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COBB'S ANGLE MEASUREMENT BY MOIRÉ TOPOGRAPHS

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The purpose of this study was an attempt to obtain information that may help medical professionals in the rehabilitation of patients with back deformities. The need for precise and detailed information is evident when one examines back deformity and considers possible therapeutic measures to correct or improve it. The technique of moiré topography consists of photographing the part of body to be studied through a specially constructed screen. Dark fringes are produced on the body because of the presence of screen. The fringes of different subjects are compared with the initially determined standards established by photographing normal children between the ages of four and seven years.

To obtain the angle of spinal curvature in the case of back deformities, measurements were performed at the points of maximum and minimum asymmetry of moiré fringes and used in the mathematical relation to calculate the angle. Let θ be the angle of spinal curvature. A reference line AB is drawn by joining the midpoint of neck to the midpoint of waist. From this line, the distances to the first visible moiré fringe on both sides is measured at different points. The position of the spine is at the midpoint of these fringes. From the position of the spine at a given point, the distance to the line AB is obtained as d. At the point of maximum asymmetry C on line AB, the distance is noted as d_1. At the point A above the point C, where the moiré fringes show minimum asymmetry, the distance is d_2. At the point B below the point C, where the moiré fringes again show minimum asymmetry, the distance is d_3. The angle of spinal curvature is then given by

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

The method and the elaboration here reported provides the necessary basis for a correct prognosis of the evaluation of back deformities. The methodology can be applied as a routine for large number of children because it takes a reasonably short time for each of them and this allows a nice screening as a part of pre-school physical examination. The moiré topography analysis will permit also the optimization of the therapeutic procedures controlling their effectiveness for each subject.

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COBB'S ANGLE MEASUREMENT BY MOIRÉ TOPOGRAPHS

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INTRODUCTION

This study was an attempt to obtain information that may help medical personnel in the rehabilitation of patients with back deformities. The need for precise and detailed information is evident when one examines back deformity and considers possible therapeutic measures to correct or improve it. Scoliosis, a disease that may affect about ten percent of children, results in an abnormal lateral curvature of a child's spine, often goes unnoticed and can get progressively worse with age. In the worst case, major back surgery is necessary to straighten the spine. It has also been found that the results of the treatment improve if the treatment is started early during the course of the condition. In recent years there has been

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considerable interest in the early diagnosis of scoliosis [1-7].

Spinal deformities may develop as early as four. The onset of spinal curvature is usually before age five, and the problem seldom occurs after age ten [8]. The clinical investigation should include diagnosis for lordosis or kyphosis also. In most cases, these cannot be detected by inspection and physical examination alone [6]. A full-length standing roentgenogram taken many times during the sensitive age period would result in exessive radiation exposure. However, X rays have to be taken at regular intervals for scoliosis patients because this is the only method available to measure Cobb's angle. The exposure can be minimized if there is a technique that is rapid, reliable, inexpensive and can provide the measurement of the Cobb's angle with acceptable accuracy. Moirè topography provides all these benefits. This paper describes a method of measuring the angle of spinal curvature using the moirè topographs in the case of scoliosis and kyphosis. Moirè fringes of children between the ages of four and seven are obtained and in the case of spinal deformity the angle of spinal curvature is measured.

HISTORICAL BACKGROUND

The power of moirè technique was first appreciated by Lord Rayleigh in 1874, particularly in the evaluation of diffraction gratings. Since then, it has been used in meteorology [9,10], strain analysis [11], refractive index gradient measurements [12], lattice defects study [13],

