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MOIRÉ TOPOGRAPHY FOR THE DIAGNOSIS AND DOCUMENTATION OF SCOLIOSIS

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Moiré topography is a biostereometric method, which produces a three-dimensional image of the shape of the trunk. In structural scoliosis an asymmetry of the two halves of the back is seen.

This method has been studied and the range of the asymmetry of the moiré pattern has been compared with clinical observations and X-ray findings in 216 cases with structural scoliosis. A statistically significant correlation between these three ways of describing a structural scoliosis was found.

Because of the sensitivity of the moiré method an asymmetry of at least one fringe interval could be regarded as a positive result. All the observed asymmetries less than one fringe interval had a lateral deviation of the spine of less than 10 degrees according to Cobb when X-ray examined. The moiré method seems to be very suitable for the screening of structural scoliosis, owing to its ability to detect and document even small deformities by photography and the simplicity of the technique which can be carried out even by staff without medical training.

Key words: scoliosis; moiré topography; screening; rotation hump

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The results of both the conservative and the surgical treatment of scoliosis have improved considerably during recent years. This is partly due to the introduction of more efficient methods of treatment but also to a greater knowledge of scoliosis. It has also been found that the results of treatment improve if the treatment is started early during the course of the condition. Therefore the interest in an early diagnosis of these deformities of the spine has now grown rapidly (Kane & Moe 1970, Asher et al. 1975, Winter 1975, Lonstein et al. 1976, Gaines et al. 1977, Adair et al. 1978).

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Screening for scoliosis is usually carried out at the school health examinations. The investigation of the spine is here based entirely upon clinical observations. The diagnosis of more severe curves is not particularly difficult. Smaller deformities, however, may easily be overlooked especially by an inexperienced investigator. One weakness of clinical investigation is that the condition of the scoliosis cannot be compared between two examinations. Without an X-ray it is not possible to see if there is an increase in the deformity of the spine.

With the introduction of the moiré topography method a new means of describing and documenting the state of the spine has been made available. This method, which is able to diagnose even very small asymmetries

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of the spine, has been tested at the Orthopedic Department of Malmö General Hospital and the results are given later in this study.

THE MOIRÉ TECHNIQUE

The physical meaning of the term moiré is the pattern of shadows which are produced by interference when periodic or quasi-periodic grids are placed one on top of the other. The width of the lines of the grid should be equal to the space between them.

The moiré effect can also arise through interference between a screen and its shadow which falls upon an object behind. The appearance of the fringe pattern is determined by the shape of the illuminated surface. In this case the various shadow lines – the contour lines – appear on the surface of the object at regular distances from the grid. These lines can be compared with the contour lines on a topographical map. The distance between the moiré screen and the contour lines is determined by:

1. The distance between the light source and the screen – l
2. The distance between the light source and the eye/camera – d
3. The screen intervals (the diameter of a screen wire plus the space between them – s.

Knowing these distances the distance to the first contour line – h – is calculated according to the following formula:

$$h = \frac{s \cdot l}{d - s}$$

Each point on the same contour line is at the same distance from the screen. The difference in distance (to the moiré screen) of two adjacent fringes is approximately equal for all the contour lines seen on the object.

With this method asymmetries between the two halves of a back can be studied and recorded by comparing the moiré patterns. If the spine is erect and without rotation these fringe patterns will be symmetric. If, on the other hand, there is a structural scoliosis characteristic differences between the shadow patterns of the two halves will be observed (Figure 1). The degree of asymmetry of the shadow patterns is here

