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# ABSTRACTS

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# MOIRÉ FRINGE TOPOGRAPHY AND SPINAL DEFORMITY

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## ABSTRACT

Orthopaedic problems cannot always be detected by inspection and physical examination only. A full length standing roentgenogram taken many times during the sensitive age period would result in too much radiation exposure to the children. The exposure can be minimized by using moiré topography which is rapid, reliable, inexpensive and simple. The technique of moire topography consists of photographing the part of the body to be studied through a specially constructed screen. Dark fringes are produced on the body because of the presence of the screen. By studying asymmetry of these fringes, considerable information about scoliosis and kyphosis has been obtained. Angle of spinal curvature in two and three dimensions may also be determined from moiré topographs. The possibility of physiotherapeutic improvement of back deformity may now be quantitatively determined by taking moiré topograph of the patient in the normal and hanging positions. This paper introduces a method to handle multiple curves of spine.

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Moiré topographs of front and back of a seven year old boy with negative bending test (reproduced from S. A. Kamal and M. M. El-Sayyad, The use of moiré topographs for the detection of orthopedic defects in children of age group four to seven years, 23rd Annual Meeting of the American Association of Physicists in Medicine, Harvard Medical School, Boston, Ma., Aug. 1981; Med. Phys. 8 (1981) 549).

## 1. INTRODUCTION

Since the Stone Age man has recognized the obvious deformity of curvature of the spine. Both the initial screening of patients with scoliosis and their follow-up present a considerable challenge to the clinician. The radiological examination of every child for the diagnosis of scoliosis and other bone deformities at an early age is not suggestive because X rays are harmful for human body. There is a need for such a process which is accurate, noninvasive, quick and can be performed without the presence of highly trained medical personnel. Moire topography seems an ideal tool for defining the contour surface of the back and relating this topographical information to back deformities. The potential uses of the moire technique have generated a great deal of interest among professionals concerned with mass screening and treatment monitoring of scoliosis patients.

This paper describes the use of moire technique for the quantification of back deformity.

## 2. HISTORICAL BACKGROUND

In 1874 Lord Rayleigh used moire technique in the evaluation of diffraction gratings. Since then, it has been used in meterology[1,2] and strain analysis[3]. Oster[4,5] employed this technique for the processing of biological data.

Takasaki[6] first described the possibility of obtaining moire pictures with good contrast of a full size living body. Since then many people have used it for screening and documentation of scoliosis[7-11]. The author has used this technique for the study of scoliosis and other back deformities[12-19]. A patient alignment system[20] was used in some of these studies.

3. DESCRIPTION OF THE PROBLEM

In the clinical measurement of back deformity, we are interested in the early detection of the problem as well as reliable criteria to judge the effectiveness of treatment. We want to accomplish this with minimum exposure of children to X rays. Many authors[21] agree that back deformities start sometime between the age of five and ten years. The onset of spinal curvature is usually before the age of five and seldom occurs after the age of ten. We screen the children between the ages of four and seven years[14,16]. This has the following advantages.

(a) The onset of back deformity can be detected early and suitable correction can be applied.

(b) It will allow sufficient time for the follow-up.

In the area of follow-up, we take moire topographs of patients at regular intervals[13]. If there is a change in moire pattern, the patient is told to have an X ray. In this way the number of X rays taken can be reduced.

A method has been proposed to determine the angle of spinal curvature in two and three dimensions[15-17] and estimate the degree of correction of spinal deformity[19]. This method, however, can be applied only to single curves. A preliminary treatment of spine with multiple curves is presented in section 6.

## 4. EXPERIMENTAL TECHNIQUES

The measurement in scoliosis consists of:

(a) Observing the outward form.

(b) Measuring a section representing the large degree of the lateral curve.

(c) Measuring the influence of scoliosis on the whole back.

The measuring methods available include oscular inspection and palpation, graph screen, inclinometer, height difference measuring meter, sliding gauge, light cutting, silhouetter, multi-light-cutting method, shadow and projection type moire topography[10]. Important conditions of measuring methods are:

(i) The accuracy can be changed to meet an object being measured.

(ii) The measurement can be instantly obtained all over the surface without touching the object.

(iii) The whole surface can be displayed as a map.