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holography [14] and the processing of biological data [15,16]. Oster [17,18] and Nishijima [19] described the science of moiré patterns. Brooks and Heflinger published a paper on moiré gauging [20]. In their method an equispaced laser interference pattern is projected on a test object, a picture of the pattern is taken and the negative plate is restored in its original position. Observing the test object illuminated by the same interference pattern through the master negative shows up a moiré pattern corresponding to the test object. The technique of moiré topography [21,22] was applied by Takasaki [23-26] to obtain moiré pictures of a full-size living body. Xenfos and Jones [27,28] applied moiré topographic techniques to the characterization of human body. Several workers have also applied moiré techniques to the construction of compensating filters [29-32]. The irregularities of a patient's surface can lead to clinically undesirable dose nonuniformities across a target volume. Compensating filters can reduce the beam intensity in regions where there is a deficit of tissue overlying the target volume. Adair, van Wijk and Armstrong [33] described the method and experimental moiré equipment used in a school screening project for the detection of scoliosis. Free [34] also applied this technique for spinal examination. Van Wijk [35] discussed the geometrical aspects of moiré fringe topography and its possible error sources. Willner has applied moiré topography for the diagnosis and documentation of scoliosis [36]. Adair, van Wijk and Armstrong [33] have reported certain cases in which the child was not positioned properly with respect to the screen. This difficulty has now been resolved by introducing a lamp and scale arrangement [37], and the technique has been used for the detection and follow-up of scoliosis [38-40]. Recently a method has been developed to measure the angle of spinal curvature [41]. The application of this method and further improvements will be discussed in this paper.

THE MOIRÉ EFFECT

Moiré is a French word which means watered [42,43]. When one family of curves is superposed on another family of curves so that the curves cross at angles of less than about 45°, a new family called the moiré pattern appears [44-47]. The width of 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. The moiré effect also arises between a screen and its shadow. In this case the various shadow lines - the contour lines - appear on the surface of the object at regular distances from the grid [36]. With this method asymmetries between the two halves of the human back can be studied and recorded by comparing the moiré patterns. If there is no deformity in the spine, fringe patterns will be asymmetric 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.

EXPERIMENTAL SET UP

The technique of moirė topography consists of photographing the body part to be studied through a specially constructed screen. Dark fringes are produced on the body by the screen. The screen was made up of 0.5 mm thick brown thread, streched 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 in a standing position. To align the patient parallel to the screen, two laser beams were used [37] (Fig. 1). The patient was asked to stand erect with his/her back (or chest) touching the screen for moirė topography, in a relaxed and normal mode, looking straight ahead. Two plastic strips (S1 and S2, as shown in Fig. 2) were used to position a mirror M. For the photograph of the back, the mirror was positioned in front of the stomach. To attach the mirror to the patient's body the distance between G and H was adjusted in such a way that the strips S1 and S2 fitted on the sides. Because the mirror did not touch the stomach, breathing did not cause any problems. For the photograph of the chest, the mirror was positioned behind the back. The patient was positioned in such a way that light from the first lamp (L1) fell on the vertical axis of the scale (z-axis of plate P) and from the second lamp (L2) on the horizontal axis (x-axis of plate P), both after being reflected from the mirror. If the patient twisted in a horizontal direction (i.e. rotated around the z-axis), light from lamp L1 did not fall on the vertical axis (z-axis); if he/she twisted in a vertical direction (i.e. rotated around x-axis), light from the second lamp L2 did not fall on the horizontal axis (x-axis). When both spots (from L1 and L2) were on the x- and z-axes, the patient was properly aligned for the moirė

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topographic picture. The vertical axis (z-axis) was drawn with the help of a plumb line.

For the photographing process, two cameras were used (SX-170 Sonar Focusing - One Step and Canon AV-1). Ideally, the light source used for creating the moiré fringe pattern should be a point source, or a line source parallel to the screen. A compromise was reached in order to provide sufficient light for the photographic exposure [48]. The source of light used in this experiment was a 1000 watt lamp. This lamp was placed 50 cm above the camera (Fig. 3). If L is the horizontal distance from the light and the camera to the screen, d the vertical distance between the camera and the light, and $s_{\circ}$ the screen interval, the difference between the n^{th} and the $(n + 1)^{th}$ fringe is [39]

$$(1) \qquad D = L s_{\circ}^{-1} d (n - d/s_{\circ})^{-1} (n + 1 - d/s_{\circ})^{-1}$$

In our case L = 100 cm, d = 50 cm, $s_{\circ}$ = 1.00 mm, For n = 1, the difference between the first and the second fringe was 0.20 cm, whereas for n = 50, the difference was 0.24 cm.

