TOWARDS A COMPUTER-AIDED PLANNING PROCEDURE FOR EPIPHYSIODESIS SURGERY

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Introduction

Epiphysiodesis is a common treatment for growth arrest in adolescent patients. The goal is to surgically remove the growth plate (GP) with minimal removal of adjacent bone [1][2]. To this end, a surgical incision is made at the height of the GP where a surgical drill is inserted and as much as possible GP is removed. Presently, however, the surgical method used for the epiphysiodesis (e.g. location of incision / used instruments) is mostly based on experience of the surgeon and preference of the patient with respect to the scar location, and it is unclear if large differences would exist for different incision locations. The goal of this study therefore was to determine differences in GP and adjacent bone removal for different incision locations and drill diameters for a population of patients. It is expected that these results can help to decide if a patient-specific computer-aided planning would be useful.

Methods

MRI images of 23 patients (age: 12-14 years) were available from which the distal femur and proximal tibia GPs were manually segmented. A statistical shape model (SSM) of the GP was created to assess the variation in GP morphology in this population.

Then, a computational intersection algorithm was developed to simulate epiphysiodesis surgery for 2 drill diameters (4.5 or 9 mm), 3 locations (lateral L, medial M or bilateral BL) and 3 positions (at the GP level GPL, 10 mm superior S or 10 mm inferior I). With this algorithm, a cylindrical volume was generated (representing the drill) with its central axis starting at each voxel representing the GP running to the incision center, and the sum of the amount of bone within all cylindrical volumes was assessed. For the neighboring bone, 2 zones were defined: a danger zone that is <5 mm from the GP, and a forbidden zone that is >5 mm from the growth plate. The algorithm was applied to the mean SSM model as well as to the models representing the ±2SD of mode 1 and 2. The main outcome parameter was the amount of GP that could be ablated without touching the forbidden zone. In addition, it was determined how much of the danger zone needed to be removed to completely remove the GP.

Results

The SSM analysis revealed that most of the variation (80%) in GP shape related to the location of the curvature of the plate (mode 1) and the entire size of the plate (mode 2).

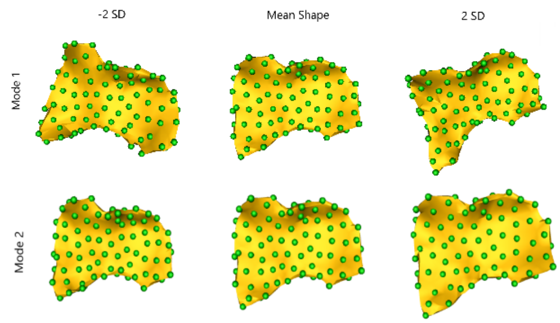

Figure 1: The first two principal modes of variation for the distal femur GP SSM, mean ± 2 SD.

For all cases 100% of the GP could be ablated without touching the danger zone, except for the 9 mm drill where still at least 82% of the GP could be ablated but up to 2% of the forbidden zone would need to be removed for full GP removal. The amount of danger zone bone removed varied in the investigated cases between 20% and 37% (Fig. 2).

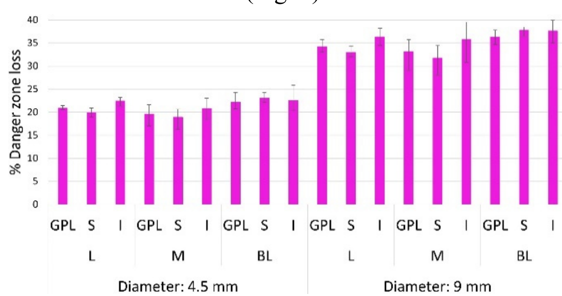

Figure 2: Ablated danger zone (%) for complete removal of the distal femur GP depending on incision site, drill diameter and position. Error bars represent the variation in shape models for mode 1 (mean ± 2 SD).

Discussion

The intersection algorithm showed that with a 4.5 mm drill both the distal femur and proximal tibia GP could be completely removed. For a 9 mm drill, however, small amounts of the forbidden zone would need to be removed and more damage to the danger zone was created. In both cases, on average, the amount of damage created to the danger zone was not very sensitive to the incision location and position. Nevertheless, considerable differences were found between geometry modes, suggesting that a computer-aided patient-specific planning could be useful.

References

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2. M. Inan et al, J. Pediatr. Orthop., vol. 28, no. 6, 2008