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Short Communication

Computational Biomechanical Models for Prediction of Scoliosis Surgery Outcome in Adolescent Idiopathic Scoliosis

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Adolescent idiopathic scoliosis is the most common form of scoliosis around 80% of all the cases [1]. It is a complex three-dimensional structural deformity of the human spine whose aetiology is unknown and mostly occurs in females [2]. Surgery is often required for correction of the severe cases (Cobb angle [3] greater than 45°) by using spinal instrumentation [4].

Planning the surgery is a complex procedure that involves many difficult decisions made by surgeons, specifically decisions made on the instrumentation configuration, i.e. the vertebrae fused together and their relative location and orientation. Such decisions can result in different correction results for a patient [5]. Despite the current use of various 2D radiological curvature pattern classifications to predict the surgery outcome after selective fusion [6], the prediction is mostly made by the surgeons' clinical experience and interpretations of the literature [7]. Therefore, the information concerning the prediction of the surgery outcome is highly demanded [8-14]. Such predictive information allows surgeons to explore different instrumentation configurations and evaluate their appropriateness for a patient, and accordingly, propose a better instrumentation configuration so as to enhance the correction of the scoliotic deformity [8,15].

Computational biomechanical models of scoliotic spine can be helpful to predict the surgical correction as a function of instrumentation configuration. The models can help identify a better configuration for a given patient before the implementation of the actual surgery and thus, mitigate the surgical complication risks [7,8]. Nevertheless, a few models have been developed for prediction of the surgery outcome [15,16]. The developed models are typically based on finite element methods and multibody formalisms [15].

The models based on the finite element methods (e.g. [17] have some major issues for use in the prediction of the surgery outcome; both from the mathematical point of view and clinical use point of view. From the mathematical point of view, the models require a high computational power relating to the number of elements used to create the models and thus, a long processing time [18]. In general, the greater the total number of the elements is, the more accurate the predictions are; but, the greater the demand is on the computational power and processing time, and the more convergence problems occur during simulation runs [19]. Another major issue is that the solutions may not be unique [20]. From the clinical use point of view, the availability of the predictive information in a short time is crucial for surgeons especially when modifying their decision about the fusion levels. This may not be offered by the existing finite element models because of their long processing time due to the high computational expenses. Overall, it can be said that the finite element models, may not be good for the surgery prediction application from the mathematical point of view, and are not surgeon-friendly from the clinical use point of view [8].

In contrast, the models based on the multibody formalisms are less complex, less computing expensive, and easier to validate [15]. In addition, they allow incorporation of independently developed models into the whole system because loads can be transferred to the model segments and analysed without changes in the boundary conditions [21]. Hence, the multibody models would be better for the application of the surgery prediction [15]. In spite of the potential benefits of multibody formalisms, few scoliotic spine models e.g. [22] have been developed based on the multibody approach. The developed models, however, may not offer sufficiently accurate predictions; the best models could offer ±5° prediction error for the post-operative Cobb angle. However, two spines with Cobb angle difference of 5° can be visually very dissimilar in terms of concavity [8]. Therefore, there is a need for a multibody scoliotic spine model that is more accurate for prediction of the surgery outcome as a function of the instrumentation configurations, which is considerably lacking in previous studies. Such a model can offer many potential benefits and can be used for many applications:

- Better patient/parent counseling by visualizing the virtual correction of the spine curvature, reducing patient/parent anxiety, improving the understanding of the disease, and encouraging better patient's/parent's compliance to the prescribed treatment,

- Evaluating different instrumentation configurations to identify a better surgical correction for a patient in order to mitigate surgical complication risks and increase the patient safety because the instrumentation configurations can be tested before their clinical application. This is contrary to the current less optimal clinical practice in which the instrumentation configurations are often used for a patient without testing,

- Allowing surgeons to practice their decision-making in instrumentation configuration selection to ensure greater clinical success for real patients. This can be one of the important future applications of such scoliotic spine model because suboptimal surgery plans and poor understanding of the mechanics of correction

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can lead to many serious problems such as the instrument extraction and rods breakage.

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