Mathematical Modeling for the Evaluation of Hexapod Frames Stability and Correction Path

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What was the question? The stability of fixation and trajectory of bone fragments movement during correction using external fixation devices are among important parameters influencing distraction regenerate formation and treatment time. The use of the hexapod–type external fixators allows simultaneous correction of multiple deformities and should provide smooth path to final correction. However, it is recognized that the existing hexapod–type external fixators have a certain degree of free play between the external supports. The purpose of this work was to create mathematical model which will help to predict the degree of instability and real path of the fragment movement for the various known hexapod frames.

How did you answer the question? Struts of different hexapod external fixators and connections between struts and external supports were mechanically tested to evaluate the amount of mobility in different planes for each connection node. Based on the testing data mathematical models were built for four available hexapod fixators. Using mathematical modeling we had developed a software application which allows to enter parameters of deformity, frame and mounting parameters to predict the amount of the free play between bone fragments. Independently, algorithms of deformity correction for two available web–based software programs were analyzed. TSF software and TL–Hex wed application use two different approaches to perform calculations of daily strut adjustments. Based on the mathematical models of these calculations another software application was developed. This application allows to perform calculation of the trajectory of bone fragment movement based on the deformity, frame, and mounting parameters.

What are the results? For all the hexapod models software demonstrates that the free play values increase in response to decrease of the distance between two rings as well as an increase of the angle between the rings. The amount of the free play though was substantially different between different frames. The minimal values of the inter–fragmentary motion were: 1.6 mm (TSF), 2.1 mm (Ortho SUV), 1.1 mm (PoliHex), 0.5 mm (TL–Hex). The displacement of the fragments as a result of the free play can reach up to 5.4 mm for the TSF frame; 7.5 mm for the Ortho SUV; up to 2.0 mm for the PoliHex and 0.9 mm for the TL–Hex frame. The analysis of trajectories of bone fragments motion revealed that TL–Hex software provides shorter path to the final correction, while in TSF software the trajectory of bone fragments was curvilineal with significant deviations from the straight line during each increment of movement reaching more than 15 mm from the direct path. The daily bone fragments travel may exceed 1 mm from the direct trajectory.

What is your conclusion? Mathematical modeling and the developed software applications can be helpful in selecting the optimal hexapod frame configurations with the minimal amount of free play. It can also help chose the more suitable device for the particular deformity and frame configuration. This analysis does not include the fixation elements (wires and half–pins) and therefore only predicts the value of the instability of the frame components. The trajectory of the bone fragments motion during correction can be curvilinear in some of the hexapod external fixators and need to be considered while planning the correction.