(iv) The measurement obtained can be checked by re-measurement.

The following methods meet these requirements.

1. Mulit light cutting method
2. Shadow type moire topography
3. Projection type moire topography

The mulit light cutting method is incapable of forming contour lines.

Moire fringes are a series of interference fringes arising from the superposition of sets of parallel lines or threads, the sets being slightly inclined to one another. The width of the lines of the grid should be equal to the space between them. The shadow type moire topography apparatus used by the author[13,14,16,18] consisted of a screen made up of 0.5 mm thick brown thread, stretched vertically across a rectangular opening in a steel frame. The distance between the threads was 0.5 mm. The frame had a horizontal support to hold the screen vertically. Each child was made to stand erect with feet together, buttocks placed close to the screen and with shoulders parallel to it. A 1000 watt lamp placed 50 cm above the camera was used as light source. The distance from camera to screen was 100 cm. For these values distance between adjacent fringes was 0.2 cm (Fig. 1). This method is simple and gives a lot of information, but it requires a large scale of equipment and it is difficult to maintain the standard of human bodies.

In projection type moire topography human body is supported on a standard holder, and a grating image is projected to his back for forming a transformed image on it according to

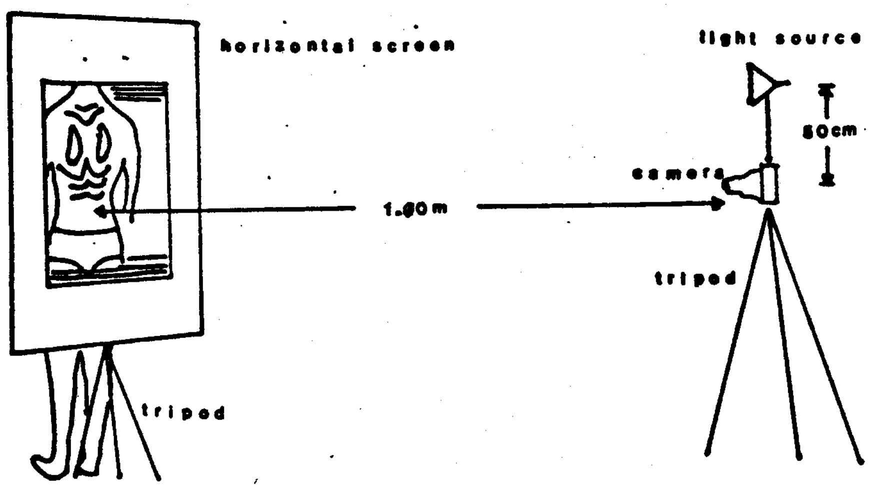


Fig. 1: Arrangement of equipment

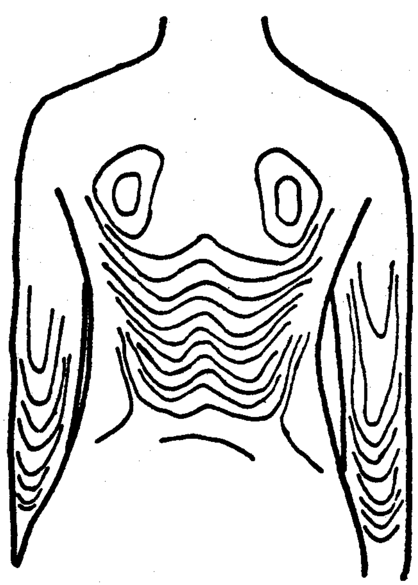

Fig. 2: Moire pattern of a normal spine

the shape of the back, which will then be formed on the standard grating through lens so as to generate contour line moire fringe between the transformed grating and the standard grating on the human back. This method gives large amount of information. Accuracy can be changed by changing grating. As compared to shadow type the distortion error in projection type is a factor of 2 or 3 in the depth and in the sides.

If there is no back deformity present the moire fringes should be symmetric on both halves of the back (Fig. 2). Any asymmetry, however, calls for a thorough evaluation by an orthopaedist.