METHOD OF STUDY

Twenty boys and girls between the ages of four and seven years were selected for the study. After taking a case history, a physical examination of the back was performed. The skin of the back was checked for areas of redness and unusual skin markings. The posture was checked in a standing position. Balance of the back muscle and the abdominal muscle was checked by guarded graduated muscle test. Guarded graduated active and passive tests for back range of motion were done to detect any back stiffness. In the active test the child was asked to bend, with knees straight and feet together, and touch fingertips to the floor. The back was observed from the rear for possible asymmetry. To pass, the child must keep the fingertips on the floor for a count of three. The distance from his/her fingertips to the floor was measured in the case of a failure. In the passive test the child was asked to hang from a bar in the wall. The body position was compared with the standing position for any difference. Deformity was classified into three stages. In the first, the child was able to correct the deformity actively by stretching his body. In the second stage, the child could not correct his deformity actively, but it could be corrected passively by hanging over the bar. The third degree was not used in this study, but it can be assigned to those whose deformity was not corrected actively or passively.

The child then came behind the screen to be photographed. Front, rear and side views were taken. In cases of deformity, the angle of spinal curvature was measured.

MEASUREMENT OF THE ANGLE OF SPINAL CURVATURE

To measure Ferguson's angle from the X ray a dot is marked in the center of the shadow of the body in each of the three vertebrae - the two end and the apical. The apical vertebra is the one that is most rotated at the crest of the curve. Lines are drawn from the apex to

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each end. The angle of the curve is the divergence of these two lines from 180 degrees.

To measure Cobb's angle from X ray [49,50] top and bottom vertebrae are located (Fig. 4). The top vertebra is the lowest one whose inferior surface tilts to the side of the concavity of the curve to be measured. The bottom vertebra is the lowest one whose inferior surface tilts to the side of the concavity of the curve to be measured. Intersecting perpendiculars are erected from the superior surface of the top and the inferior surface of the bottom vertebrae, and the angle formed by these perpendiculars is the angle of the curve (Cobb's angle).

To relate these angles to the moiré topograph of the back, consider Fig. 5. The angle of spinal curvature for a single curve scoliosis can be written as

$$\theta = \angle CAO + \angle CBO \qquad (2)$$

To measure this angle, the midpoint of the neck P is joined to the midpoint of the waist Q. To find the position of 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 gives the position of the spine, provided the positioning during X-ray and moiré examinations is identical [41]. From 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. Considering

C as the origin and taking the distance on the right as positive and that on the left as negative, we get

$$(3) \qquad d_1 = \tfrac{1}{2}(CH + CE)$$

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

$$(4) \qquad d_2 = \tfrac{1}{2}(AD + AG)$$

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

$$(5) \qquad d_3 = \tfrac{1}{2}(BF + BI)$$

Therefore

$$(6) \qquad \theta = \tan^{-1}|d_1 - d_2|/CA + \tan^{-1}|d_1 - d_3|/BC$$

The railroad sign line in Fig. 5 represents the position of 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. We suggest that measurements be taken at two points far below the point of maximum asymmetry and a line be drawn. Similarly measurements be taken 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.

Both of these methods are illustrated by showing measurements performed on the moiré topograph of one of our subjects. The case represents a seven-year-old boy who had a negative forward bending test. From the moiré topograph of the back, we get

$AD = 11.0$ mm, $AG = -21.0$ mm, $CH = 4.0$ mm, $CE = 8.0$ mm, $HF = 1.0$ mm, $BI = -5.0$ mm, $AC = 42.0$ mm, $CB = 20.0$ mm, $d_1 = \frac{1}{2}(CH + CE) = 6.0$ mm, $d_2 = \frac{1}{2}(AD + AG) = -5.0$ mm, $d_3 = \frac{1}{2}(BF + BI) = -2.0$ mm,

$\theta = \tan^{-1}|d_1 - d_2|/AC + \tan^{-1}|d_1 - d_3|/CB = \tan^{-1}(11.0/42.0) + \tan^{-1}(8.0/20.0)$

Therefore

$$\theta = 36.48^{\circ}$$

From the photograph of the back an angle of 36.5° is measured. The moiré photograph of the front gives

$CH = -10.0$ mm, $CE = 14.0$ mm, $AD = 1.5$ mm, $AG =-5.5$ mm, $d_1 = 2.0$ mm, $d_2 = -2.0$ mm, $d_3 = 0$, $\theta = \tan^{-1}(4.0/32.5) + \tan^{-1}(2.0/27.0) = 11.25^{\circ}$.

The angle measured from the photograph of the front is 11.5°.

