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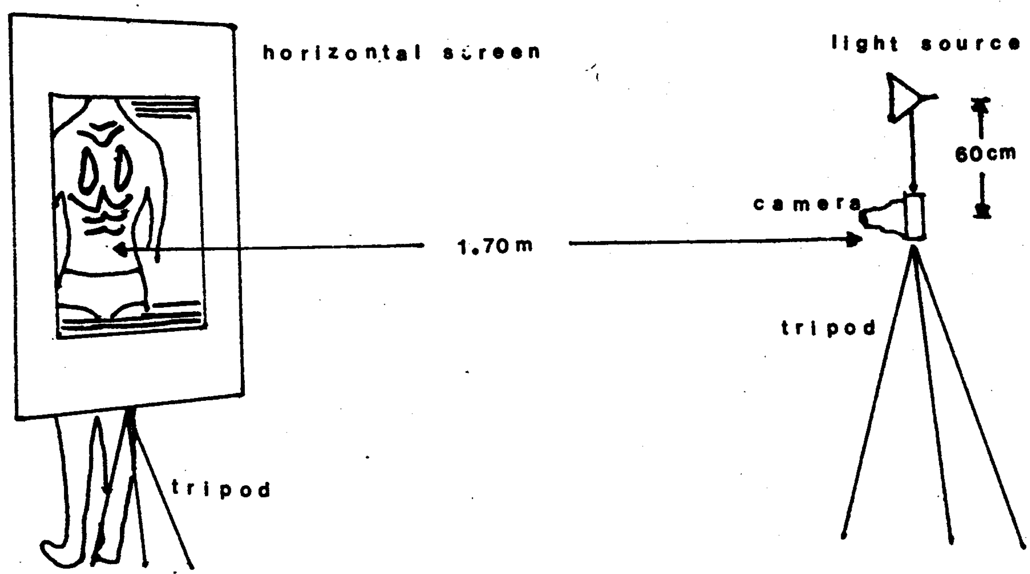

FIGURE 1: Arrangement of Equipment

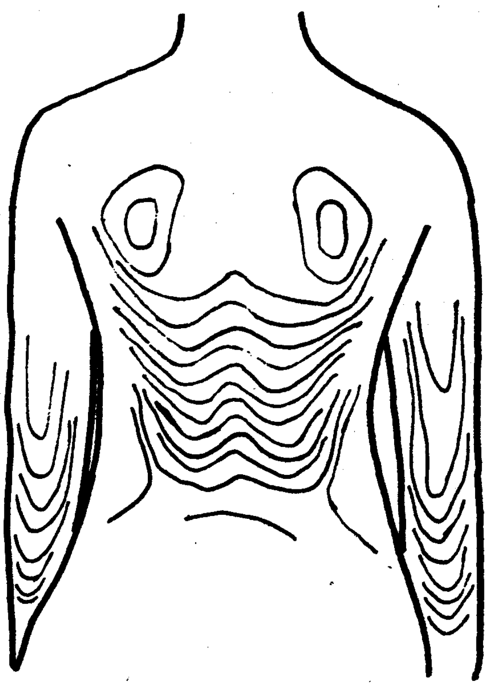

FIGURE 2: Moiré Pattern of a Normal Spine (Fig. 1 (a) of ref. 11 — reproduced by permission.)

MEASUREMENT OF THE ANGLE OF SPINAL CURVATURE BY MOIRÉ TOPOGRAPH

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SUMMARY

A method for the measurement of angle of spinal curvature from moiré topographs for scoliosis and kyphosis is described. The angles measured in this way are compared with the angles measured from roentgenograms by Cobb's method.

KEY WORDS

moiré topograph, spinal curvature, scoliosis, kyphosis, Cobb's method

I. INTRODUCTION

Orthopedic problems cannot always be detected by inspection and physical examination only.[1] A full length standing roentgenogram taken many times during the sensitive age period would result in too much radiation exposure to the children. However, Xrays have to be taken at regular intervals for scoliosis patient, because this is the only method available to measure Cobb's angle.[2] The exposure can be minimized if there is a technique which is rapid, reliable, inexpensive and can provide the measurement of the Cobb's angle with acceptable accuracy. During the recent years there has been considerable increase in the use of moiré topography for the screening and documentation of scoliosis. In this paper a method is described to measure the angle of spinal curvature using the moire topographs in the case of scoliosis and kyphosis.