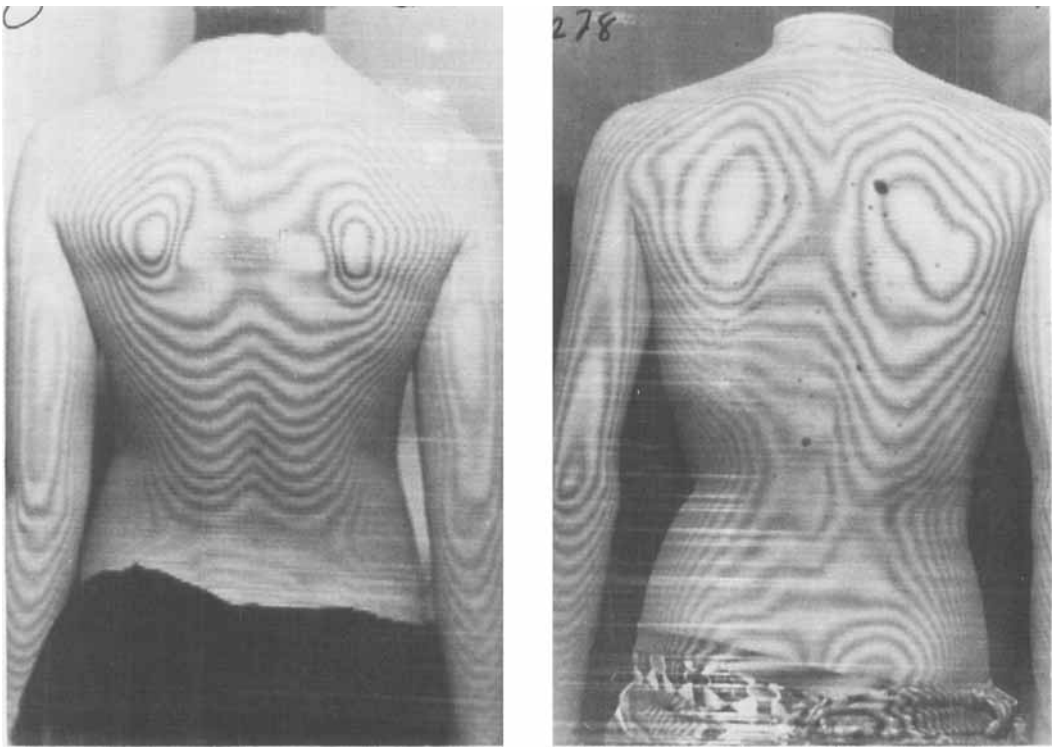

Figure 1. The moiré photographs of a normal back (left) and a thoracolumbar scoliosis of 37 degrees (right).

Figure 2. The moiré equipment.

determined by the rotation of the scoliosis rather than by its lateral deviation.

The moiré apparatus

The apparatus consists of the following components (Figure 2). The moiré frame (with an opening of 75 × 50 cm) 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. The light source consists of a studio light with an intensity of 1000 watt. It is fixed to the same tripod as the camera which is on a level with the central point of the moiré frame. A single-lens reflex camera (Canon AE with 85 mm focal length lens) is used. Generally, black and white film is used (Tri-X pan 400 ASA). The exposure time is 1/125 second and the aperture size 5.6–8.

In this study the following distances between the components of the apparatus were chosen:

The light source/camera – moiré frame, 170 cm

Light source – camera, 60 cm.

Under these circumstances the difference in distance to the frame between adjacent contour lines will be 0.7 cm. In order to compare the moiré photos from examination to examination the patient must be accurately repositioned against the moiré screen with the back just touching the screen at the shoulders and buttocks. It is also necessary to make the children stand erect, relaxed and with equal load on both legs.

The interpretation of the moiré pictures

The pictures are easily obtained and do not require trained medical personnel. The evaluation of the photograms, however, should be performed by members of the school health staff.