CONCLUSION AND RECOMMENDATIONS

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The moiré topographic technique offers numerous possibilities in the documentation of orthopaedic defects. With accurate measurements X rays would not be needed to measure Cobb's angle. The possibility of physiotheraputic improvement of back deformity can now be quantitatively determined by taking a moiré topograph of the patient (in the normal and stretched conditions). Furthermore, moiré topographs of the lower limb would reveal information about leg and foot deformities. For young children the topographs of the full body would reveal many orthopaedic disorders that remain undiagnosed in early stages.

The method and the elaboration here reported provide the necessary basis for a correct diagnosis and prognosis of back deformities. It also offers a means of determining effectiveness of treatment, The methodology can be applied routinely to large numbers of children because it takes a reasonably short time for each child. Screening could be performed as a part of the pre-school physical examination. The moiré topographic analysis will also permit the optimization of the physiotheraputic and rehabilitation procedures.

REFERENCES

[1] A. Bonnel, A. Workman, J. C. Brown and M. J. Miller, A new approach to the prevention of scoliosis, Presented to Scoliosis Research Society, September 1975.

[2] W. J. Kaner and J. H. More, Clin. Orthop. 60 (1970) 216.

[3] R. B. Winter, Acta Orthop. Scand. 46 (2975) 3.

[4] M. A. Asher, F. Adler and R. R. Jacobs, J. Kans. Med. Soc. 76 (1975) 285.

[5] J. E. Lonstein, R. B. Winter, J. H. Moe, A. J. Binaco, R. G. Campbell and M. A. Norval, Minn. Med. 59 (1976) 51.

Proc. 34th Annual Conf Eng. Med. Biol., Houston, 1982, p 311

[6] R. B. Winter, Mod. Med., May 1 (1975) 38.

[7] R. W. Gaines, L. M. McKinley and K. D. Leatherman, Kentucky Med. J. 75 (1977) 231.

[8] Rothman and Simeone, The Spine, Saunders, 1975, Philadelphia, p. 203.

[9] J. Guild, The Interference System of Crossed Diffraction Gratings, 2nd Ed., Lippincott, 1967, Philadelphia, p. 914.

[10] J. Guild, Diffraction Gratings as Measuring Scales, Oxford Univ. Press, 1960, London and New York.

[11] P. S. Theocaris, Moiré Fringes in Strain Analysis, Pergamon, 1969, Oxford.

[12] Y. Nishijima and G. Oster, J. Opt. Soc. Am. 54 (1964) 1.

[13] A. R. Lang, Nature 220 (1968) 652.

[14] G. Oster, Holography as a moiré phenomenon, in Symposium on Modern Optics, ed. by J. Fox, Wiley (Interscience), 1967, New York, p. 541.

[15] G. Oster, Ann. N. Y. Acad. Sci. 157 (1969) 38.

[16] G. Oster, Moiré patterns in science and art, in Advances in Biological and Medical Physics, vol. 16, ed. by J. H. Lawrence, J. W. Gofman and T. L. Hayes, Academic Press, 1977, New York, p. 333.

[17] G. Oster, Endeavour 27 (1968) 60.

[18] G. Oster, The Science of Moiré Patterns, 2nd Ed., Edmund Scientific Co., 1969, Barrington, NJ.

[19] G. Oster and Y. Nishijima, Sci. Am. 208 (1963) 54.

[20] R. E. Brooks and L. O. Heflinger, Appl. Opt. 8 (1969) 935.

[21] P. S. Theocaris, Expt. Mech. 4 (1964) 153.

[22] D. M. Meadows, W. O. Johnson and J. B. Allen, Appl. Opt. 9 (1970) 942.

[23] H. Takasaki, Appl. Opt. 9 (1970) 1457.

[24] H. Takasaki, Appl. Opt. 12 (1973) 845.

[25] H. Takasaki, Moiré Topography, Proceedings of the Symposium of Biostereometrics 1974, Amer. soc. Photogrammetry, 1974, p. 590.

[26] H. Takasaki, Photogram. Eng. and Remote Sensing 41 (1975) 1527.

[27] S. S. Xenofos and C. H. Jones, Phys. Med. Biol. 24 (1979) 250.

