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Computer modeling of selected projectional factors of the 84-in focal film distance anteroposterior full spine radiograph compared with 40-in focal film distance sectional views

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Abstract

Objective: The purpose of this study was to compare the 84-in focal film distance anteroposterior (A-P) full spine view to selected sectional views taken at a 40-in focal film distance for angles of divergence and changes produced by lateral translation and variation in source object distance.

Methods: Computer models were used to determine angles of divergence and study the effects of lateral translation and changes in source object distance.

Results: Lateral translation produced less projected axial (y-axis) vertebral rotation on the 84-in A-P full spine view than the film at 40 in. Angles of divergence are equal on the 14 × 17-in film at 40 in compared with the 84-in A-P full spine, and 70% of the 84-in full spine view is within the angles of divergence of the 40-in 10 × 12. The 84-in A-P full spine produced lowering and lengthening of the projected ilium when source object distance was reduced.

Conclusion: In this study, the 84-in A-P full spine produced less projected vertebral rotation on lateral translation. Its angles of divergence were greater than the 40-in 10 × 12 and equal to the 40-in 14 × 17-in film. Except for a 5.4-in section at both the upper and lower margins, the 84-in full spine view was within the angles of divergence of a 40-in 10 × 12. The full spine film produced projected ilium lengthening and lowering.

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Introduction

The appropriate use of radiographs is a popular area of discussion in the chiropractic profession. Practicing doctors of chiropractic may select from a wide variety of views to aid in patient care. Yet, not all views are met with equal acceptance. The role of one traditional chiropractic radiograph, the anteroposterior (A-P) full spine, is controversial, with Taylor[1] indicating that some chiropractors thought of the procedure as a routine part of practice, whereas others felt that it should never be done.

Although the A-P full spine view has been taught to many chiropractic students and detailed in books such as those by Winterstein,[2] Hildebrandt,[3] and Rowe,[4] this projection has its detractors. It has been criticized by Harrison et al,[5] who stated that the anterior-posterior full spine "was highly susceptible to projection distortion." Furthermore, in an era where radiography is moving toward digital film, the majority of which are sectional in nature, some may even question the need for an article such as this, which compares selected projectional factors of the 84-in focal film distance A-P full spine radiograph to those of sectional views taken at a 40-in focal film distance.

However, a working knowledge of the A-P full spine view is important. The A-P full spine may be used for scoliosis evaluation[6]; and additionally, there are doctors of chiropractic who use the A-P full spine as part of their assessment when viewing of the full spine.

The present study compares the angles of divergence of the 84-in focal film distance A-P full spine view to those of 40-in focal film distance sectional films.[2,4] This article then proceeds to delineate the portion of the 84-in A-P full spine view that is within the 40-in sectional film's angles of divergence. The affects of lateral (x-axis) vertebral translation on projected axial rotation on the 84-in A-P full spine are compared with those produced on 40-in sectional views. Finally, the effect on the projection of the ilium produced by the elevated position of the tube found in the 84-in A-P full spine, as opposed to the lower tube position found on 40-in sectional views of the pelvis, is illustrated.

Methods

The models for this study were created using a Solid Works 2008 Version SP3.1 3-D Computer Assisted Design Mechanical Engineering Program (Dassault Systemes HQ, Villacoublay, France). This program allowed the production of the models needed to study angles of divergence, angles of film contact, projected changes in axial (y-axis) rotation produced by lateral translation, and projected changes in ilium position and length due to changes in source object distance. We have expressed the majority of the data by rounding off to the nearest 100th, as any further detail is unnecessary.

Translation on the x-axis

The measurement of axial (y-axis) rotation may be of interest in the assessment of spinal problems.[7,8] However, translatory movement of the vertebra on the x-axis may be a confounder for these measurement methods. Vertebral translation along the x-axis (lateral translation) produces projected axial (y-axis) rotation on the film.[9] To compare this effect between an A-P full spine radiograph taken at an 84-in focal film distance and a sectional view taken at a 40-in focal film distance, the following procedure was performed.

