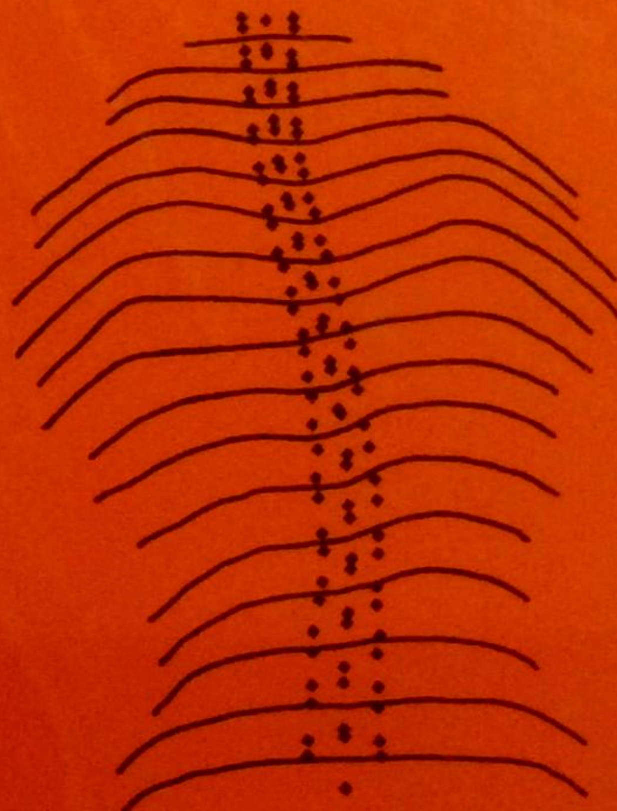
Surface Topography and Spinal Deformity



Edited by
I. A. F. Stokes · J. R. Pekelsky · M. S. Moreland

200 Figures and 62 Tables

SEMPER BONIS ARTIBUS

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Moiré topography for the study of multiple curves of spine

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Abstract

Moiré topography is applied to obtain quantitative information about the multiple curves (i.e. curves in multiple planes) of spine. Techniques for estimating angles of spinal curvature from topograms are given. A mathematical formulation is proposed to measure the degree of correction of trunk deformity.

1. Introduction

During the recent years moiré topography has been increasingly used for the study of spinal deformities. The author has used this technique for screening (Kamal and Khan, 1979; Kamal and El-Sayyad, 1981), follow-up (Kamal and Lindseth, 1980), documentation (El-Sayyad and Kamal, 1982) and quantification (El-Sayyad and Kamal, 1981; Kamal, 1982a,b; 1983a,b) of scoliosis. A patient alignment system was used in some of these studies (Kamal, 1982c).

In this paper, a method is proposed to determine the degree of correction of spinal deformity of curves in three dimensions, based on surface topography.

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2. Angle of Spinal Curvature

A relation for the measurement of the angle of spinal curvature is derived elsewhere (Kamal, 1982a) and applied in different clinical situations (Kamal and Lindseth, 1980; El-Sayyad and Kamal, 1981). Here the method is briefly described.

Consider Fig. 1. The angle of spinal curvature for a single curve scoliosis can be written as

$$\theta = \angle CAO + \angle CBO \qquad (1)$$

To measure this angle, the midpoint of the neck P is joined to the midpoint of the pelvis Q. To find the position of the spine at a given point draw a line perpendicular to PQ. Let this line intersect PQ at C and a particular moiré fringe at H and E such that E is always on the right side of H. The midpoint O of the line segment HE is assumed to give the position of the spine, provided the positioning during the X-ray and the moiré examinations is identical (Kamal, 1982a). From the position of the spine at a given point, the distance to the line PQ is obtained as $d = CO$. The point where d is maximum is denoted by d_1. Considering C as the origin and taking the distance on the right as positive and that on the left as negative, d_1 can be written as:

$$d_1 = \tfrac{1}{2}(CH + CE) \qquad (2)$$

At a point A above the point C on the line PQ, where the moiré fringes show minimum asymmetry d should be minimum and is given by

$$d_2 = \tfrac{1}{2}(AD + AG) \qquad (3)$$

At a point B below the point C on the line PQ, where the moiré fringes show minimum asymmetry, the distance is given by

