Can surface topography replace radiography in the management of patients with scoliosis?

HR Weiss*, S Seibel

Abstract

Introduction
Scoliosis is a three-dimensional deformity of the spine and trunk, which during adolescence, can be effectively treated conservatively. Scoliosis patients are exposed to multiple X-ray investigations during treatment. One can reduce the need for X-rays during the regular follow-ups when clinical measurements are taken (angle of trunk rotation, surface topography); however, as indications and follow-ups of treatment still rely on the measurement of the Cobb angle (CA) on a full-standing X-ray, the exposure of children and adolescents with scoliosis cannot be avoided. Claims have been made recently that surface topography can predict the CA satisfactorily. The aim of this report is to analyse patients from our centre to test the repeatability of the results from that previously reported using the Diers Formetric® system.

Materials and methods
Twenty-five patients (four males and 21 females) with adolescent idiopathic scoliosis (AIS) had a Formetric® scan and an antero-posterior X-ray of the spine at the time they presented for having their first brace in the office of the senior author. The average age was 12.9 years (10–14 years), average CA was 38.2°. The CA as measured on the X-ray was correlated to the scoliosis angle (SA) as provided by the Formetric® system.

Results
Correlation was relatively high ($r = 0.84$), and the differences between the two series of measurement were not significant ($P = 0.08$). However, only 9/25 measurements were in the range of technical error ($\pm 5°$). In 12/25 patients, the Formetric® SA measurements were six or more degrees too low (maximum 38°). In 4/25 patients, the Formetric® SA measurements were six or more degrees too high (maximum 8°).

Conclusion
Although the correlation between X-ray and surface measurements was comparable with that published before, we cannot conclude that the device can be reliably used in the surveillance of patients with AIS, as the differences in one case were as high as 38°. Currently, there is no proof that surface measurement devices can reduce the need for X-rays.

Introduction
Scoliosis, simply defined as a lateral curvature of the spine, has been recognized clinically for centuries. It is a three-dimensional deformity of the spine and trunk, which may deteriorate quickly during periods of rapid growth. Although scoliosis may be the expression or a symptom of certain diseases, such as neuromuscular, congenital or certain other syndromes or tumours, the majority of patients with scoliosis (80%–90%) are called ‘idiopathic’ because a certain underlying cause still has not been found. The treatment of symptomatic scoliosis may primarily be determined by the underlying cause. The treatment of the so-called idiopathic scoliosis is determined by the deformity itself. As most of the curves progress during growth, and some also progress in later life, the main aim of any intervention is to stop curvature progression.

In patients with idiopathic scoliosis during adolescence, the risk for being progressive can be calculated using the formula by Lonstein and Carlson. Based on this formula, the treatment indications of scoliosis patients during growth are determined.

The deformity, however, is not described well by the Cobb angle alone as Scoliosis is a three-dimensional deformity. In order to quantify the deformity completely, three-dimensional terminology and measurements are required. However, for practical purposes, the deformity is most conventionally measured on standing coronal plane radiographs using the Cobb technique.

Adolescent idiopathic scoliosis (AIS) is the most frequent diagnosis of scoliosis.

The prevalence is very dependent on the curve size cut-off point, decreasing from 4.5% for curves of 6° or more to only 0.29% for curves of 21° or more. It is also very dependent on sex, being equal for curves of 6–10° but 5.4 girls to 1 boy for curves of 21° or more. The bigger the curve, the more girls are involved, with the girl/boy ratio being 10/1 in curvatures exceeding 40°.

Scoliosis patients are exposed to multiple X-ray investigations during growth because the risk of getting cancer is increased in such population. Ways to reduce the amount of radiation have to be found.

One can possibly reduce the need for X-rays during regular follow-ups when clinical measurements are taken (angle of trunk rotation (ATR),...
Materials and methods
This work conforms to the values laid down in the Declaration of Helsinki (1964). The protocol of this study has been approved by the relevant ethical committee related to our institution in which it was performed. All subjects gave full informed consent to participate in this study.

