

Surface Topography and Body Deformity

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Reproducibility of moiré topographs

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Abstract

This paper examines the issues regarding the reproducibility of moiré topographs and outlines the need for an objective criterion for reproducibility. A criterion is proposed to obtain reproducible moiré pictures. An experiment is designed to test this criterion.

1. Introduction

Moiré fringe topography has proved to be extremely useful in the diagnosis and documentation of scoliosis. It is also being applied in the evaluation of anterior chest wall deformity. The power of this technique lies in the fact that it is simple, inexpensive, noninvasive and does not use any ionizing radiation. In addition the technique provides a map of three-dimensional surfaces by generating contours which are curves of constant height. Unlike contouring with holographic techniques, stability is not required. In addition, the resolution of moiré contouring systems can be varied continuously.

The technique of moiré 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. The study of these fringes gives valuable information about skeletal deformities.

2. Description of the problem

Moiré topography is being applied in the evaluation of spinal deformities for more than eight years. Adair, van Wijk and Armstrong (1977) felt that the few positive cases in their pilot screening program for scoliosis, which were missed by the moiré technique were due to the fact that some children were not properly aligned or had to be rotated by the shoulders to obtain the required

orientation. Moiré technique is also being applied for the follow-up of scoliosis patients. If the moiré topographs are to be compared at subsequent intervals, then there must be some reference point. Shochat and Csongradi (1983) used moiré technique in the evaluation of anterior chest wall deformity. They placed the patient behind the screen facing the camera with the abdomen in contact with the screen. This technique provided a central fringe which was used as a reference point. However, during therapy and surgery for pigeon chest the shape of the abdomen is not guaranteed to be the same as the initial one. Hence this technique is not reliable. There is another consideration when positioning of the patient is done for the study of posture and spinal deformities. If one tries to obtain any type of reproducible position, one is immediately distorting the condition one is trying to examine, particularly if one tries to rotate the trunk on the pelvis. Even the positioning of feet tends to rotate one hip to a mild degree as observed in small curves.

During recent years there has been considerable concern over the accuracy and repeatability of moiré topographs (Csongradi, Jefferson, Turner-Smith and Harris, 1987; Bannon and Tredwell, 1987; Jones, Scull, Dutton, White, Slinger and O'Connor, 1987).

3. Attempts to position the patient and the moiré apparatus

My group used a special lamp and scale arrangement to position the patients in some of the earlier studies (Kamal, 1982). Two laser beams were used to align the patient vertically and horizontally. A mirror was attached to the patient's sides using two plastic strips. The proce-

dures were later on discarded because it was felt that any constraining device tended to impose an abnormal posture on the subject (El-Sayyad and Kamal, 1982). Neugebauer tried positioning at the pelvis, but later stopped because he felt that it disturbed the patients. However, the Oxford group is using positioning at the anterior superior iliac spine and they are satisfied with the outcome.

In the FUJINON system feet are positioned, patient is tilted at five degrees and the symmetric fringes on the buttocks are considered as reference. This represents an improvement because the patient is not disturbed and the camera is rotated to obtain the reference position. However, it has some drawbacks.

- a) If an attempt is made to compare measurements performed on the moiré topograph to those performed on X-rays e.g. the angle of spinal curvature the patient position during moiré should be identical to that during X-rays.
- b) The patient is still restrained on the frame and the foot pad, thus masking significant change in the posture.
- c) The buttocks symmetrical fringes cannot be considered as reference for follow up because during physical therapy spine as well as hips would be affected.
- d) As far as I know no quantitative studies are done to determine the extent of reproducibility using this criterion.

The problem we are facing today is to find a criterion for reproducibility which (i) does not disturb the natural posture of the patient; (ii) does not involve any landmarks in the spinal area or trunk for scoliosis study and chest and abdomen for chest wall deformity, because these would not remain unchanged during physical therapy; (iii) is easy to apply.