$$d_3 = \tfrac{1}{2}(BF + BI) \qquad (4)$$

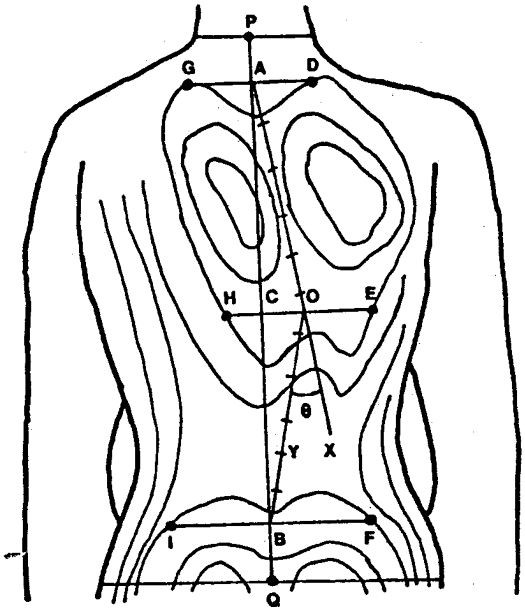

Fig. 1: Measurement of the angle of spinal curvature (in two dimensions) from moiré topograph of the back

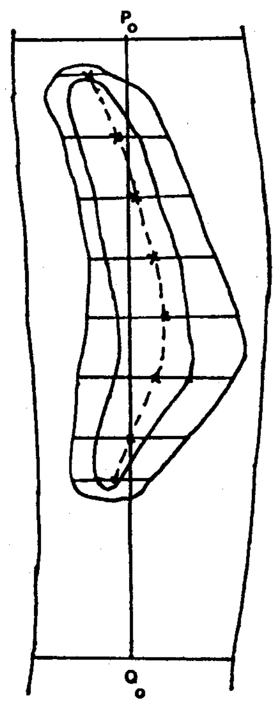

Fig. 2: Moiré topograph of the side in the standing position.

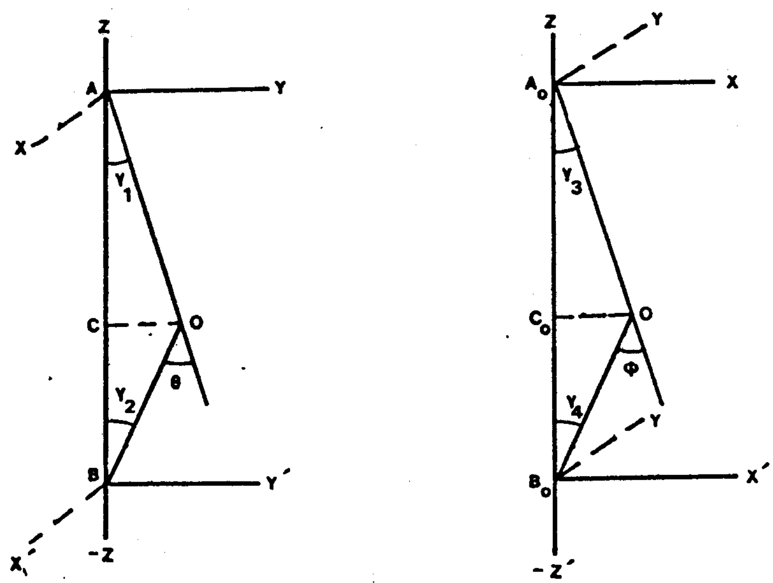

Fig. 3a,b: Projections of a point O on the spine in yz (frontal) and xz (sagittal) planes.

The angle of spinal curvature is, therefore, given by

$$\theta = \tan^{-1}|d_1 - d_2|/AC + \tan^{-1}|d_1 - d_3|/CB \qquad (5)$$

The railroad sign line in Fig. 1 joins three assumed points on the spine. The way the angle is measured looks similar to Ferguson's method for measurements performed on the X rays.

The question now is which fringe should be chosen to perform the measurements. The fringes near the edge would be inappropriate because of edge effects. If the first fringe is chosen, measurement error would be more significant because CH and CE are small. Therefore a compromise has to be reached regarding the fringe chosen.

Often it is difficult to find the exact point of maximum asymmetry. However, an area of asymmetry can be easily judged. It is suggested (El-Sayyad and Kamal, 1981) that measurements be taken at two points far below the point of maximum asymmetry and a line be drawn. Similarly, measurements be performed at two points far above the point of maximum asymmetry and a line be drawn joining these points. The intersection of these lines would give the angle of spinal curvature which can be geometrically measured. The way the angle is measured looks similar to Cobb's method for measurements performed on the X rays.

Moiré topograph of the side (arm raised) will give information about kyphosis and lordosis.