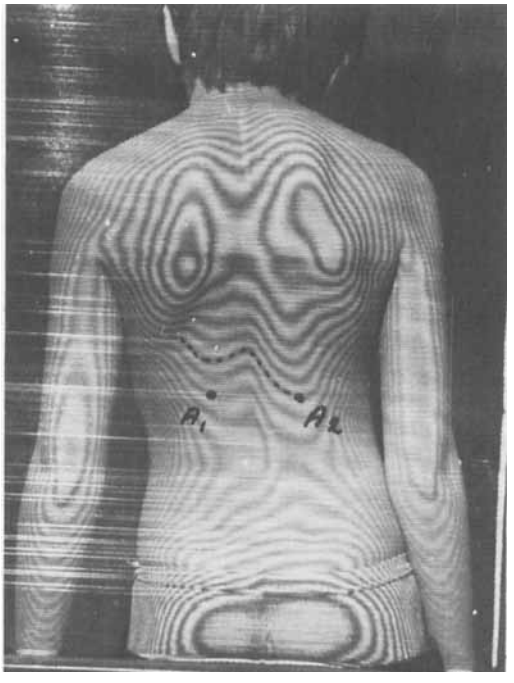

Figure 3. A 10-year-old girl with a right convex thoracic scoliosis (24 degrees and apex T 9). A deviation of two moiré fringes is seen between the two symmetric points A_1 and A_2 indicating a right convexity. A deviation of the number of contour lines is also seen laterally to the scapular contact surfaces.

The asymmetry between the moiré pattern of the convex half and that of the concave one can be deduced from the following observations:

1. Contact surfaces of varying size between the scapulae and the wires of the screen occur in the case of thoracic and thoracolumbar scolioses (Figure 3). If the curve is located distally in the lumbar spine an asymmetry of the contact surfaces of the buttocks will also be visible.

2. A difference in level of the contour lines between the convex and concave halves is most noticeable at the level of the vertex of the scoliosis. If there are curves in the proximal thoracic spine this difference in level is seen proximally to the contact surfaces of the scapulae. If, on the other hand, the scoliosis is located in the lower half of the thoracic spine and in the lumbar spine the difference in the level of the contour lines will be seen distally to the contact surfaces of the scapulae (Figure 3). If two symmetrical points are marked one on each side of the body the relationship of these to the fringe pattern will be evident. The more fringes that separate the two,

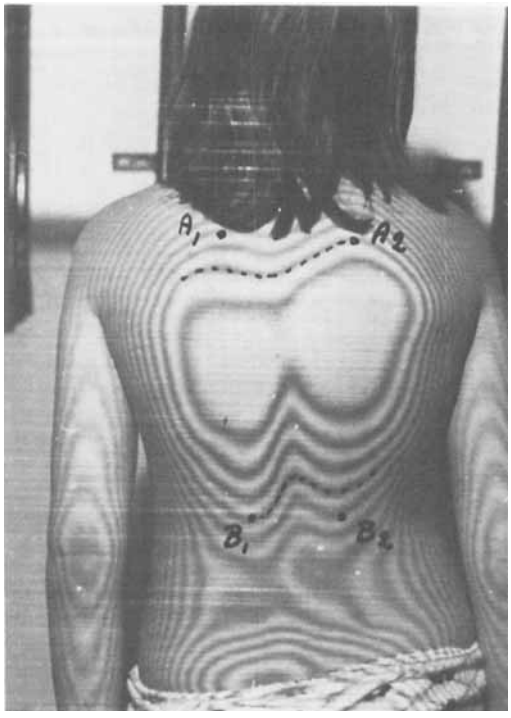

Figure 4. A 16-year-old girl with a right convex thoracic curve (20 degrees and apex T 4) and a left convex thoracolumbar curve (18 degrees and apex T 12). The symmetric points A_1 and A_2 are located on different contour lines with a deviation of two moiré fringes. The symmetric points B_1 and B_2 are also seen to be on separate contour lines with a deviation of one moiré fringe.

the larger is the rotational deformity. The shapes of the contour lines also differ to a greater extent with increasing deformity of the back. The contour lines on the concave half become more and more vertical and lose their rounded shape across the paravertebral muscles. On the convex half the rounded form of the contour lines will be more and more noticeable (Figure 3).