We searched our database for 25 consequent patients with the following inclusion criteria:

- Diagnosis of AIS
- No prior brace treatment before presentation in our centre
- Standing antero-posterior (AP) X-ray of the spine made the same day as the surface scan
- Presentation for brace treatment

Twenty-five patients (four males and 21 females) with AIS had a Formetric® scan and an AP X-ray of the spine at the time they presented for having their first brace in the office of the senior author. The average age was 12.9 years (10–14 years), and the average CA was 38.2° (range 20–82°). The CA, as measured on the X-ray, correlated to the scoliosis angle (SA) as provided by the Formetric®4D system.

As in the first study, the measurement protocol described by the manufacturers was followed for each measurement obtained, and participants were asked to stand in their normal, comfortable posture. The examiner did not position the participants, with the exception of accurate positioning of the feet on the ground reaction platform, which we have additionally used, and there were no external markers placed. Anatomical bony landmarks were detected automatically by the Formetric®4D system, and the examiner did not manually change any of the landmark locations that were selected by the machine.

At first, the SA provided by the surface system (Figure 1) was compared and correlated to the CA of the bigger curve as seen on the radiograph. As we have recognized that the surface measuring device does not always measure the bigger curvature, we made a hand comparison, checking all the printouts and assorting the curvature as measured by the device to the same curvature (lumbar or thoracic) on the X-ray, even if it was the smaller curve of the patient’s pattern of curvatures (3/25).

There were 16 thoracic, 2 double thoracic, 1 lumbar, 2 thoracolumbar and 4 double major curve patterns.

Results
The correlation was relatively high when comparing the highest SA to the highest CA; however, there was a significant difference (t-test: P = 0.047) comparing the average SA of 29° (SD 11.4) to the CA of 38° (19.1) (r = 0.83; P < 0.05).

Correlation after proper matching of the curves (lumbar to lumbar/thoracic to thoracic) was relatively high (r = 0.84; P < 0.05), and the differences between the two series of measurements were no more significant (t-test: P = 0.08). However, only 9/25 measurements were in the range of technical error (+/-5°). In 12/25 patients, the Formetric®SA measurements were six or more degrees too low (maximum 38°). In 4/25 patients, the Formetric®SA measurements were six or more degrees too high (maximum 8°).

Discussion
Surface topography uses the shape of the back of a patient to calculate the existing asymmetry with the help of ‘triangulation’. The system projects stripes of white light (raster lines) on the back of a standing patient and captures a digital photo of the image to assess pinpoint surface asymmetry, thereby identifying bony landmarks. The projected parallel lines are distorted by the back surface of the trunk, and the degree of their distortion is the basis for the calculation. The machine then compares the observed surface topography...
to a database of thousands of radiographic and topographic measurements of patients with scoliosis, utilizing a complex algorithm to quickly re-create a three-dimensional representation of the patient’s spine without exposing them to radiation. All curve patterns have different expressions with respect to the shape of the back deformation; thus, it seems unreasonable to calculate an equivalent of the CA, which is the deviation of a scoliotic curve in frontal plane as measured on an X-ray. Nevertheless, a claim was made that there was a strong correlation between SA and CA in a recent paper. It was concluded that The Formetric®4D is comparable to radiography in terms of its test-retest reproducibility. Although this device does not predict curve magnitude exactly, the predictions correlate strongly with the Cobb angles determined from radiographs. It can be reliably used in the surveillance of patients with AIS.

At the end of the paper, it was stated that ‘Surface topography will not completely replace radiographic analysis in monitoring patients with AIS, as it cannot evaluate the actual bone morphology the way a radiograph can. However, it has obvious advantages to repeat radiographs in the adolescent population, importantly the reduction in exposure to ionizing radiation. If it can deliver reliable and comparable results, it should replace radiographs during clinic visits when curve surveillance is necessary but exposure to radiation can be avoided. Identified topographic changes can then be followed up with radiographic imaging to confirm curve progression and determine therapeutic intervention.’

