EOS 3D Imaging: assessing the impact of brace treatment in adolescent idiopathic scoliosis

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One of the major revolutions in the field of adolescent idiopathic scoliosis (AIS) during the past 10 years is the development of 3D imaging devices in standing position, such as EOS (EOS Imaging). 3D vision of the spine is new; we need to be humble and learn how it may help in the management of AIS. But we now have access to the transverse plane deformity. We do not know how to heal idiopathic scoliosis. Thus, the main issue in the field of AIS management is to avoid progression of mild scoliosis. Brace treatment is the main treatment option for mild scoliotic patients during growth. However, the efficacy of brace treatment is not consensual. We have demonstrated through a 3D analysis of brace treatment that some braces are truly efficient, some are not and others worsen the spinal deformity. Therefore, we have to anticipate the effect of a brace on a specific patient. With 3D analysis we are now able to evaluate if a brace really improves the spinal shape in the 3 dimensions or not. Moreover, we have the patient 3D geometry (spine and rib cage) and we are able to collect objective clinical data that could help achieve relevant parametric finite element models. These models could help in the prediction of brace effect but they need to be validated with clinical data. We see a close future where we will all have the 3D trunk shape of our patients on our screens along with all computed angles we need and then an instant prediction for the best-fit brace geometry for our patient.

One of the major revolutions in the field of adolescent idiopathic scoliosis (AIS) during the past 10 years is the development 3D imaging in standing position. The concept of AIS as a 3D deformity was brought for the first time in the early 80s by Perdriolle [1] and Dubousset and Graf [2]. Before them, AIS was a curve on a single AP view radiograph. From the concept to the routine use of 3D, we had to wait until the 21st century and the work of Georges Charpak, the 1992 Nobel Prize of physics, to see the development of standing position stereoradiography and its evolution in the actual EOS system (EOS Imaging) [3]. Accuracy and reproducibly of the system and its software for 3D reconstruction of the spine have been validated and are constantly improving [4]. From now on, 3D analysis of the spine in a standing position is possible routinely.

Now that we have the tool, we have to learn how to use it. AIS professionals all over the world have learned AIS from the patient and from standard AP and lateral X-rays. 3D is new and EOS provides a large amount of data. We therefore need to be humble and learn a new way to describe AIS. EOS and 3D have created a lot of questions and but few answers yet. One thing is sure; we now have a good point of view on the transverse plane, which we think, is where we can early detect a progressive AIS deformity. We have demonstrated that a progressive curve had a specific 3D pattern, which can be detected early before the progression of the Cobb angle [5]. This test could be accessible at the first clinical exam from a single EOS

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stereoradiography and could predict the evolution of a mild scoliotic curve (Cobb angle <25°). Before, we had to wait 6 months or one year and consecutive radiographs to diagnose a progressive curve.

We do not know how to heal idiopathic scoliosis. Thus, the main issue in the field of AIS management is to avoid progression. But progression was the only way to be sure to treat only true progressive AIS. Now, by means of the 3D progressive pattern, it is possible to treat only progressive AIS at the first exam. But at this stage, for mild scoliosis with a Cobb angle below 25°, treatment options are not consensual. Most surgeons would recommend a simple medical supervision but few would initiate a brace treatment. Because we know that each step toward progression of a scoliotic curve is a point of no return, we think that the earlier the treatment is started, the more efficient it will be. Despite the actual recommendations [101], we think a mild scoliosis (Cobb <25°) needs a brace at the first exam, if we can prove it is a potentially severe curve. The controversy stands in the surgeons' opinion of the efficacy of brace treatment. Several authors have underlined the lack of statistical evidence of brace treatment efficacy [6]. However, we have recently demonstrated that this lack of statistical evidence should not restraint the use of brace treatment [7]. Some braces are truly efficient, some are not and others worsen the spinal deformity. Our plea is to invite AIS professionals to consider a specific brace for each specific patient and not to standardize brace treatment. And most of all we need to analyze the 3D effect of the brace on the spine.

The difficulty of brace treatment is to obtain a 'patient-specific' treatment. Between the patient's scoliotic curve with its specificity (age, magnitude, reducibility, location, and so on) and a 'patient-specific-tolerable' brace, stands a great gap, which could be filled partially with 3D Imaging. The main issue is to predict the effect of a brace on a specific patient. Before 3D, we could only predict the effect of braces empirically. With 3D, we are able to start digitizing each step of the whole process of brace conception.

The first main step is to achieve a 3D reconstruction of the rib cage and the external trunk shape along with the spine. Then we will need the most realistic finite element model (FEM) of the spine and chest. We have yet progressed toward this goal with a recent study on the validation of a method of 3D reconstruction of the rib cage in scoliotic patients [8,9]. With actual systems of computer- assisted conception of braces, the external trunk shape is easily obtained. A combination of the external trunk shape with the EOS 3D skeletal reconstruction of the spine and chest should provide a patient-specific 3D geometrical model. It is the key point to assess the effect of a brace on the whole trunk with parametric FEM.

Parametric FEM of the scoliotic spine and the growing spine have been developed during the past 10 years [10,11]. Numerical models were also created to predict the effect of brace treatment but their main limitation was that they were not clinically validated [12,13]. With 3D analysis of the spine and brace treatment, we have the patient 3D geometry and we are able to collect the missing clinical data in order to achieve more relevant parametric FEM. But there are still problems to solve. For example, flexibility of the curve is a difficult parameter to implement in a FEM because it relies on different factors like the age of the patient, the location and the severity of the curve [14]. It is true for severe curves, but flexibility becomes more negligible for mild scoliosis as they are almost all completely flexible. This is the reason why we promote a brace treatment for mild scoliosis below 25°.

Nonetheless, the harder work is now to collect 3D data on our patients and to distinguish what is efficient or not with the different types of braces for each specific type of curve. We have to leave the era of empiric conception of braces and to formalize the process. The principles of correction are similar for most of braces but each designer claims to reach better correction in the three planes than the other. We need to overwhelm our egos and reach reproducible scientific data. With 3D analysis, we are now able to evaluate if a brace really improves the spinal shape in the 3 dimensions or not. Once brace conception will cease to be a self-interested business on a self-designed brace, randomized prospective studies will reassure skeptical surgeons on brace efficacy.

EOS 3D Imaging system is a great tool, which announces a great improvement of our knowledge of AIS and its management. EOS software improves permanently and engineers are working on more automation of 3D reconstruction. Furthermore, EOS system is a low-dose imaging system, which is more suitable for the follow-up of children than standard full spine X-rays. Tomorrow, we will all have the 3D trunk shape of our patients with on our screens along with all computed angles we need. We will have parametric models that will instantly predict the best-fit brace for our patient. Then the clinical and 3D radiological data during the follow-up will improve the model. It is not science fiction it is the close future.

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