A simple modeled vertebra was created. The modeled vertebra was composed of a circle representing the vertebral body and a triangle for the modeled spinous process. A modeled x-ray tube's focal spot was represented by a point, from which the modeled rays of the radiographic beam were extended outward until they reached the modeled film. The modeled film is represented by a line, erected perpendicular to the modeled central ray. The center of the vertebral body was placed 6 in from the modeled film. This placement is similar to the placement of the anterior margin of the vertebral body in a position 6 in from the modeled film, which has been used in previous studies.[9,10,11,12] The vertebral model was centered on the central ray, which passed through the center of the modeled vertebral body and the modeled spinous process. Two additional lines, representing rays of the radiographic beam, were projected outward from the modeled tube and passed tangent to the lateral body margins. All 3 rays were extended to the point where they intersected the line representing the radiographic film, and the distance between these points of intersection was recorded. The modeled vertebra was then translated parallel to the modeled film, for a distance of 3 in. This distance was selected with the intent to be large enough to allow the demonstration of any projected rotation that might occur.[9] In that position, the drawing of the 3 rays was repeated; and the distance between the points of contact of these rays with the modeled film was recorded. This measurement was done with the modeled tube at both 40 and 84 in (Figs 1 and 2).

Angles of divergence

The rays of the radiographic beam start in the tube, at what, for our purposes, is a point. As the rays move toward the film, they diverge. The angle formed between the central ray, which strikes the center of the film, and the rays that strike the film at either its upper or lower edge, when the tube is positioned at the level of the center of the film and the film is perpendicular to the central ray, is the angle of divergence.[2] This angle of divergence has also been termed the *angle of incidence* by Rowe.[4]

One of the criticisms of the A-P full spine view is that the angles of divergence of a 14 × 36-in radiograph film are greater than would occur if a smaller film were used. This means that objects that are seen at the superior and inferior film margins will have been projected by rays of the radiographic beam that are at a greater angle relative to the central ray. Therefore, as the angle of divergence increases, the rays strike the film and the objects being projected more obliquely. This could create a more distorted projection of the structures. To aid in determining the angles of divergence found in the 84-in A-P view, 2 models were constructed.

Fig 3 shows modeled radiographic tubes and film. Film sizes of 10 × 12, 14 × 17, and 14 × 36 in are depicted. A modeled tube was placed 40 in from, and at the level of, the center of the 2 smaller modeled films. Rays were projected to the center, superior, and inferior margins of the 10 × 12- and 14 × 17-in modeled films with the central ray perpendicular to the film. The angles of divergence between the central ray and the upper and lower rays for both film sizes were

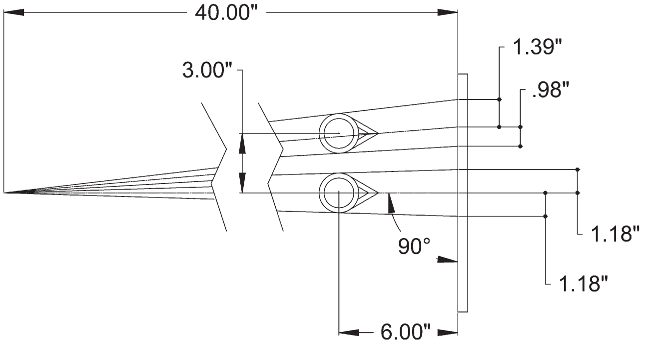

Fig 1. A modeled tube is placed 40 in from a modeled film. A modeled vertebra is positioned on the center line, which represents the central ray. Lines representing rays of the radiograph beam are erected tangent to the lateral body margins and extended to contact the modeled film. The model is laterally translated parallel to the modeled film. The distances between the projected lateral body margins and the projected spinous process, at their points of contact with the modeled film, are indicated.

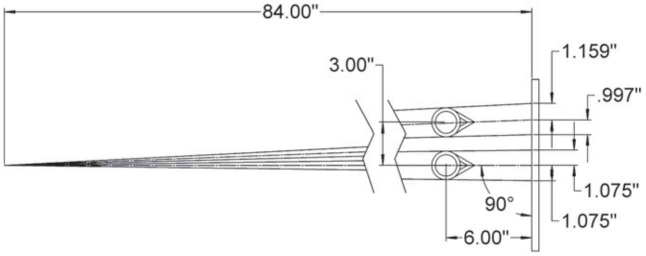

Fig 2. A modeled tube is placed 84 in from a modeled film. A modeled vertebra is positioned on the centerline, which represents the central ray. Lines representing rays of the radiographic beam are erected tangent to the lateral body margins and extended to contact the modeled film. The model is laterally translated parallel to the modeled film. The distances between the projected lateral body margins and the projected spinous process, at their points of contact with the modeled film, are indicated.