3. In scolioses located in the mid-thoracic spine the asymmetry of the moiré pattern is most visible laterally to the contact surfaces of the scapulae (Figure 4). On the convex half, an increasing number is found due to the hump. By studying the difference in the contour lines at 1 cm lateral to the scapulae plateau an estimation of the asymmetry of the chest can be obtained.

Because of the sensitivity of the method to record asymmetries of the shadow pattern even in very small rotational deformities of the spine, a difference less than one fringe interval has been accepted as "a normal spine".

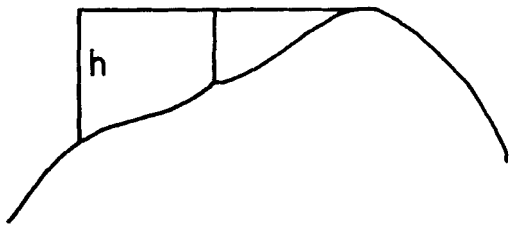

Figure 5. Clinical evaluation of rotation in a forward bending position.

PATIENTS AND METHOD

The study included 216 children with a structural scoliosis with a varying range of severity (5 degrees to 65 degrees according to Cobb 1948). Five cases were congenital scolioses, three paralytic scolioses and 208 children had a scoliosis of the idiopathic type. One hundred and thirty-seven cases were single primary curves and 79 were double primary curves. In the latter group both curves were studied with the moiré method. One hundred and forty-seven curves were located in the thoracic spine (Th 1 to Th 11) and 160 were thoracolumbar and lumbar curves (Th 12 to L 5).

All the children were investigated clinically (forward bending test), roentgenographically (Standing AP X-ray) and with the moiré method on the same occasion. The range of the rotation was determined according to Figure 5.

RESULTS

All cases were first diagnosed clinically with a positive forward bending test which showed a visible asymmetry of the trunk caused by a rotation of the spine.

When comparing the range of the curve according to Cobb and the range of the deviation of the contour lines on both halves of the back a significant correlation was seen (Figure 6). All the 11 cases with a lateral deviation of less than 10 degrees had a deviation of less than one fringe interval which in our study had been designated as the lower limit for a positive result. With a deviation of more than one fringe interval practically all of the scolioses exceeded 10 degrees. When the deviation was three fringe intervals or more all cases had a curve of

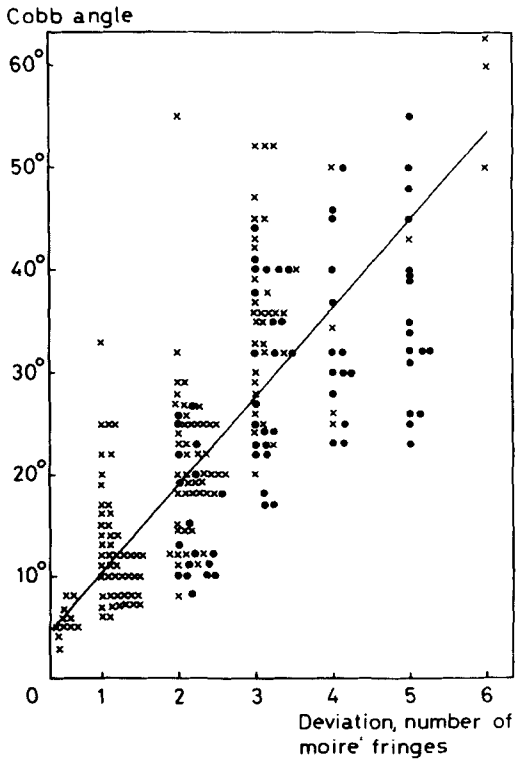

Figure 6. Correlations between lateral deviations and asymmetries of moiré fringes in structural scoliosis (only the maximal curves are included). ● = maximal deviation of the moiré fringes laterally to the contact surface of the scapulae. x = proximally or distally to the scapulae. y = 8 x + 4. 8, $r_{218} = 0.77$.