Lord Rayleigh in 1874 was the first to appreciate the power of moiré technique, particularly in the evaluation of diffraction gratings. Since then, it has been used in meterology[3,4] and strain analysis.[5] Oster[6,7] employed this technique for the processing of biological data. Takasaki[8,9] first described the possibility of obtaining moire pictures with good contrast of a full size living body, Adair, van Wijk and Armstrong[10] described the method and experimental moire equipment used in a school screening project for the detection of scoliosis. Van Wijk[12] discussed the geometrical aspects of moiré fringe topography and its possible error sources. Boyer and Goitein[13] have described a technique by which individualized Ellis compensating filters can be rapidly and accurately produced from moire pictures. In radiation therapy, the irregularities of a patient's surface can lead to clinically undesirable radiation dose non-uniformities across a target (tumor) volume. Compensating filters can reduce the beam intensity in regions where there is a deficit of tissue overlying the target volume.

II. INSTRUMENTAL CONSIDERATIONS

Moiré is a French word which means watered.[14] Moiré fringes are a series of inference fringes arising from the superposition of sets of parallel threads or lines, the sets being slightly inclined to one another[15,16]. The width of the lines of the grid should be equal to the space between them. The overlaps produce the appearance of dark bands. If the two sets are perfectly regular, these bands are straight, but deviations in either or both give wavy lines as in the characteristic appearance of moiré silk. The moire effect also arises where there is an interference between screen and its shadow which falls upon an object behind. In this case the various shadow lines and contour lines — appear on the surface of the object at regular distances from the grid.[11] With this method asymmetries between the two halves of the back can be studied and recorded by comparing the moire patterns. If the spine is normal (without any deformity) fringe patterns will be symmetric on both sides of the back. If, on the other hand, there is a structural scoliosis, characteristic differences between the shadow patterns of the two halves will be discovered.

The apparatus used by Willner[11] consists of the moire frame with an opening of 75 x 50 cm. (see fig. 1). It is equipped with nylon wires which extend horizontally between the vertical sides of the frame. The diameter of the wires and the space between them are both 1 mm. The frame is fixed to a tripod which can be raised or lowered in order to facilitate the investigation of children of various heights. A studio light with an intensity of 1000 watt is used as a light source. It is fixed to the same tripod as the camera which is on a level with the central point of the moire frame. The camera is a single-lens reflex Cannon AE with 85 mm focal length. Generally black and white 400 ASA film is used. The exposure time is 1/25 second aperture sized is 5.6-8. The distance between light source and camera is 60 cm. Under these

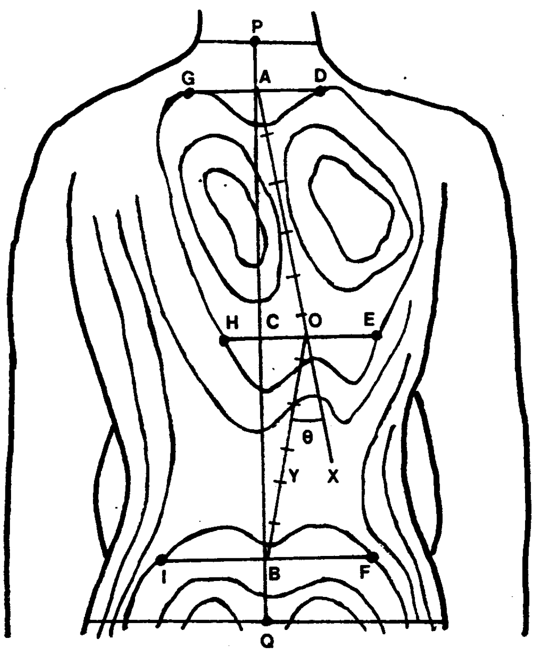

FIGURE 3: Measurement of the Angle of Spinal Curvature by Moiré Topographs.

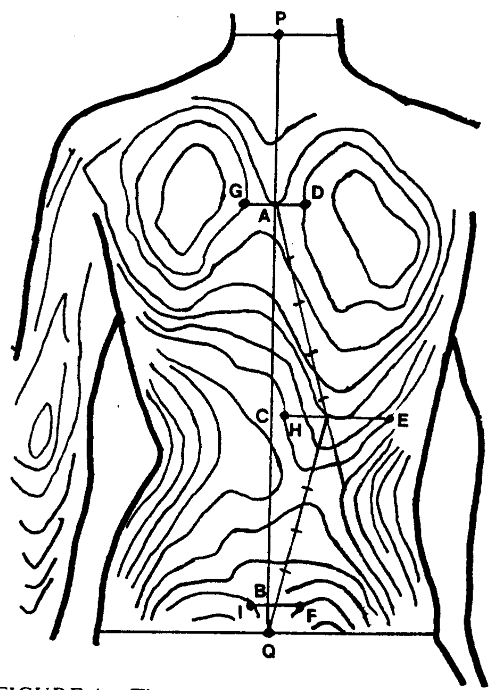

FIGURE 4: Thoracolumber Scoliosis of 37 degrees. (Fig. 1(b) of ref. 11 - reproduced by permission)

circumstances the difference in distance to the frame between adjacent contour lines will be 0.7. Figure 2 shows moire pattern of normal spine.