## 5. ANGLE OF SPINAL CURVATURE

To be able to measure angles from a moire topograph is one of the principal concerns of a clinician[22]. The author proposed a method to measure two dimensional angle of spinal curvature[15] and applied it in clinical situations[13,16]. The method is briefly described as follows:

The angle of spinal curvature for the case of a single curve scoliosis can be written as (Fig. 3)

(1) $$\theta = \sphericalangle CAO + \sphericalangle CBO = \gamma_1 + \gamma_2$$

To measure this angle, the midpoint of the neck P is joined to the midpoint of the waist Q. To find the position of spine at a given point draw a line perpendicular to PQ. Let this line intersect PQ at C and a particular moire fringe at H and E

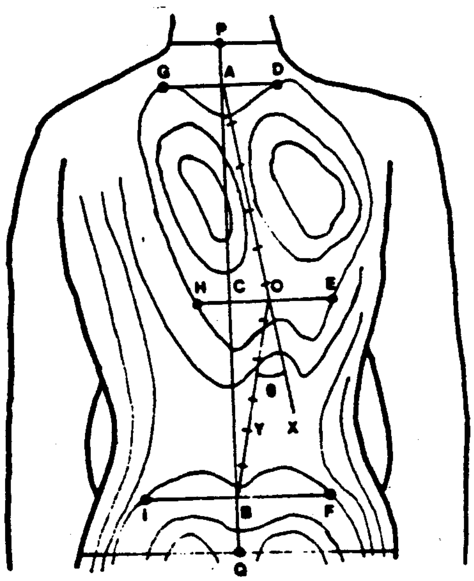


**Fig. 3:** Measurement of the angle of spinal curvature (in two dimensions) from moire topograph of the back

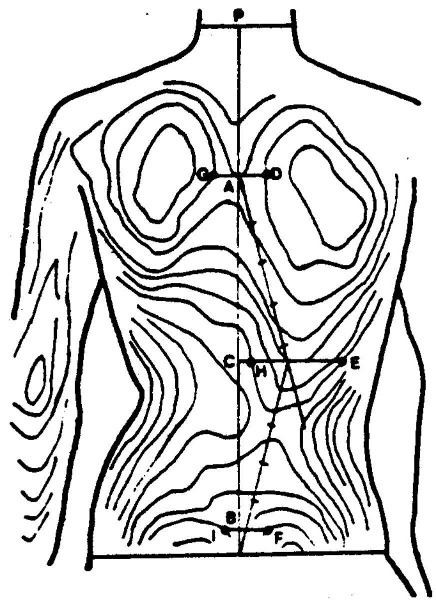


**Fig. 4:** Thoracolumber scoliosis of 37° (Fig. 1(b) of ref. 3 - reproduced by permission)

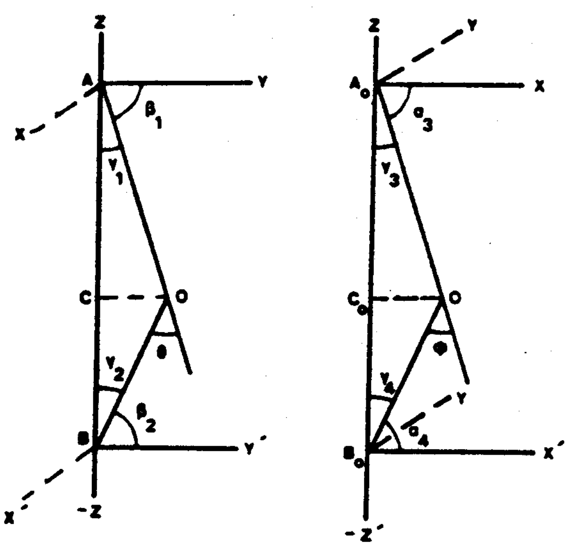


**Fig. 5:** Projections of spine in yz- and xz-planes

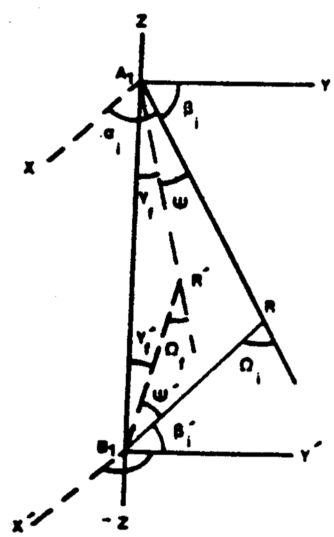


**Fig. 6:** Spine shown in three dimensions

such that E is always on the right side of H. The midpoint O of the line segment HE gives the position of the spine at a given point, the distance to the line PQ is obtained as d = CO. We look for a point where d is maximum and denote it by $d_1$. If we consider C as origin and take the distance on the right as positive and that on the left as negative we have