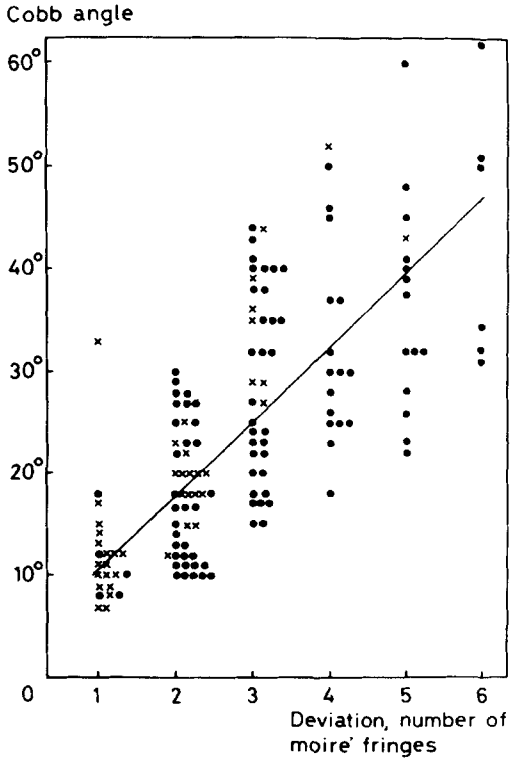

Figure 7. Correlations between lateral deviations and asymmetries of moiré fringes in thoracic curves (Th 1–Th 11). ● = maximal deviation of the moiré fringes laterally to the contact surface of scapulae. x = proximally or distally to the scapulae. y = 6.7 x + 6.1, $r_{148} = 0.73$.

more than 20 degrees, which was the borderline for active treatment of a growing child. A wide range of lateral deviation was seen in all the various groups of deviations of fringe intervals. However, it must be remembered that the moiré method registered the rotation and the X-ray examination the lateral deviation of the scoliosis.

When comparing the moiré pattern with the X-ray findings in scoliosis partly located in the thoracic region (Figure 7) and partly in the thoracolumbar and lumbar spine (Figure 8) a closer correlation was found in the lumbar region. In Figure 6 a deviation of two fringe intervals or more was associated with a scoliosis of more than 20 degrees.

Another significant correlation was found when comparing the deviation of the contour intervals with the range of asymmetry of the hump (Figure 9).

Finally, a comparative study of the X-ray observed lateral deviation and the clinically estimated size of the hump was performed (Figure 10).

DISCUSSION

During the last few years the importance of early diagnosis of the structural scoliosis in progress in the growing child has become