III. MEASUREMENT OF ANGLE

Suppose Θ is the angle of spinal curvature for the case of single curve scoliosis measured by Ferguson method.[2] To relate this angle to the moiré topograph of the back consider fig. 3.

$$\theta = \langle BOX = 2 \langle CBO = 2 \langle CAO \quad (1)$$

provided OA = OB. Therefore

$$\tan \theta/2 = OC/AC \quad (2)$$

which gives

$$\theta = 2 \tan^{-1} (OC/AC) \quad (3)$$

Fig. 3 is just an illustration to show the geometry. The angle θ may be obtuse or acute depending on the angle of spinal curvature. However, equation number 3 will hold in both cases. To determine OC we obtain measurements at the maximum and minimum asymmetry of the moiré fringes on both sides of the back. Line PQ in the middle of the figure is considered as the reference line. To draw the line PQ, the midpoint of the neck is joined to the midpoint of waist. From this line, the distance to the first visible moiré fringe on both sides is measured at different point. The position of the spine is obtained by taking the average of these distances. From the position of the spine at a given point, the distance to the line PQ is obtained as d. If we are able to find a point on line PQ on both sides of which the moire fringes have maximum asymmetry, the distance at this point will be maximum and is denoted by d. Let E and H be the points on the nearest visible moire fringe corresponding to right and left sides of the back such that line HCE is perpendicular to line PQ. The point 0 is the midpoint of the line segment HE. If we consider C as origin and take the distance on the right as positive and that on the left as negative, we have

$$d_1 = ½ (CH + CE) \quad (4)$$

At the point A, the point where the moire fringes show minimum asymmetry, d should be minimum and given by

$$d_2 = ½ (AD + AG) \quad (5)$$

using the same convention. If the spine lies entirely on one side of PQ, we have

$$OC = |d_1| - |d_2|. \quad (6)$$

and if at A and C, the spine lies on opposite sides of PQ the relation is

$$OC = |d_1| + |d_2| \quad (7)$$

This shows that we can write

$$OC = |[d_1 - d_2]| = |[d_2 - d_1]| \quad (8)$$

with sign conventions adopted in (4) and (5). Using (4) and (5) in (8) we get

$$OC = ½ [(AD + AG) - (CH + CE)] \quad (9)$$

Therefore using equation number 3 we have

$$\theta = 2\tan^{-1} [(1/CA) \cdot | (AD + AG) - (CH + CE)|] \quad (10)$$

Equation (1) holds if AO and OB are equal. If they are not equal, we have

$$\theta = \langle BOX = \langle BOY + \langle YOX \quad (11)$$

Since OY is parallel to AB we have

$$\theta = \langle CAO + \langle CBO \quad (12)$$

$$\theta = TAN^{-1} [|d_1 - d_2|/AC] + \tan^{-1} [|d_1 - d_3|/BC] \quad (13)$$

To calculate angle CBO we look for a point of minimum asymmetry below C. We calculate d using the relation (see fig. 2)

$$d_3 = ½ (BF + BI) \quad (14)$$

using the convention of eq. (4).

We illustrate the method by applying the above relation to the measurements performed on fig. 4 of ref.[11] (reproduced here as fig. 4)

CE = 18.0 mm, CH = 3.5 mm, BF = 4.0 mm, BI = 2.0 mm, AD = 5.0 mm,

AG = -5.0 mm, CA = 32.0 mm, CB = 29.5 mm, d_1 = 10.75 mm, d_2 = 0, d_3 = 1.0 mm

Therefore,

$\theta = \tan^{-1} (10.75/32.0) + \tan^{-1} (9.75/29.5) = 36.86°$

The reported value[11] (measured from X-ray) is 37°.

The difficulty in judging the point of maximum and minimum asymmetry can be resolved by taking many measurements along the line PQ and using the maximum and minimum values in the calculation. The results will be more accurate if the measurements are taken through microscope or from the magnified slides on the screen. It is hoped that with accurate measurements on the moiré topographs, the X rays will not be needed for the measurement of the angle of spinal curvature.

Note that this method is applicable for lateral curvature having a single curve. For kyphosis the moire topograph of the back will not give any information. For this a side view (moiré topograph), with hand excluded, will give the measure of angle by applying the same formula.

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