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Title
A Review of 3-D Ultrasound Application in the Process of Screening, Evaluation and Orthotic Treatment of Patients with Adolescent Idiopathic Scoliosis

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Summary
X-ray measurement is the gold standard of curve assessment in subjects with Adolescent Idiopathic Scoliosis (AIS). Clinical ultrasound has been utilized to facilitate the monitoring of the curve progression while eliminates frequent radiation to adolescents throughout the treatment procedure.

Introduction
AIS is a three dimensional (3D) spinal deformity characterized by lateral curvature and vertebral rotation. For decades, the implementation of X-rays has been known as the most common method for detection of spinal curvature in the coronal plane as well as the indicator of curve progression in scoliotic cases. However, due to the detrimental effect of radiation exposure during the adolescence and limited 2D derived information, the researchers have developed other methods to overcome the drawbacks of conventional radiography. Non-ionizing properties of ultrasound waves facilitate the frequent application of this modality to monitor the spinal curvature. Therefore, the aim of this paper is to provide an overview of the existing literature on the current status of ultrasound application for scoliosis assessment including the involvement of ultrasound evaluation in the process of spinal orthotic treatment.

Methods
The literature was searched through multiple databases including Medline/PubMed, CINAHL, Cochrane, Embase, and Web of Science considering the different combinations of keywords namely AIS, clinical 3D ultrasound, Center of Lamina (COL) method, Spinous Process Angle (SPA), curve progression, flexibility and spinal orthotic treatment. As an inclusion criterion, the papers published in the English language between 1989 and 2019 were considered. More than

40 papers were identified and screened, after checking the eligibility, 20 out of 40 were found to be related for further analysis focusing on desired parameters. By using the data extraction form, a summary of each paper characteristics and the results of each study were generated.

Results

Totally, 20 included articles were allocated into the following sub-categories: development and evaluation of feasibility and reliability of spinal curvature measurement derived from the ultrasound system through the in-vitro and in-vivo studies, assessment of spinal flexibility, and assisting role of this modality to the process of orthotic treatment. The overall results of this review suggest that the ultrasound image acquisition may become a feasible alternative to decrease the repetitive radiographic spinal assessment. The utilization of positioning tracking system in ultrasound transducers provides the precise anatomical coordinates to reconstruct the whole spine and to analyze the acquired landmark images in the stack of scanned B-mode images. The increased intensity of vertebral components including the transverse processes, laminae, and spinous processes provides remarkable landmarks to facilitate the curve measurements through the semi-automated and automated systems. Spinal orthoses have been shown to be the effective conservative protocol capable to prevent the curve progression in the orthotic treatment of AIS patients. Lateral bending X-ray can indicate the flexibility of the spine. However, as those radiographs are rarely taken prior to the spinal orthotic design, ultrasound can detect the flexibility and the potential of in-orthotic curve correction.

Conclusion

Further development and conducting the studies with a large number of participants will probably support the clinical ultrasound as a reproducible portable system for assessment and monitoring scoliosis. It may even alternate the conventional orthotic fitting and design while application of freehand 3D ultrasound system and a volume reconstruction procedure provide the real-time evaluation of in-brace curve correction. There are potentials to implement the ultrasound system in evaluation and measurement of curvature in the real plane of curvature (between the coronal and sagittal plane) as due to the projection properties, the Posterio-anterior (PA) radiographs may not represent the true 3-D deformity. However, several limitations including the effect of severe curves with a large amount of Apical Vertebral

Rotation (AVR) on measurements values, the occurrence of missing curves, underestimation or overestimation of ultrasound measurement and impact of Body Mass Index (BMI) should be taken into consideration when conducting the ultrasound related studies.

References

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