Thus, we need to differentiate between reliable results in repeated testing and a possible replacement of CA measurement on X-rays. For the latter case, it obviously still cannot be used.

We have shown earlier that postural sway and breathing influences the results of surface topography measurements; however, at the time these studies were performed, the system was using the ‘single-shot’ technique and using one single picture for data acquisition. Today, the Formetric®4D system uses an averaging algorithm; however, the technical error as shown in the cited study is not very different to the one reported in initial papers. As it seems, the measurements can be manipulated by artificial positioning of the patient, and therefore, it is most important that positioning of the patient is standardized at large.

Practically, in our clinical environment, the Formetric®4D system could not replace X-rays. We are also able to monitor the findings at regular follow-ups with the help of the Formetric®4D system by use of the Scoliometer® (ATR). This is the reason that in our department, X-rays are only made when there seems to be a deterioration, when a patient has outgrown a brace or when the final result of treatment has to be documented. The in-brace X-rays necessary to check appropriate pad placement and correction cannot be replaced by the Formetric®4D system.

Besides this, a significant reduction of patients’ exposure to radiation is possible when reducing the field size to the region of interest. Many X-rays in the follow-up of patients with scoliosis fully expose the head to thigh region, while especially, in the follow-up, a drastic reduction of field size is possible (Figure 2).

Nevertheless, the Formetric®4D system currently seems to be a useful tool as—besides the values provided—it generates a nice picture with the fringe pattern on the patients’ back surface, enabling the treating physician to compare the actual state of the patient with the previous one taken months earlier. Especially, for motivating the patients to wear a brace, these pictures may be of great value (Figures 3 and 4).

Conclusion
Although the correlation between X-ray and surface measurements was comparable with that published before, we cannot conclude that the device can be reliably used in the surveillance of patients with AIS, as the differences in one case were as high as 38°.

The system does not predict the frontal curve magnitude (SA) exactly.

The Formetric®4D system seems to be a useful tool, enabling the treating physician to compare the actual state of the patient with the previous one taken months earlier.

Conflict of interests
HRW is advisor of Koob GmbH & Co KG, Abtweiler, Germany; SS declares to have no competing interest.

Figure 2: Many full-standing X-rays are made from head to legs. It is possible to reduce the field size to the region of interest, and there would still be no limitation of angle measurement.

Licensee OA Publishing London 2013. Creative Commons Attribution License (CC-BY)

For citation purposes: Weiss HR, Seibel S. Can surface topography replace radiography in the management of patients with scoliosis? Hard Tissue 2013 Mar 22;2(2):19.
3. Hawes MC, O’Brien JP. The transformation of spinal curvature into spinal deformity: pathological processes and implications for treatment. Scoliosis 2006 Mar;1(1):3.
4. Lonstein JE, Carlson JM. The prediction of curve progression in untreated idiopathic scoliosis during growth. J Bone Joint Surg Am 1984 Sep;66(7):1061–71.
5. Weiss HR, Negrini S, Rigo M, Kotwicki T, Hawes MC, Grivas TB, et al. Indications for conservative management of scoliosis (SOSORT guidelines). Stud Health Technol Inform. 2008;135:164–70.
6. Stokes IAF. Three dimensional terminology of spinal deformity: A report presented to the Scoliosis research Society by the Scoliosis research Society Working Group on 3-D Terminology of Spinal Deformities. Spine 1994 Jan;19(2):236–48.
7. Cobb JR. Outline for the study of scoliosis. In: Edwards JW, editor. AAOS, Instructional Course Lectures. Volume 5. Ann Arbor: The American Academy of Orthopaedic Surgeons; 1948.p261–75.
8. Lonstein J. Patient evaluation. In: Lonstein J, Bradford D, Winter R, Ogilvie J, editors. Moe’s textbook of scoliosis and other spinal deformities. Philadelphia: WB Saunders; 1995.p.45–86.
9. Rogala EJ, Drummond DS, Gurr J. Scoliosis: Incidence and natural history. J Bone Joint Surg Am. 1978 Mar;60:173–6.
10. Yoshinaga S. Epidemiological findings on health effects of medical radiation exposures. Nihon Rinsho. 2012 Mar;70(3):410–4.
11. Ronckers CM, Land CE, Miller JS, Stovall M, Lonstein JE, Doody MM. Cancer mortality among women frequently exposed to radiographic examinations for spinal disorders. Radiat Res 2000 Jul;147(1):83–90.
12. Don S. Radiosensitivity of children: potential for overexposure in CR and DR and magnitude of doses in ordinary radiographic examinations. Pediatr Radiol. 2004 Oct;34(Suppl. 3):S167–72.
13. Doody MM, Lonstein JE, Stovall M, Hacker DG, Luckyanov N, Land CE. Breast cancer mortality after diagnostic radiography: findings from the U.S. Scoliosis Cohort Study. Spine (Phila Pa 1976). 2000 Aug;25(16):2052–63.
14. Weiss HR, Dieckmann J, Gerner J. The practical use of surface topography: following up patients with Scheuermann’s

