Evaluating Spinal Deformity Using Surface Topography
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WP Bunnell described the scoliometer in 1984 as a simple, reliable, and inexpensive measurement of trunk asymmetry that was related to the deformity of scoliosis. (1) This asymmetry, which was caused by the rotation and deformity of the rib cage, was related to the magnitude of the scoliosis curve, although the correlation between trunk rotation and Cobb Angle is not very strong, ranging from 0.3 to 0.5 in published studies (2, 3). Use of the scoliometer is now widespread, however, in screening for scoliosis and determining which patients need orthopaedic and radiographic follow-up. This surface topography evaluation has proven to be a useful clinical tool, and has led to more research work in the field.

Moiré topography (also referred to as rasterstereography) is a mathematical technique for reproducing the contour of a surface by studying the distortion of a grid that is projected on it. This technique was developed in the 1960’s, and was used by medical researchers beginning in the mid 1980’s. Early systems projected a grid of light onto a subject’s back, and took a photo. This photo was then digitized and analyzed by computer software to produce a topographical model. The prediction of the shape of the spinal deformity using surface landmarks was first described by Turner-Smith, Harris et al, and produced strong correlational models of prediction (4). The analysis was initially slow and burdensome, and did not lend itself to efficient use by those in clinical practice. As computer capability improved, however, the analytical power of this technology became more evident.

Two early systems, ISIS and Quantec, developed computer models that estimated radiographic Cobb Angles using surface topography data. Correlations were good (r = 0.8 and tended to be within 10 degrees of the radiographic measurements (5).

The formetric system was first developed at the University of Muenster, and then taken commercial by the DIERS company (Schlangenbad, Germany) in the mid 1990’s using a sophisticated evaluation of the surface topography of the trunk. A more complex mathematical model that correlated the topographic scan with nearly 500 reference radiographs of the spine was developed by Drerup and Hierholzer in Muenster (6,7). This was used to produce an accurate 3D reconstruction of the subject’s spinal column from the topographic image that is taken. Validation of this model was done by the DIERS company over many years of research in partnership with several international and German universities (8).

Early studies showed that the formetric system could accurately locate anatomic landmarks on the human body (10, 11, 12) and subsequent research demonstrated that the system was able to more accurately find those landmarks than even an experienced clinician could (13). Studies from the University Muenster showed that the accuracy of rasterstereography in patients with idiopathic scoliosis with Cobb <50 degrees is excellent and even in patients with Cobb angles between 50 and 88 degrees it is still satisfactory (14, 15, 16). In addition, these researchers were also...
able to demonstrate that rasterstereography can be used in patients with scoliosis after anterior and posterior correction and fusion (17, 18).

Independent evaluation of the formetric system began after it was introduced into the European and US markets. Initial studies of reproducibility done on volunteer patients measured 30 consecutive times showed strong test-retest reproducibility, with a Chronbach’s Alpha of 0.996 for angular measurements of scoliosis (19). The standard deviation for scoliosis measurements was 3.4 degrees, which is similar to what would be encountered measuring Cobb Angles on radiographs. Sixty-six topographical scans were then compared to radiographs from the same patients, and the correlation between them was strong (r = 0.700) and statistically significant (p < .0001).

A separate study of reproducibility used different examiners, and found that the intra-rater reliability was high (Chronbach’s Alpha from 0.921 to 0.992) as was the inter-rater reliability (Chronbach’s Alpha 0.979) (20). The Body Mass Index (BMI) was also measured in these 51 volunteers, and correlated to the reliability of the measurements. No change in reliability was found with increasing BMI (21).

A clinical study looking at the effect of BMI in female patients found that for BMI readings between 16 and 29, the formetric was able to produce reliable measurements. There was a correlation between reliability and BMI (r = 0.65) showing that it was easier to measure thinner patients, but even at the maximum BMI measured of 29, the spinal measurements had a standard deviation of only 4.6 degrees (22).

Mangone et al. demostrated in 2013 that the rasterstereographic evaluation of vertebral rotation showed a good correlation with radiographically measured vertebral rotation, thereby confirming the possibility to use this method for deformity assessment in patients with idiopathic scoliosis.

Surface topography also has many benefits in the long-term surveillance of spinal deformity. Because it exposes patients to no ionizing radiation, it can be used during every follow-up visit for the largest number of data points on the timeline. This will allow clinicians to pick up a change in deformity sooner. It also images the patient in their normal, habitual posture, avoiding some of the unnatural changes in posture induced by positioning the patient in front of the x-ray machine. One study followed 16 patients with AIS for a mean of 8 years (range 3-10) to compare their change in topography to their change in radiographic Cobb Angle (24), and found an excellent correlation between the two.

The use of rasterstereography is however not limited to patients with scoliosis. Multiple studies have shown the versatility of this technique, since it can also be utilized e.g. to determine and treat pelvic obliquity, to evaluate for lumbar back pain and for changes of the spinal posture due to thoracic/lumbar spine fractures (25, 26,
27, 28, 29). Furthermore, clinical tests such as the forward bending test and the Matthiass posture test can be quantified with rasterstereography (30,31).

The next phase of surface topography is to use it under dynamic conditions. The Formetric can measure patients at a rate of 60 frames per second, giving the clinician the opportunity to see the 3D shape of the spine change during the gait cycle. Initial studies of the reliability and validity of this new method by Betsch and colleagues indicate that it can produce accurate measurements over time during walking (32, 33). A number of similar studies are also underway.