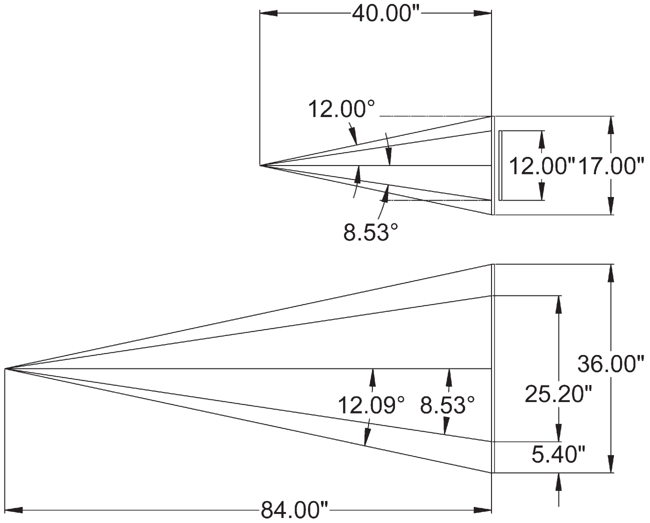

Fig 3. A modeled tube is positioned 40 in from and level with the center of modeled 10 × 12-in and 14 × 17-in radiographic films, whereas a second modeled tube is placed 84 in from and level with the center of a modeled 14 × 36-in film. Rays are projected outward from the tubes to the center, superior, and inferior edges of the modeled films with the central ray perpendicular to the modeled radiographic film. The angles of divergence are indicated. The points of contact on the 14 × 36-in film where the angles of divergence are equal to the angles of divergence of the 10 × 12-in film are noted.

determined. This process was repeated for the 14 × 36-in film at a modeled focal film distance of 84 in. Finally, the points of contact on the 14 × 36-in film where the angles of divergence were equal to the angles of divergence, which occurred at the superior and inferior edges of the 10 × 12-in film at the 40-in focal film distance, were indicated.

Pelvis

An observer might be concerned that the pelvis could be rotated on its y-axis (axial rotation) in the course of an A-P full spine radiograph. If this rotation occurred, then measurements that indicate misalignment might merely be a result of projection of the rotated pelvis, rather than true osseous misalignment. This concern may be justified. Weinert[13] found that pelvic rotation could result in projected changes, including changes in the projected heights of the innominates and femur heads. To illustrate the projected innominate height changes, which might be produced by axial rotation, we constructed a computer model (Fig 4).

Fig 4 shows an oval used as a modeled ilium. The modeled ilium is translated in the same plane, along the z-axis, to be placed at 2 distances from a modeled radiographic film. This change in distance from the radiographic film could occur with axial rotation of the pelvis. The modeled tube is superior to the ilium, as it would be in a full spine view. Rays are extended from the modeled tube so that they are tangent to the upper and lower edges of the modeled ilium in each of the 2 positions. These rays are continued until they strike the modeled radiographic film. The relative heights of their points of contact with the film and the sizes of the projected ilia are seen in the figure.

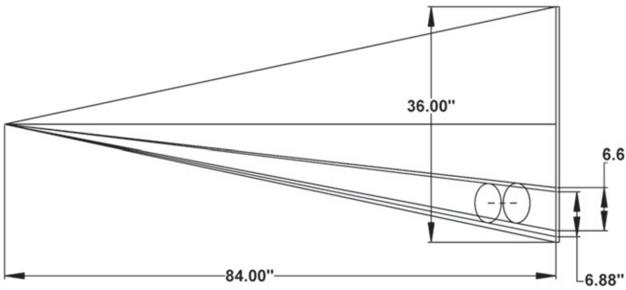

Fig 4. An oval is used as a modeled ilium. The modeled ilium is positioned, on the same plane on the z-axis, at 2 distances from a modeled radiograph film. Rays, which decline as they near the modeled film, are extended so that they are tangent to the upper and lower edges of the modeled ilium in each of the 2 positions. These rays are continued until they strike the modeled radiograph film. The positions of these points of contact and the projected size of each modeled ilium is indicated.