El-Sayyad (1983) followed-up twelve scoliosis patients between the ages of four and seven years for three months during intensive physical therapy program. The angle of spinal curvature was measured from the moiré topographs and Cobb's angle was measured from the X rays. The correlation coefficient was found to be 0.85. El Sayyad (1983) points out that the parameter must be treated with care as systematic changes may alter the shape of the back, and therefore the values of the angles, without altering the correlation.

3. Multiple Curves

For multiple curves the outline of the spine can be drawn by taking more measurements and finding the position of the spine at every point as described in the previous section (Kamal, 1983b). Since the vertebral column consists of 33 connecting bones, ideally the line PQ should be divided into 33 equal parts and the position of the spine shown in every region. The clinician, however, has to decide how much accuracy one wants. Fig. 2 shows the moiré topograph of the side. Measurements are taken at 8 different points to estimate the position of the spine. It is assumed that these eight points lie on the lateral projection (outline) of the spine. Once the outline of the spine is drawn, the angle(s) of spinal curvature can be measured.

4. Degree of Correction of Spinal Deformity

Degree of correction of spinal deformity for a single curve is given elsewhere (Kamal, 1983a). Here the degree of correction is defined for multiple curves. Fig. 3 shows projection of a point 0 on the spine in yz and xz-planes. The back lies in the yz-plane (frontal plane) and the side lies in the xz-plane (sagittal plane). The point B ($=B_o$) is chosen as origin. The back and side photographs may not have the same scale. To adjust the scales, photograph a stick on both back and side photographs. If μ is the ratio of the length on the back photograph to that on the side photograph, the corrected length for the side may be written as

$$z_{corrected}(\text{side}) = \mu z_{measured}(\text{side}) \qquad (6)$$

Let me write

$$x = f(y,z) = \tfrac{1}{2}ay^2 + byz + \tfrac{1}{2}cz^2 \qquad (7)$$

in the neighborhood of any point on the spine. The coordinate x represents the deviation of the curve from the yz-plane. Rotating the y, z-axes by an angle α

$$y' = y \cos \alpha + x \sin \alpha \tag{8a}$$
$$z' = -y \sin \alpha + x \cos \alpha \tag{8b}$$

where

$$\alpha = \tfrac{1}{2} \tan^{-1}[2b/(c - a)] \tag{9}$$

equation (8) can be written as

$$x = \tfrac{1}{2}K_{1i}y'^2 + \tfrac{1}{2}K_{2i}z'^2 \tag{10}$$

where

$$K_{1i} = a + c - 2b^2/[4b^2 + (c - a)^2]^{\frac{1}{2}} \tag{11a}$$
$$K_{2i} = a + c + 2b^2/[4b^2 + (c - a)^2]^{\frac{1}{2}} \tag{11b}$$

The patient is then asked to hang freely from a bar and the improvement in the deformity is noted (El-Sayyad and Kamal, 1981). The curvatures are again measured after guarded graduated passive correction as K_{1i}', K_{2i}'; $i = 1,2, \ldots, n$.

The degree of correction of spinal deformity is defined as

$$D = (50/n) \sum_{i=1}^{n} [(1 - K_{1i}^{-1}K_{1i}')^2 + (1 - K_{2i}^{-1}K_{2i}')^2] \tag{12}$$

The spinal deformity is classified as severe, intermediate or mild if D lies between 0-33.33, 33.34-66.66, 66.67-100 respectively. Geometrically if $K_{1i}' = K_{1i}$ $K_{2i}' = K_{2i}$; $i = 1, 2, \ldots, n$, there is no correction and $D = 0$. On the other hand, if $K_{1i}' = K_{2i}' = 0$; $i = 1, 2, \ldots, n$, the deformity is completely corrected and $D = 100$.

The analysis presented here may also be applied to clinical radiographs of back and side to determine the shape and curvature of the spine.

5. Conclusion

Hierholzer and Lüxmann (1982) have analyzed the scoliotic spine using invariant shape parameters. Their analysis and the formulation presented here may be used to study the vertebral rotation and torsion.

The moiré topographic analysis of the three-dimensional spine will permit the optimization of therapeutic procedures controlling their effectiveness for each patient.

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Spinal deformities, especially scoliosis, present a clinical challenge and are the subject of much research study. Clinicians and researchers are very aware that we need an improved three dimensional description of both the spine and overall trunk deformity. Optical, radiographic and other new techniques have been developed to meet this challenge. Since 1980 an international group of clinicians, engineers and scientists has met bi-anually to share techniques, results and data on the form of spinal deformities, especially its relationship to the body surface shape, and has undertaken to write a book to represent the current state of knowledge.

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