close to full correction. We investigated whether there is a correlation between the delta joint orientation angles (ΔJOA or d-JOA), namely the mLDFA (mechanical lateral distal femoral angle) and MPTA (medial proximal tibial angle),[5] and the delta interscrew angles (ΔISA or d-ISA). We aimed to derive formulas through regression analyses that would enable estimation of JOA when one knows the ISA. The hypothesis was that a close correlation exists between d-ISA and d-JOA regardless of the remaining growth potential of the related physis.

Patients and methods

This was a retrospective study to include consecutive patients treated with eight-plate hemiepiphysiodesis at a single university hospital between 2009 and 2013. After the institutional review board approval, patients were identified retrospectively according to the surgery type. Inclusion criteria involved patients operated for genu valgum or genu varum, and treated by eight-plate hemiepiphysiodesis in the distal femur and/or proximal tibia. Patients with all diagnoses at all ages were included. Diagnoses were miscellaneous from congenital, developmental, metabolic, posttraumatic and idiopathic causes. They included Blount's disease, Diamond-Blackfan syndrome, cystinosis, diastematomyelia, fibular hemimelia, Fanconi-Bickel syndrome, Stickler syndrome, rickets, multiple hereditary exostosis, congenital absence of patella, arthrogryposis, coxa vara, mucopolysaccharidosis, and posttraumatic (Cozen phenomenon). Exclusion criteria included double plate hemiepiphysiodesis of the same hemiphysis[6] and simultaneous eight-plate applications of both proximal tibia and distal tibia hemiphyses within the same tibia segment. X-rays were obtained before the surgery, at the immediate postoperative period and at the final follow-up. Accompanying surgeries at the same setting were noted. Ipsilateral proximal tibial osteotomies were performed in 5 cases together with distal femoral hemiepiphysiodesis. Middiaphyseal femoral osteotomies were done in two cases together with distal femoral hemiepiphysiodesis and a distal tibial osteotomy was performed in one case together with proximal tibial hemiepiphysiodesis (Table 1). The remaining 45 segments had eight-plate hemiepiphysiodesis, only. In three patients where the osteotomy was performed within the same segment, correction through the osteotomy site was acute. The mLDFA or the MPTA in those patients were measured on the immediate postoperative X-ray, instead of a preoperative X-ray. Final follow-up X-ray was determined as the last X-ray with the eight-plate on the bone. Mechanical axis of the lower extremity was not a parameter to be measured at any time during the study. All measurements were made within the same individual bone segment, either femur or tibia. Demographic characteristics of the patients along with the type of the frontal plane deformity present, the treatment modality, if any, accompanying surgeries, and duration of follow up are given in Table 1. Patients received the same postoperative care. They were allowed to do range of motion exercises, and weight-bear as tolerated immediately. All patients included in the study have completed the follow-up.

Joint orientation angles, namely, the mLDFA and MPTA were measured on preoperative and postoperative AP X-rays of femur or tibia, respectively. Interobserver and intraobserver reliability of these angles were tested previously, and it was stated as good to very good.[7] Two of the investigators who were trained in limb deformity analysis reviewed the X-rays on two separate occasions. Intraclass correlation coefficient was used in testing agreement. We described 'Interscrew angle' (ISA) as the angle between the long axes of the screws of the eight-plate on each side of the physis (Fig. 1). Because most of the segments were valgus and few were varus, instead of the joint orientation angles themselves, the difference between the before and after measurements were obtained. So a delta value for each JOA was calculated. Immediate postoperative and final follow-up ISAs were measured and the difference was analyzed in comparison to the preoperative and final follow-up JOAs in order to find a correlation using Pearson correlation coefficient. Regression analyses were performed while investigating the effect of ISA on the JOA. Statistical analysis was performed with IBM SPSS Version 21.0 for Windows (SPSS Inc., Chicago, IL, USA). Continuous variables in this study were given with mean ± standard deviation or median [min – max] as appropriate. Categorical variables were summarized as frequencies and percentages. Correlation between the changes in angles was determined by Pearson correlation coefficient. Stepwise multiple linear regression analysis was used to verify the relation between JOA and ISA. Significance level was determined as $p < 0.05$. Confidence intervals at 95% were noted, as well. The resultant data were reviewed and analyzed by a biostatistician.

Results

There were 53 segments of 30 patients included in the study. Eighteen were males, and 12 were females. Mean age at surgery was 9.1 (range 3–17). There are 29 femurs, and 24 tibias included in the study. Four patients had all four segments operated. Fifteen patients had single segment operated, femur or tibia. The remainder had two segments operated horizontally or vertically. Thirty-three segments (18 femur and 15 tibia) were operated using eight-plate (Orthofix, Verona, Italy), and 20 segments (11 femur and 9 tibia) were operated using eight-plate (Ortopro, Istanbul, Turkey). Both products have same material properties and implant design. The two different brands did not show any significant difference in terms of correlation between the d-JOA and d-ISA ($p = 0.994$). Mean follow-up time was 21.5 (range, 7–46) months. Intraclass correlation coefficient (ICC) yielded very good interobserver and intraobserver reliability (ICC was 0.950 for JOA and 0.993 for ISA for the interobserver reliability, and 0.980 for JOA and 0.997 for ISA for the intraobserver reliability). The ISA in the femur changed from 12.1 ± 10.1° at the immediate postoperative period to 32.3 ± 14.3° at the final follow-up and in the tibia it changed from 8.3 ± 8.0° at the immediate postoperative period to 25.4 ± 12.8° at the final follow-up. The d-ISA in the femur was 20.2 ± 9.8° and in the tibia it was 17.1 ± 11.4°. The d-JOA in the femur was 14.9 ± 7.9° and in the tibia it was 9.2 ± 6.6°. Scatter Plots have been created for evaluating the correlation between the d-JOA and the d-ISA, which revealed linear correlation. Using Pearson correlation coefficient, strong correlation was found between d-JOA and d-ISA. ($r = 0.759$ (0.615–0.854, 95%CI), $p < 0.001$). Because strong correlation was found between the d-JOA and d-ISA, stepwise multiple linear regression analyses were carried out in order to create formulas that will allow us to make some predictions. Age, gender and d-ISA were considered as independent factors to predict d-JOA. As a result of the analysis, only d-ISA was found significant. Following are such formulas: For femurs ($\Delta JOA = 2.519 + 0.611 \times \Delta ISA$) and for tibias ($\Delta JOA = 1.385 + 0.457 \times \Delta ISA$). 95% Confidence Intervals were given along with these scatter plots that described strong correlation (Fig. 2A and B).

Discussion

Tension band hemiepiphysiodesis is a well-established technique that corrects deformities through the contralateral growing hemiphysis by tethering the ipsilateral hemiphysis after the

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