Results

Translation

With the modeled vertebra centered on the modeled central ray, the rays placed tangent to the lateral body margins strike the modeled film at equal distances from the point of contact of the central ray, which passes through the modeled spinous process. As the modeled vertebra is translated parallel to the film, movement of the projected spinous is away from the center of the projected vertebral body. The movement is toward one projected lateral body margin and away from the opposite side. The spinous, therefore, is projected more toward the medial vertebral body margin than occurs in the centered view. Translation yields projected y-axis (axial) rotation.

In the 40-in focal film distance, with the model in the centered position, the width of the projected vertebral body is 2.36" with the projected spinous in the middle at 1.18" from either side of the projected vertebral body. With the vertebra translated 3 in, the projected vertebral body is 2.37" in width with the projected spinous closer to the medial projected body margin, being 0.98 in from the projected medial body margin and 1.39 in from the projected lateral body margin (Fig 1). If the position of the projected spinous in the translated position were in the center of the projected vertebral body, it would be 1.185 in from each lateral body margin. However, the position of the projected spinous in the translated position is off centered by 0.205 in, which is 9% of the projected vertebral body width.

In the model with the 84-in focal film distance in the centered position, the projected body width is 2.150 in with the projected spinous in the middle at 1.075 from either side of the projected vertebral body. With the vertebra translated 3 in, the projected vertebral body is 2.156 in in width with the projected spinous closer to the medial projected lateral body margin, being 0.997 in from the projected medial body and 1.159 in from the projected lateral body margins (Fig 2). The position of the projected spinous in the translated position is off centered by 0.081 in, which is 4% of the projected body width.

Angles of divergence

As determined by the use of Fig 3, the angles of divergence are less for the modeled 10 × 12-in film than in either the 14 × 17- or 14 × 36-in films. The 10 × 12-in film at a 40-in focal film distance produced an angle of divergence between the central ray and the superior and inferior rays of 8.53°. However, the angles of divergence for the modeled 14 × 17-in film at a 40-in focal film distance and the 14 × 36-in film at an 84-in focal film distance are almost equal. The angle of divergence is 12° for the 14 × 17-in film, whereas the angle of divergence is 12.09° for the 14 × 36-in modeled film. The points of contact on the 14 × 36-in film at 84 in, where the angles of divergence are equal to those that occur at the superior and inferior edges of the 10 × 12-in film at a 40-in focal film distance, are noted. These points are 5.40 in from the superior and inferior edges of the 84-in 14 × 36-in modeled film.

Pelvis

When the modeled ilium is moved closer to the modeled tube, it is projected lower on the radiographic film. In addition, the projection of the modeled ilium, which is closer to the modeled tube, is longer than that of the one closer to the modeled film.

Discussion

The full spine A-P view taken at 84" has varying projectional characteristics when compared with sectional views taken at 40".

In lateral translation, there is less projected axial rotation in the 84" full spine view when compared with 40" sectional films. Although this would be of minimal importance to those who measure the rotation of vertebrae relative to immediately adjacent segments, it might offer confusion for those wishing to use absolute projected rotation in their analysis.[14,15,16] We have calculated the numbers in Fig 2 to the 1000th of an inch as opposed to the 100th of an inch used in the other figures for a purpose. Taking the measurements to this extreme is both cumbersome and unnecessary for practical purposes. However, the rounding of the numbers calculated in Fig 2 resulted in the appearance that the projected body width increase of the model in the translated position was greater in the 84" model than in the 40" model when the opposite is true. Taking the numbers out to the 1000th allowed us to more accurately display this phenomenon, but was not necessary in the other figures.

The angles of divergence are approximately equal when comparing the 14 × 17-in film taken at 40 in to the full spine view at 84 in, and the angles of divergence are less in the 10 × 12-in film at 40 in than in the full spine radiograph taken at 84 in. However, except for a 5.40-in section at both the superior and inferior of the 14 × 36-in film, the angles of divergence of the 14 × 36-in film taken at 84 in are within those of the 10 × 12-in film at 40 in. Therefore, 70% of the 14 × 36-in 84-in focal film distance A-P full spine view is within the angles of divergence of a 40-in focal distance 10 × 12-in film. Appropriate collimation of the 84-in full spine view would not only reduce radiographic exposure, but would also reduce the area of the 84-in A-P full spine view that is outside the angles of divergence of the 40-in focal film distance 10 × 12-in film. A future study measuring the percentage of spine and pelvic structures on clinical 84" focal film distance A-P full spine views that falls outside the angles of divergence of clinical 40" 10 × 12-in views is being planned.