[28] S. S. Xenofos, C. H. Jones and D. R. Dance, Phys. Med. Biol. 24 (1979) 262.

[29] S. Fajita, S. Sakuma, N. Imagunbai, Y. Ayakawa and N. Miyata, Nippin Acta Radiol. 34(6) (1974) 25.

[30] S. S. Xenofos and C. H. Jones, Measurement of surface topography by moiré fringe patterns, in Digest of the Fourth Int. Conf. on Med. Phys., 1976.

[31] W. Binder, A. Cabej, K. H. Karcher and G. Windishbauer, Strahlentherapic 153 (1977) 82.

[32] A. L. Boyer and M. Goitein, Med. Phys. 7 (1980) 19.

[33] I. V. Adair, M. C. van Wijk and G. W. D. Armstrong, Clinic. Orthop. 129 (1977) 165.

[34] R. F. Free, Spinal examination using moiré fringe photogrammetry, Proc. Symp. Biostereometrics 1974, Am. Soc. Photogrammetry, 1974, p. 634.

[35] M. C. van Wijk, J. Biomech. 13 (1980) 605.

[36] S. Willner, Acta Orthop. Scand. 50 (1979) 295.

[37] S. A. Kamal, A new process for patient alignment, Bull. Amer. Phys. Soc. 27 (1982) 301 (poster presentation)[¥].

[38] S. A. Kamal and M. A. Khan, Moiré contour recorder, 19th Annual Science Conference, Quaid-i-Azam University, Islamabad (Pakistan), 1979 (in Urdu)[ξ].

[39] S. A. Kamal and R. E. Lindseth, Moiré topography for the detection of orthopedic defects, Periodic Structures, Gratings, Moiré Patterns and Diffraction Phenomena, Proc. Soc. Photo-Opt. Instr. Eng. 240 (1981) 293[£].

[40] 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, Twenty-third Annual Meeting of AAPM, Boston, 1981; Med. Phys. 8 (1981) 549 (presented by title)[θ].

[41] S. A. Kamal, J. Islamic Med. Assoc. (USA) 14 (1982) 146[€].

[42] The World Book Encyclopedia, vol. 13, Field Enterprises, 1964, Chicago, p. 575.

[43] The New Encyclopaedia Britannica, 15 Ed., vol. VI, Encyl. Britannica Inc., 1976,

[¥] Full text: https://www.ngds-ku.org/Papers/C17.pdf

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

[£] Full text: https://www.ngds-ku.org/Papers/C08.pdf

[θ] Full text: https://www.ngds-ku.org/Papers/C11.pdf

[€] Full text: https://www.ngds-ku.org/Papers/J04.pdf

Chicago, p. 971.

[44] J. Thewlis, Concise Dictionary of Physics, 2nd Ed., Pergamon, 1979, Oxford, p. 222.

[45] H. J. Gray and A. Isaacs, A New Dictionary of Physics, Longman, 1975, p. 353.

[46] D. N. Lapedes (ed.), McGraw-Hill Dictionary of Physics and Mathematics, McGraw-Hill, 1978, New York, p. 638.

[47] McGraw-Hill Encyclopedia of Science and Technology, vol. 8, McGraw-Hill, 1977, New York, p. 620.

[48] B. Drerup, Eine Apparatur zur Dokumentation von Erkrankungen des Haltings - und Bewegungsapparates durch Moiré Topographie, Sonderforschungsbereich 88, Westfalische Wilhelms - Universität Münster, 1977.

[49] S. L. Turek, Orthopaedics: Principles and Their Applications, Lippincott, 1967, Philadelphia, p. 914 (Ch. 28: The Back).

[50] M. O. Tachdijian, Pediatric Orthopedics, vol. 2, Saunders, 1972, Philadelphia, London and Toronto, p. 1201.