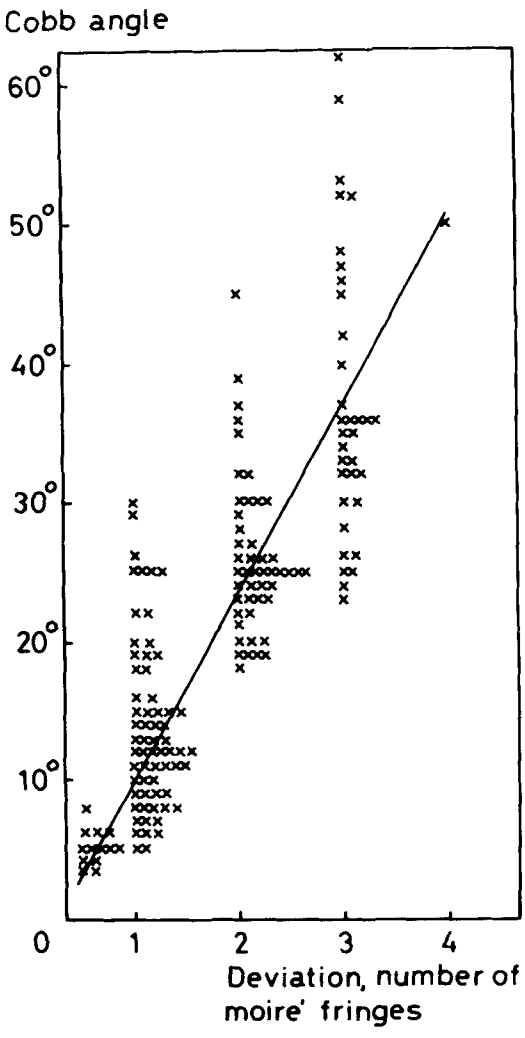

Figure 8. Correlations between lateral deviations and asymmetries of moiré fringes in thoracolumbar and lumbar curves (Th 12–L 5). Maximal deviations are only seen distally to the contact surface of the scapulae. $y = 12.4\ x + 1.1$, $r_{159} = 0.84$.

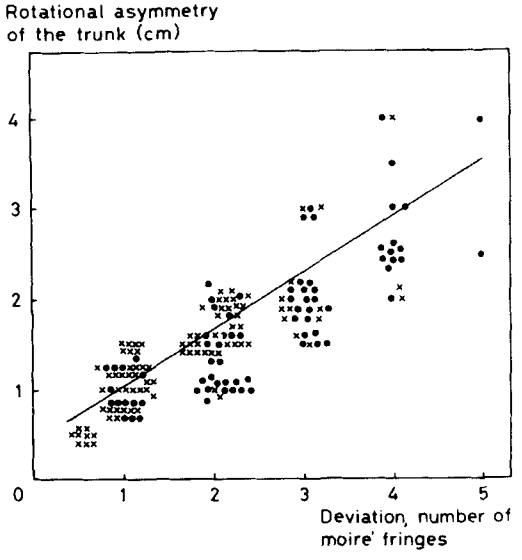

Figure 9. Correlations between the clinically estimated size of the humps (cm) and the asymmetries of the moiré fringes in the structural scoliosis. x = located in the thoracic spine (Th 1–Th 11). ● = in the thoracolumbar or lumbar spine (Th 12–L 5). $y = 0.55\ x + 0.45$, $r_{166} = 0.83$.

evident. Therefore interest in the various screening methods has also increased.

The criteria for an acceptable screening method are:

1. The possibility of diagnosing very slight deformities of the spine;

2. A minimal number of false positive and negative results;

3. A simple technique with a minimal risk of personal error and which allows the investigation of many children in a short time;

4. The possibility to document the findings for comparison with subsequent examinations.

Most screening methods used nowadays to detect scoliosis are exclusively clinical studies. Roentgenological screening is neither ethically nor economically justifiable. With moiré topography a new optical biosteriometric method has been introduced for school screening of scoliosis.

This method was first described by Takasaki (1970, 1973). An evaluation of the moiré method has been published by Drerup (1977).

The interest in the use of the moiré technique in school screening has increased during the last few years. Recently a moiré screening program was published by Adair et al. (1978). They found that the moiré method