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

At 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

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

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

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

Therefore

(5) $$\tan \gamma_1 = |d_1 - d_2|/CA, \qquad \tan \gamma_2 = |d_1 - d_3|/BC$$

The railroad sign line in Fig. 3 represents the position of spine. The way the angle is measured looks similar to Ferguson method for X rays. Sometime it is difficult to judge the points of maximum and minimum asymmetry[15]. An area of maximum asymmetry can, of course be judged. In those situations[16] take measurements at two points far above the point of maximum asymmetry and draw a line joining these points. Similarly take measurements at two points far below the point of maximum asymmetry and draw another line. The intersection of these would give the angle of spinal curvature which can be geometrically measured. The way the angle is measured looks similar to Cobb method for X rays. A fortran program

COB.FOR is written and tested to calculate the angle $\theta$ from the measurements performed on the moire topograph of the back.

Fig. 4 (reproduced by permission) shows a thoracolumber curve of $37^{\circ}$ measured from X ray (Fig. 1(b) of ref.[8]). Measurements performed on moiré topograph give CE = 13.5 mm, CH = 2.6 mm, BF = 3.0 mm, BI = −1.5 mm, AD = 3.75 mm, AG = −3.75 mm, CA = 24.0 mm, BC = 22.1 mm, $d_1$ = 8.05 mm, $d_2$ = 0, $d_3$ = 0.75 mm,

$$\theta = \tan^{-1}(8.05/24.0) + \tan^{-1}(7.3/22.1) = 36.8^{\circ}.$$

Moiré topograph of the side (with hand excluded) gives information about kyphosis and lordosis. For side topograph $d_1$, $d_2$ and $d_3$ in eq. (5) are replaced by $d_4$, $d_5$ and $d_6$ respectively (see Fig. 5 and 7)

$$(6) \quad \tan\gamma_3 = |d_4 - d_5|/C_oA_o, \quad \tan\gamma_4 = |d_4 - d_6|/B_oC_o$$

A, B, C are used for moire topograph of back and $A_o$, $B_o$, $C_o$ for side.

The measurement in scoliosis essentially represents a kind of three dimensional measurement[23]. Three dimensional angle of spinal curvature named as 'Asr Angle' was defined in terms of direction cosines of the spine[17,19]. 'Asr' (Arabic) means frame, and is taken from the following verse of Al-Quran

نَحْنُ خَلَقْنَٰهُمْ وَشَدَدْنَآ أَسْرَهُمْ وَإِذَا شِئْنَا بَدَّلْنَآ
أَمْثَٰلَهُمْ تَبْدِيلًا ﴿٢٨﴾

'We, even We created them, and strengthened their frame. And when We will, We can replace them, bringing others like them in their steed' (Sura 76:28).

Fig. 5 shows projections of spine in yz- and xz-planes. If we consider spine in three dimensions (Fig. 6), we have

(7) $\Omega_i = \gamma_i + \gamma_i'$

where $\gamma_i = \sphericalangle B_1A_1R$ and $\gamma_i' = \sphericalangle A_1B_1R$. is called 'Normal Asr Angle' (NAA) which is measured when the subject is standing. Spinal deformity may be partially or completely corrected if the patient is asked to hang freely from a bar in the wall[16]. Angle is again measured after guarded graduated passive correction. 'Corrected Asr Angle' (CAA) is, therefore, given by

(8) $\Omega_f = \gamma_f + \gamma_f'$

Let $\psi = \sphericalangle RA_1R'$, $\psi' = \sphericalangle RB_1R'$ be the angles between old and new spinal positions. We, therefore, have (Fig. 6)

(9a) $\cos\psi = \cos\alpha_i \cos\alpha_f + \cos\beta_i \cos\beta_f + \cos\gamma_i \cos\gamma_f$

(9b) $\cos\psi' = \cos\alpha_i' \cos\alpha_f' + \cos\beta_i' \cos\beta_f' + \cos\gamma_i' \cos\gamma_f'$

where $\alpha_f = \sphericalangle XA_1R'$, $\alpha_f' = \sphericalangle X'B_1R'$, $\beta_f = \sphericalangle R'A_1Y$, $\beta_f' = \sphericalangle R'B_1Y'$.