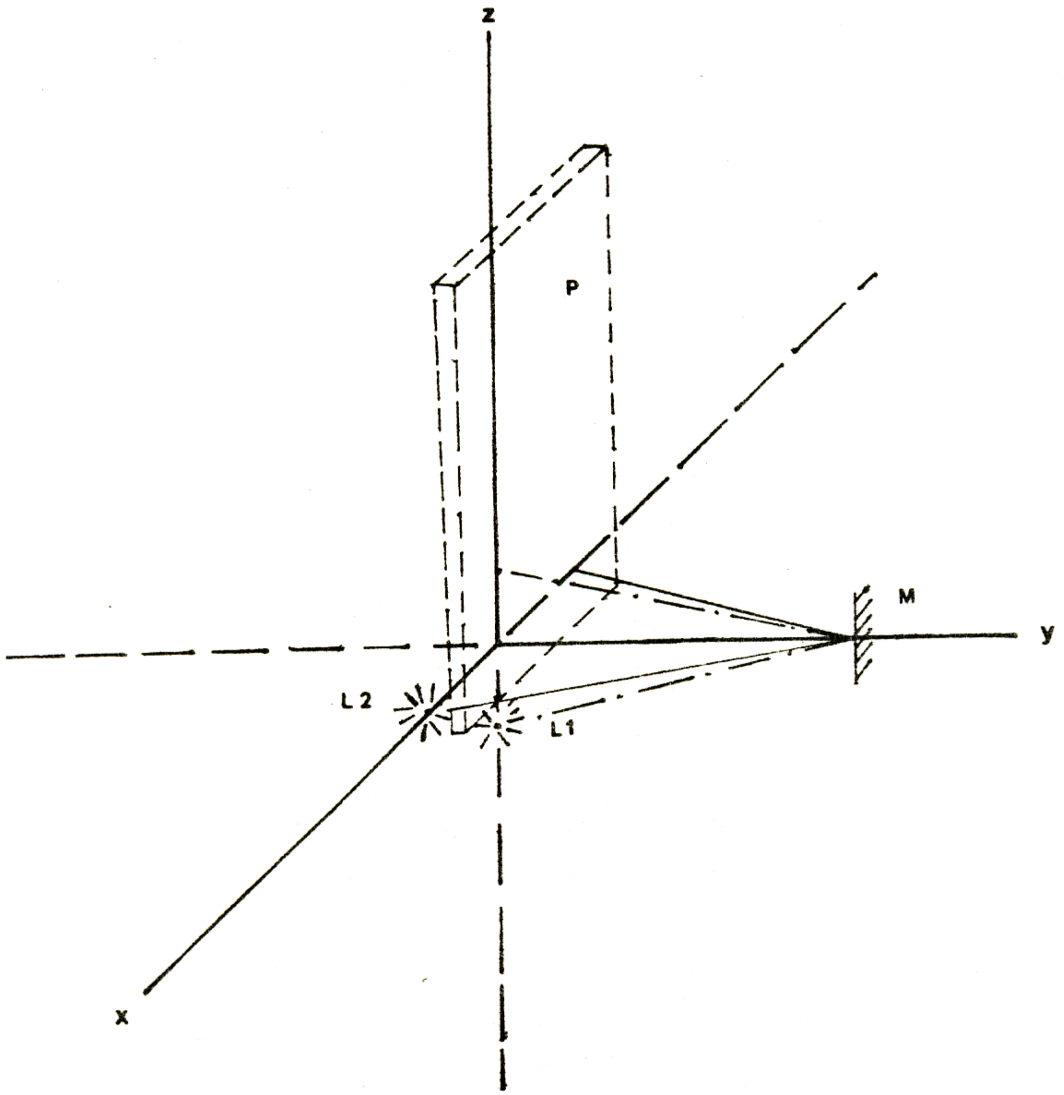

Fig 1. Patient alignment system

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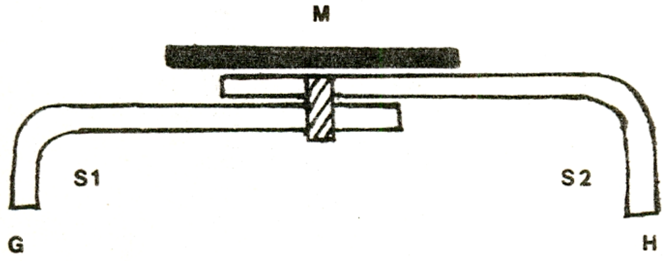