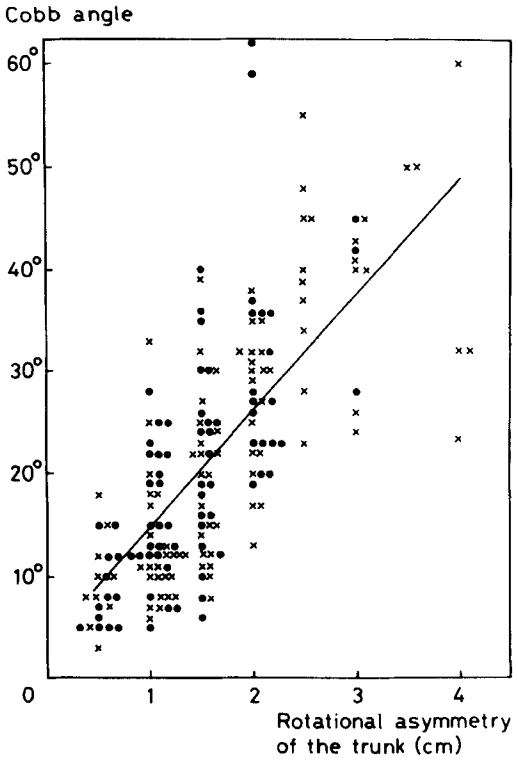

Figure 10. Correlations between lateral deviations and sizes of the humps in structural scoliosis. x = located in the thoracic spine (Th 1–Th 11). ● = in the thoracolumbar or lumbar spine (Th 12–L 5). $y = 11.6\ x + 3.7$, $r_{180} = 0.73$.

registered X-ray diagnosed scoliosis with greater accuracy than clinical observation (forward bending test), 94 per cent and 46 per cent, respectively.

In the straight trunk the moiré patterns are equal in both halves of the back (Figure 1). On the other hand, with an increasing asymmetry of the trunk the two moiré patterns deviate more and more from each other. However, it is important to remember that the deviations of the moiré pattern are mainly caused by a rotation and not by a lateral bending. The latter is measured and discussed roentgenographically when describing the spinal deformity. This means that the moiré technique and the X-ray examination describe two separate properties of structural scoliosis.

As the moiré method has been shown to be very sensitive and to register even very insignificant asymmetries of the trunk we decided to accept as "normal spines" all those whose asymmetries are characterized by a deviation of less than one fringe interval (with the equipment we used). In no case in this study was a deviation of less than one fringe interval found to accompany a lateral deviation of more than 10 degrees according to Cobb. This means that the risk of getting a false negative result or missing a case requiring active treatment would appear to be small.

On the other hand, defining all types of asymmetries as positive results, the moiré method will be burdened with a large number of false positive results without any clinical value.

Even if this study as a whole shows a statistically significant correlation between the deviation of the contour intervals and the range of the X-ray examined lateral deviation according to Cobb a wide spread of lateral deviation is seen in all the groups of deviations of fringe intervals. In the thoracolumbar and lumbar scoliosis a deviation of two contour intervals or more is indicative of curves of more than 20 degrees. In thoracic scoliosis most of the midthoracic curves are mainly detected by the deviation of fringe intervals lateral to the shoulders. Here there seems to be a wider distribution of lateral deviations in the groups of deviations of fringe intervals than in the groups with maximal deviation below the shoulders.

As expected, a significant correlation was observed between the range of the hump and the moiré asymmetry. In reality both these observations describe the same component of the scoliosis, viz. the rotation.

A significant correlation was also seen between the range of the hump deformity measured clinically and the lateral deviation as measured by X-ray examination as formerly discussed by, among others, Götze (1973). However, this correlation was not so evident as that between the moiré asymmetry and the X-ray observation.

The moiré method, however, demands that the children stand in a correct position in relation to the grid. This means that there should be slight contact between both the shoulders and buttocks and the screen. An incorrect position, however, can easily be observed by the photographer if he studies and counts the number of contour lines on either side of the midline between the shoulders, which should be equal.

The advantage of this method in comparison with clinical ones is the possibility to document the condition of the back. Furthermore the moiré method is easy to apply and can be managed by paramedical staff. The investigation can be performed rapidly by two persons; one photographs and the other helps the children to stand in a correct position. About 40 children can be investigated per hour.

When studying the moiré photos it is important to look for the maximal deviation of the fringe intervals between the two halves of the trunk laterally as well as above or below the contact surfaces of the shoulder. Also the difference in size and level of these contact surfaces must be studied.

CONCLUSION

Our observations show that the moiré technique is suitable for the screening of structural scoliosis because of:

1. Its sensitivity to even small deformities;
2. The simplicity of the technique;
3. The possibility of documenting the condition of the back for comparison with subsequent examinations.

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