The degree of correction of spinal deformity is defined as

(10) $D = 100(\sin\psi + \sin\psi')/(\sin\gamma_i + \sin\gamma_i')$

The degree of correction of spinal deformity is classified as severe, intermediate or mild if D lies between 0-33.33, 33.34-66.66, or 66.67-100 respectively. $\alpha_i$, $\beta_i$, $\gamma_i$, $\alpha_i'$, $\beta_i'$, $\gamma_i'$ can be obtained by using the relations[17,19]

$$(11a)\quad \cos\alpha_i = |d_4 - d_5| / [(d_1 - d_2)^2 + (C_1A_1)^2 + (d_4 - d_5)^2]^{1/2}$$

$$(11b)\quad \cos\beta_i = |d_1 - d_2| / [(d_1 - d_2)^2 + (C_1A_1)^2 + (d_4 - d_5)^2]^{1/2}$$

$$(11c)\quad \cos\gamma_i = (1 - \cos^2\alpha_i - \cos^2\beta_i)^{1/2}$$

$$(12a)\quad \cos\alpha_i' = |d_4 - d_6| / [(d_1 - d_3)^2 + (B_1C_1)^2 + (d_4 - d_6)^2]^{1/2}$$

$$(12b)\quad \cos\beta_i' = |d_1 - d_3| / [(d_1 - d_3)^2 + (B_1C_1)^2 + (d_4 - d_6)^2]^{1/2}$$

$$(12c)\quad \cos\gamma_i' = (1 - \cos^2\alpha_i' - \cos^2\beta_i')^{1/2}$$

where

$$(13a)\quad P_1 = (CA + BC)/(C_oA_o + B_oC_o)$$

$$(13b,c)\quad C_1A_1 = P_1(C_oA_o), \quad B_1C_1 = P_1(B_oC_o)$$

After guarded graduated passive correction, we have

$$(14a)\quad \cos\alpha_f = |d_4' - d_5'| / [(d_1' - d_2')^2 + (C_1'A_1')^2 + (d_4' - d_5')^2]^{1/2}$$

$$(14b)\quad \cos\beta_f = |d_1' - d_2'| / [(d_1' - d_2')^2 + (C_1'A_1')^2 + (d_4' - d_5')^2]^{1/2}$$

$$(14c)\quad \cos\gamma_f = (1 - \cos^2\alpha_f - \cos^2\beta_f)^{1/2}$$

$$(15a)\quad \cos\alpha_f' = |d_4' - d_6'| / [(d_1' - d_3')^2 + (B_1'C_1')^2 + (d_4' - d_6')^2]^{1/2}$$

$$(15b)\quad \cos\beta_f' = |d_1' - d_3'| / [(d_1' - d_3')^2 + (B_1'C_1')^2 + (d_4' - d_6')^2]^{1/2}$$

$$(15c)\quad \cos\gamma_f' = (1 - \cos^2\alpha_f' - \cos^2\beta_f')^{1/2}$$

where

$$(16a)\quad Q_1 = (C'A' + B'C')/(C_o'A_o' + B_o'C_o')$$

$$(16b,c)\quad C_1'A_1' = Q_1(C_o'A_o'), \quad B_1'C_1' = Q_1(B_o'C_o')$$

A fortran program ASR.FOR is written and tested which gives NAA, CAA, D and classifies the deformity as severe, intermediate or mild.