Fig 2. Mirror attachment

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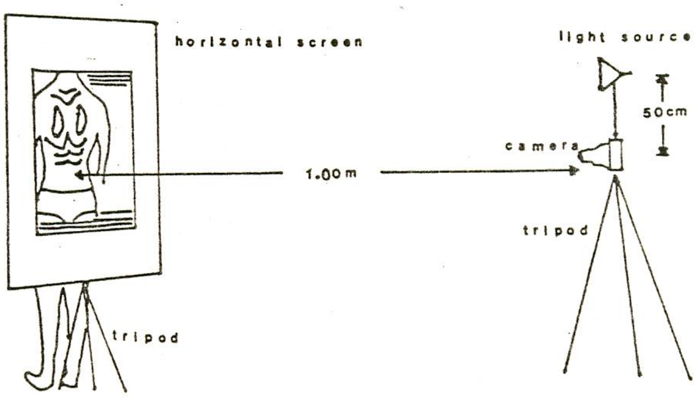

Fig 3. Arrangement of equipment

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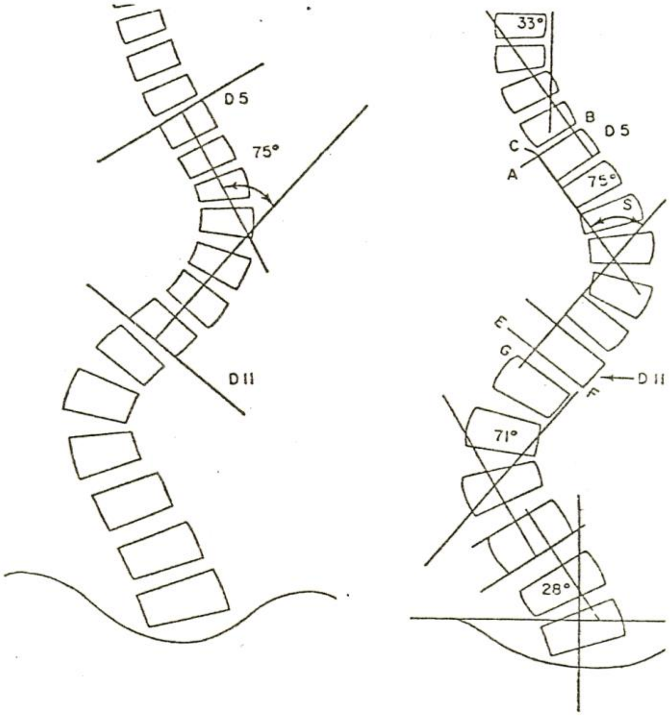

Fig 4. Measurement of Cobb's angle

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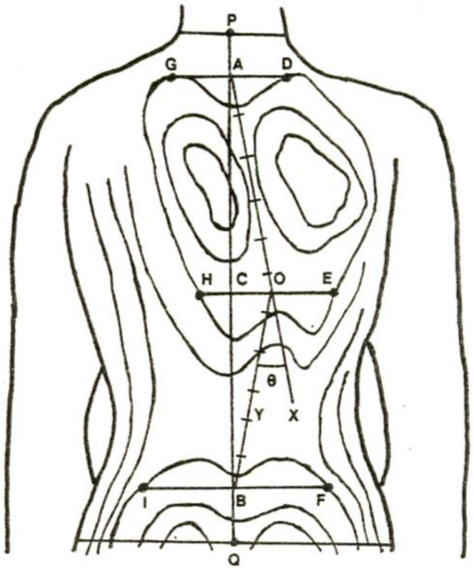