Figure 3: Scoliosis patient on the Diers Formetric printout sheet at the start of treatment at 13.6 years. Cobb angle was 56° before brace treatment was started.

Figure 4: Patient from Figure 3 on the Diers Formetric printout sheet at the end of treatment at 16.6 years. Cobb angle was 43°, still. The clinical picture as can be seen on the printout is rather symmetric and a spinal deformity is hardly visible.

Consent
Written informed consent was obtained from the patient for publication of this case report and accompanying images. A copy of the written consent is available for review by the Editor-in-Chief of this journal.

References
1. Goldberg CJ, Moore DP, Fogarty EE, Dowling FE. Adolescent idiopathic scoliosis: natural history and prognosis. Stud Health Technol Inform. 2002;91:59–63.
2. Asher MA, Burton DC. Adolescent idiopathic scoliosis: natural history and long term treatment effects. Scoliosis 2006 Mar;1(1):2.

Licensee OA Publishing London 2013. Creative Commons Attribution License (CC-BY)

For citation purposes: Weiss HR, Seibel S. Can surface topography replace radiography in the management of patients with scoliosis? Hard Tissue 2013 Mar 22;2(2):19.
disease. Pediatr Rehabil. 2003 Jan-Mar; 6(1):39–45.
15. Weiss HR, Verres CH, El Obeidi N. Ermittlung der Ergebnisqualität der Rehabilitation von Patienten mit Wirbelsäulendeformitäten durch objektive Analyse der Rückenform. Phys Rehab Kur Med. 1999;9:41–7.
16. Weiss HR, Steiner A, Reichel D, Petermann F, Warschburger P, Freidel K. Medizinischer Outcome nach stationärer Intensivrehabilitation bei Skoliose. Phys Med Rehab Kuror. 2001;11:100–3.
17. Weiss HR, Verres CH, Steffan K, Heckel I. Outcome measurement of scoliosis rehabilitation by use of surface topography.
18. Frerich JM, Hertzler K, Knott P, Mardjetko S. Comparison of radiographic and surface topography measurements in adolescents with idiopathic scoliosis. Open Orthop J. 2012;6:261–5.
19. Weiss HR, Lohschmidt K, El Obeidi N. The automated surface measurement of the trunk. Technical error. In: Sevastik JA, Diab KM, editors. Research into spinal deformities I, IOS Press; 1997.p323–6.
20. Weiss HR, Lohschmidt K, El Obeidi N. Trunk deformity in relation to breathing. A comparative analysis with the formetric system. In: Sevastik JA, Diab KM, editors. Research into spinal deformities II, IOS Press; 1997.p246–9.
21. Weiss HR. Conservative treatment effects in spinal deformities revealed by surface topography—a critical review of literature. 5th International Conference on the Conservative Management of Spinal Deformities, Athens, April 2–5, 2008.
22. Schumann K, Püschel I, Maier-Hennes A, Weiss HR. Postural changes in patients with scoliosis in different postural positions revealed by surface topography. Stud Health Technol Inform. 2008;140:140–3.