4. Reproducibility criterion

The reproducibility questions important to a biomechanics researcher are ones of *stability* and *objectivity* (Disch and Hudson, 1980). Stability means if one takes several moiré pictures of an

object and measures them, one should obtain the same values. Objectivity means if several people take moiré pictures of an object and measure them, they should obtain the same values. In this paper mainly the stability aspect will be studied. I define a reproducible photograph (including moiré topographs) as the one which is similar to the original one. In Euclidean geometry two triangles are similar if their angles are congruent and their respective sides are proportional. It can be proved that two triangles are similar if two of the three angles are congruent.

For a photograph (moiré topograph) of the front the three anatomical landmarks chosen as the vertices of the triangle are the left and the right nipples and the naval. For a photograph of the back the anatomical landmarks are the left and the right scapula and a point marked on the spinal processes at the naval level (Fig. 13). Let α_j , β_j and γ_j be the angles measured initially. The index $j = 1, 2, \dots, N$ is the case number and N is the total number of subjects studied. Let α'_j , β'_j and γ'_j be the angles measured during the second visit.

The deviations are

$$(1a) \quad \psi_j = (\alpha_j - \alpha'_j) / (\alpha_j + \alpha'_j)$$

$$(1b) \quad \chi_j = (\beta_j - \beta'_j) / (\beta_j + \beta'_j)$$

The averages are

$$(2a,b) \quad \langle \psi \rangle = \text{Sum}(\psi_j) / N, \quad \langle \chi \rangle = \text{Sum}(\chi_j) / N, \\ j=1 \dots N \quad j=1 \dots N$$

The sample standard deviations are

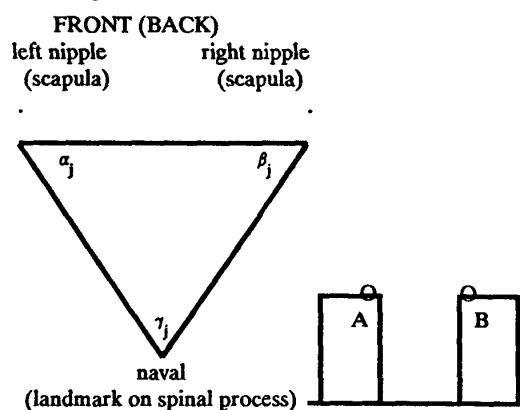


Fig.1 Anatomical landmarks

Fig.2 Fist positioning

$$(3a) \quad S_{\psi} = [\text{Sum} (\psi_j - \langle \psi \rangle)^2 / (N - 1)]^{1/2}$$

$$(3b) \quad S_{\chi} = [\text{Sum} (\chi_j - \langle \chi \rangle)^2 / (N - 1)]^{1/2}$$

The maximum of these deviations is then recorded

$$(4) \quad S = \max(S_{\psi}, S_{\chi})$$

The method proposed will be considered reliable if $S < 0.05$. In order to find a standard for reproducibility on moiré topograph avoiding the area being studied, it is proposed that symmetric fringes on the knees be considered as reference provided the patient does not have any leg deformity. In many cases of skeletal deformities, however, this is not the case. If the fists of the hands are taken as reference, they will be relatively independent of the skeleton. However, since the fists can be rotated easily, a standard plane is needed. Fig. 2 shows a pair of stands which the child can hold in his palms and thus fixing the position of fists. This positioning will not significantly effect the posture. The child will be asked to stand relaxed looking straight ahead on some fixed point on the wall. Symmetric fringes on the front and back sides of the fists can be used for positioning the camera for the study of chest as well as back.

5. Materials and methods

A shadow moiré apparatus is being used to conduct the study. The specifications of the moiré set up are described elsewhere (Kamal et al. 1988). For the criterion to have statistical validity hundred normal healthy boys of class seven are requested to participate in the photographing process. The children are marked on the back using a skin marker and photographed with their shoes and stockings off as recommended by Free (1974). Two photographs of the back are taken by the same person to determine the reliability of the procedure. The angles are measured on all the photographs. In the end factor S will be calculated.

6. Conclusion and discussion

If the factor S comes out to be less than 0.05, the

criterion could be applicable. Further work in reproducibility could be done to study the stability based on fist as well as knee positioning for front photographs. Objectivity studies could also be done for both fist and knee positioning to compare the results of different observers.

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