Let the moire topographs of back and side when the patient is

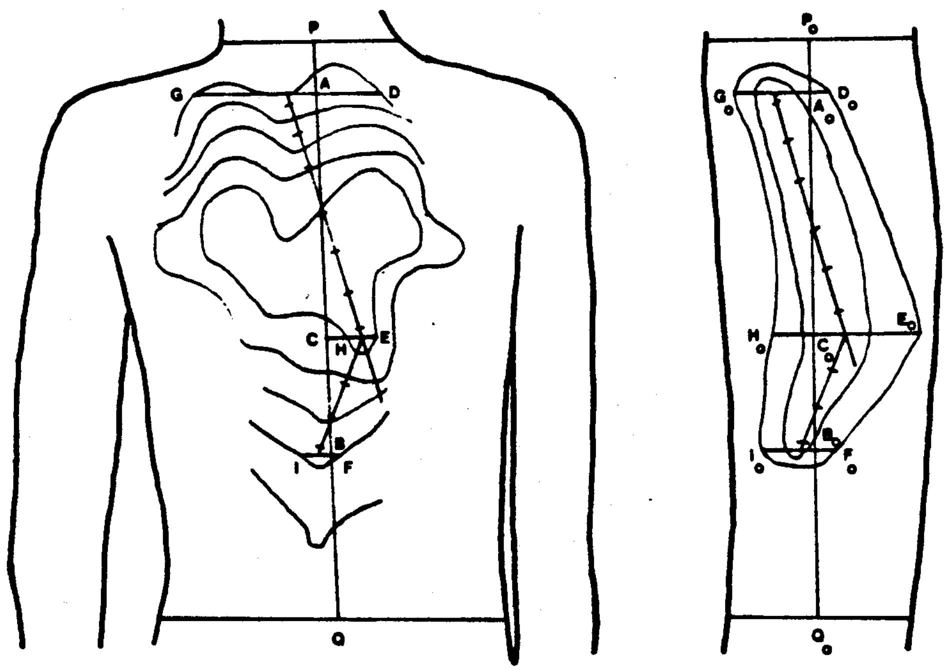


Fig. 7: Moire topograph of back and side in the standing position

standing look like Fig. 7. We have AD = 8.25 mm, AG = -15.75 mm, CH = 2.25 mm, CE = 6.75 mm, BF = 0.75 mm, BI = -3.75 mm, CA = 31.5 mm, BC = 15.0 mm, $d_1$ = 4.5 mm, $d_2$ = -3.75 mm, $d_3$ = -1.5 mm, $A_oD_o$ = 1.9 mm, $A_oG_o$ = -10.1 mm, $C_oH_o$ = -5.6 mm, $C_oE_o$ = 13.9 mm, $B_oF_o$ = 3.4 mm, $B_oI_o$ = -7.1 mm, $C_oA_o$ = 31.5 mm, $B_oC_o$ = 15.0 mm, $d_4$ = 4.15 mm, $d_5$ = -4.1 mm, $d_6$ = -1.85 mm, $\cos\alpha_i = 0.2455 = \cos\beta_i$, $\cos\gamma_i = 0.9378$, $\cos\alpha_i' = 0.3482 = \cos\beta_i'$, $\cos\gamma_i' = 0.8704$, $\alpha_i = 75.78^o = \beta_i$, $\gamma_i = 20.31^o$, $\alpha_i' = 69.73^o = \beta_i'$, $\gamma_i' = 29.59^o$, $\Omega_i = 49.81^o$.

Let the moire topographs of back and side when the patient is hanging freely from a bar in the wall look like Fig. 8. We get A'D' = 8.25 mm, C'H' = 3.0 mm, C'E' = 4.5 mm, B'F' = 0.75 mm, B'I' = -3.75 mm, C'A' = 31.5 mm, B'C' = 15.0 mm, $d_1'$ = 3.75 mm, $d_2'$ = -3.75 mm, $d_3'$ = -1.5 mm, $A_o'D_o'$ = 1.9 mm, $A_o'G_o'$ = -10.1 mm, $C_o'H_o'$ = 12.4 mm, $B_o'F_o'$ = 3.4 mm, $C_o'E_o'$ = 12.4 mm, $B_o'I_o'$ = -7.1 mm, $A_o'C_o'$ = 31.5 mm, $C_o'B_o'$ = 15.0 mm, $d_4'$ = 3.4 mm, $d_5'$ = -4.1 mm, $d_6'$ = -1.85 mm, $\cos\alpha_f = 0.2256 = \cos\beta_f$, $\cos\gamma_f = 0.9477$, $\cos\alpha_f' = 0.3137 = \cos\beta_f'$, $\cos\gamma_f' = 0.8962$, $\alpha_f = 79.96^o = \beta_f$, $\gamma_f = 18.60^o$, $\alpha_f' = 71.62^o = \beta_f'$, $\gamma_f' = 26.33^o$, $\Omega_f = 44.93^o$, $\cos\psi = 0.9995$, $\cos\psi' = 0.9985$, D = 10.28.
The deformity is, therefore, classified as severe.