One potential problem associated with increases in the angles of divergence is a greater likelihood of creating projectional overlap. This occurs when a particular ray passes through more than one structure and these structures are then projected onto the film in an overlapping fashion. However, the absolute angle of the rays is not the only component of this type of projection distortion. The lateral curves of the spine and the shape of the vertebrae also play a role.[2]

Winterstein[2] looked “at the comparative visualization of the interbody disc spaces of both the full spine and the sectional methods.” He indicated that visualization was equal between the A-P full spine and sectional views in the cervical, upper, and midthoracic and lower lumbar areas, being less good than sectionals in the lower thoracics, but slightly better than a sectional view in the upper lumbar area.

We have also shown that the elevated position of the tube in relation to the pelvis in the 84-in A-P full spine view produces a lowering and lengthening of the ilium when the source object distance is decreased. These errors are influenced by the angle of the rays, which would most often be at a greater angle of decline in the full spine view as compared with sectional views, coupled with the position of the object being viewed.

Winterstein[17] has previously proposed methods to aid in correcting for some projectional errors by mathematical means. Although it is beyond the scope of this article to explore these procedures, this type of mathematical correction is of interest and might provide another method for approaching projection problems. We hope that an understanding of this problem will prompt the clinician to use care in patient placement.

As can be seen, the 84-in A-P full spine radiograph possesses particular projectional factors, which, in some instances, will differ from those of other views. These factors need to be understood by the clinician so that appropriate procedures may be selected. We are hopeful that our findings will cause both clinicians and policy makers to consider the use of the A-P full spine taken at an 84-in focal film distance as an alternative to other views when a radiograph of the entire spine is indicated. We recommend that clinicians should not choose a particular radiograph solely because of tradition or the type of technique used. These findings should be a part of the evaluation process when deciding what radiographs, if any, are needed in a particular case.

Limitations

This study looks solely at the factors we have listed; however, there are a number of other factors that we did not explore. We did not attempt to evaluate radiation exposure. We did not evaluate whether there were advantages of taking the radiographs P to A instead of A to P. We stipulated that the A-P full spine should only be taken when a radiograph of the cervical, thoracic, and lumbar areas was needed, but did not explore when or why full spine films may be appropriate. We did not attempt to discern when radiographs are needed in general or the cost issues related to the use of full spine radiography. All these factors may influence the selection, if any, of radiographs and are beyond the scope of our study.

Our vertebral model is a general representation. It is not crafted to specifically represent a cervical, thoracic, or lumbar vertebra, but is a general representation to show the concepts that we wished to demonstrate. The dimensions used are needed to model the projectional changes that occur because of translation, but cannot be used in an individual case. In addition, we used only the spinous process for our analysis, instead of also demonstrating the movement of the pedicles, which are used by some clinicians in the assessment of axial rotation. This was done to simplify our presentation, as we were able to use 1 point as opposed to 2 points if we had used the pedicles or the 3 points that would have been required to look at both the spinous and the pedicles. However, the use of the spinous alone was appropriate for our article and allowed us to demonstrate the concept we wished to explore.

Our article notes that the projection of the ilium on the 84-in focal film distance A-P full spine view results in the ilium being projected lower and with a greater length, as it is moved closer to the tube and away from the film. This is sufficient for our article; however, it is hardly a full modeling of an actual pelvis. We recognize this as a limitation of our study and hope to do further work in this field at a future time.

Conclusion

In this study, the 84-in focal film distance A-P full spine produced less projected axial (y-axis) rotation than 40-in focal film distance sectional views when lateral translation was present. It also produced changes in projected ilium height and length. It produced greater angles of divergence than the 40-in 10 × 12, and the angles of divergence were equal to the 40-in focal film distance 14 × 17 film. It is noteworthy that 70% of the area of the 84-in full spine radiograph is within the angles of divergence of a 40-in 10 × 12 film, with only a 5.4-in area at both the superior and inferior margins of the film being outside the 40-in focal film distance 10 × 12-in film's angles of divergence.

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