Fig 5. Measurement of the angle of spinal curvature by moiré topographs

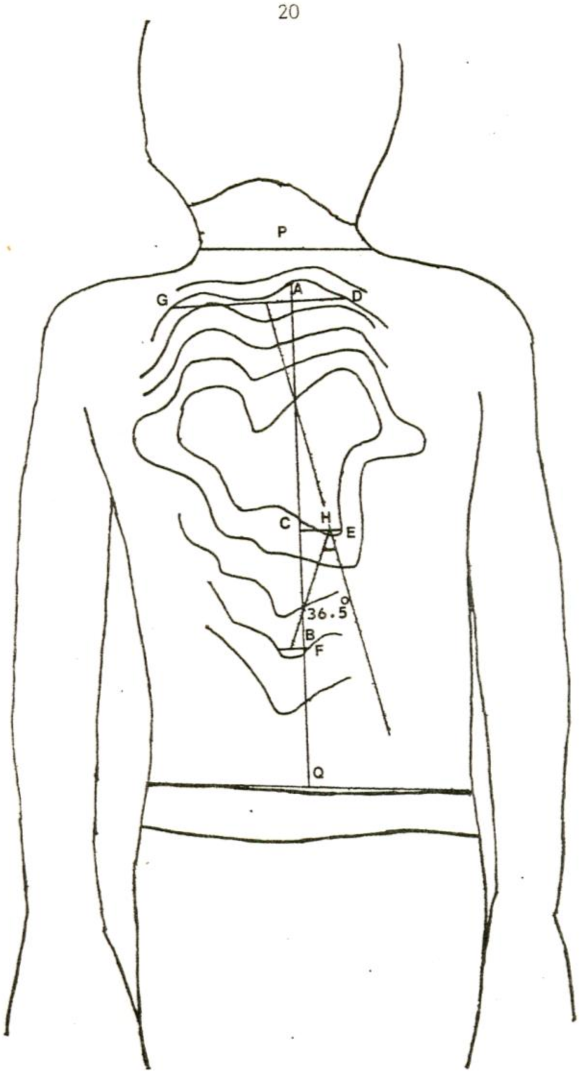

Fig 6. Moiré topograph of back of a seven year old boy with negative bending test

Abstract (*corresponding author's homepage*)**:** https://www.ngds-ku.org/Presentations/Cobb.pdf
Web address of this document (*corresponding author's homepage*)**:** https://www.ngds-ku.org/Papers/C12.pdf

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MEETINGS AT A GLANCE

TIME	8:00	8:30	9:00	10:00	11:30	12:00	1:00	1:15	1:30	4:45	5:00	5:30	7:00	7:30
Saturday Sept. 19		EMBS Sessions							EMBS Sessions			EMBS Mixer		EMBS Workshops
Sunday Sept. 20		EMBS Sessions			EMBS Lunch				EMBS Sessions					EMBS Workshops
			Short Courses—Azalea, Bluebonnet											
Monday Sept. 21		EMBS CompMed Sessions						EMBS CompMed Sessions						
	Microcirculation—Grove BioHeat Transfer—Nile Ventricular Mech I-Gr Ballrm Respiratory System I-Crystal ECG Data Compression-Embassy Neurology/EMG-Continental Clinical Eng-Belvedere A Ultrasound-Marco Polo						Biorheology—Grove Visual Systems—Venetian Ventricular Mech II-Gr Ballrm Resp System II/III-Crystal ECG/MCG-Embassy Autom EEG Analysis-Continental Cancer Therapy-Belvedere A Ultrasonics/Imaging-Marco Polo							
			Student Papers-Venetian		Lunch w/Authorities-Emerald					PLENARY-Gr Ballrm		Reception/Exhibits-Exhibit Hall		
Tuesday Sept. 22		Substrate Transport I-Grove Cardiac Pacing I-Gr Ballrm Respiratory Sys IV-Crystal Cardiac Valves-Embassy EEG Analysis-Continental Medical Imaging-Marco Polo Fracture Biomech I-Camellia Electrophysiology-Bluebonnet Space Medicine I-Azalea							Substrate Transport II-Grove Cardiac Pacing II/III-Gr Ballrm Respiratory System V-Crystal Vascular Dynamics-Embassy Evoked Spinal Analysis-Continental Cardiovasc Nuclear Med-Marco Polo Fracture Biomech II-Camellia Cardiology-Bluebonnet Space Medicine II-Azalea					
			Exhibits/Posters-Exhibit Hall	AEMB Council-Nile		Lunch w/Authorities-Emerald							Professional Dinners	
Wednesday Sept. 23		Cardiac Pacing IV/V-Gr Ballrm Respiratory System VI-Crystal Atherosclerosis-Embassy Rehabilitation I-Continental Biomech/Jt Function-Camellia Modeling I-Azalea Membrane Separation-Grove Instrumentation-Bluebonnet Positron Imaging-Marco Polo							Cardiac Pacing VI-Gr Ballrm Respiratory System VII-Crystal Cardiovasc Mechanics-Embassy Rehabilitation II-Continental Biomech/Human Motion-Camellia Modeling II-Azalea					
			Exhibits/Posters-Exhibit Hall			Lunch w/Authorities-Castilian								