## 6. GENERALIZATION FOR MULTIPLE CURVES

The above relations hold good in the case of single curve. For multiple curves the outline of the spine can be drawn

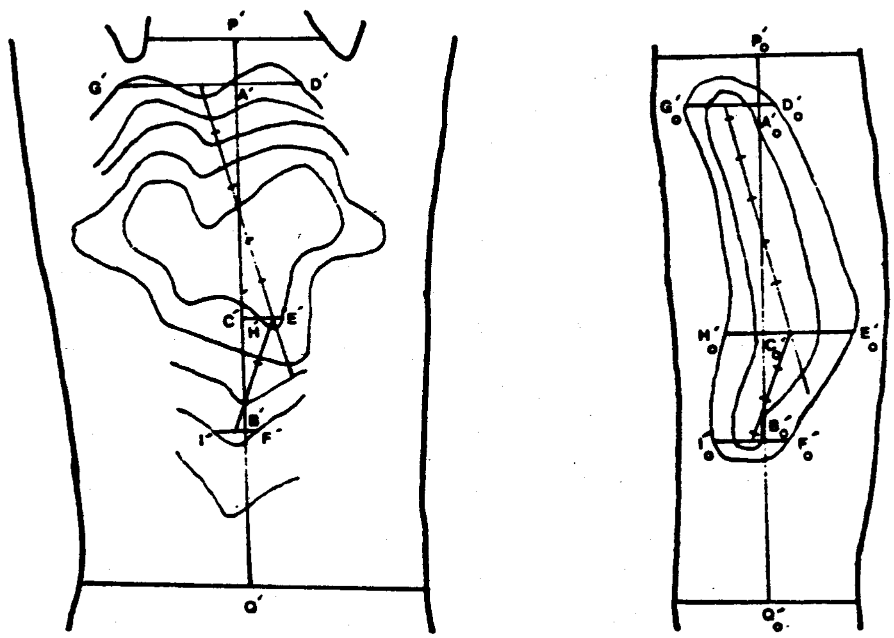

Fig. 8: Moire topograph of back and side in the hanging position

by taking many more measurements and finding the position of spine at every point as described in the previous section. Since the vertebral column consists of 33 connecting bones, ideally the line PQ should be divided into 33 equal parts and position of spine shown in every region. The clinician, however, has to decide how much accuracy he wants. Fig. 9 shows the moire topograph of side in the hanging position. Measurements are taken at 8 different points and outline of spine is drawn.

## 7. CONCLUSION

The problems facing the clinician dealing with scoliosis are to know

(a) how much scoliosis is present

(b) where the scoliosis is present

(c) etiology of the disease

Moire topography can be helpful in solving these problems. Etiology of the disease can be better understood if we donot confine ourselves to the study of back using moire topography. The relationship of back deformities to chest and leg deformities as well as face deformities should be studied. Considerable information about genetic and heriditary nature of spinal deformities can be obtained by screening younger siblings of scoliosis patients. Moire topography would play an increasing role in all these studies.

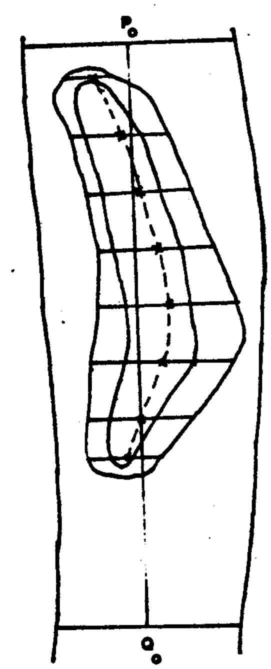


Fig. 9: Moire topograph of side in the standing position

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[v] Full text: https://www.ngds-ku.org/Papers/C04.pdf

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