# EFFECTS OF PELVIC POSITIONING AND SIMULATED DORSAL ACETABULAR RIM REMODELING ON THE RADIOGRAPHIC SHAPE OF THE DORSAL ACETABULAR EDGE

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**A radiographic study was conducted to evaluate the effect of pelvic rotation and of simulated dorsal acetabular rim (DAR) remodeling on the radiographic appearance of the dorsal acetabular edge (DAE). The DAE is the line connecting the cranial and caudal rims of the acetabulum when viewing a pelvic radiograph made with the dog in the ventrodorsal position with the hind limbs extended. In this study, it was hypothesized that the DAE would change with pelvic rotation and simulated DAR damage. Ventrodorsal radiographs of eight canine pelves were made at 0°, 5°, and 10° of left and right pelvic rotation over its longitudinal axis. These radiographs were repeated following removal of 2, 4, and then 6 mm of bone from the right DAR of each pelvis. The ratio of acetabular width to maximum depth of the DAE was calculated. The area between the DAE and a straight line connecting the cranial and caudal acetabular rims was measured digitally. The DAE depth and area changed with pelvic rotation, and with increasing simulated DAR damage. A linear relationship between the obturator foramina width ratio and pelvic rotation allowed estimation of the degree and direction of pelvic rotation. Equations were developed from the data to assist with the estimation of the amount of DAR remodeling on a clinical radiograph.** *Veterinary Radiology & Ultrasound, Vol. 48, No. 1, 2007, pp 8–13.*

**Key words: canine hip dysplasia, defect area, dorsal acetabular edge, dorsal acetabular rim, pelvic rotation.**

## Introduction

CANINE HIP DYSPLASIA (CHD) is one of the most common orthopedic diseases of large and giant breed dogs; it frequently leads to debilitating osteoarthritis.[1] CHD is thought to be a polygenetic condition, dominated by a major gene and influenced by environmental factors.[2]

Joint laxity has been described as the inciting event leading to damage to the femoral head and acetabulum, and the eventual development of osteoarthritis.[3] The subsequent joint degradation has been thoroughly described.[4] The cartilaginous labrum is damaged first. As this is displaced and articular cartilage erodes, the subchondral bone of the dorsal acetabular rim (DAR) bears the load and microfractures of the trabeculae of the rim can be identified. It is often at this stage that lameness is first observed.[4]

Changes in the outline of the acetabulum on the ventrodorsal pelvic radiograph are described subjectively as CHD progresses.[4–6] Shallowness occurs as new bone forms on the floor of the acetabulum. Osteophytes may be evident on the cranial acetabular rim. Alteration in the shape of the dorsal acetabular edge (DAE), which is defined as the line connecting the cranial and caudal aspects of the acetabulum on the ventrodorsal pelvic radiograph (Fig. 1), has been described to represent damage to the DAR. Changes to this line are also important as this may affect the subjective assessment of coverage of the femoral head.[3,7–9] The DAR can also be evaluated by projecting the pelvis along its longitudinal axis.[10] This view is technically difficult to achieve and displays only one point along the caudal portion of the DAR.[11]

Identifying changes in the DAR is important for two reasons. First, this is the location of the first bone damage in a lax hip and the severity of that damage will likely reflect the prognosis.[4] Second, the state of the DAR is an important factor in deciding how effective a triple pelvic osteotomy might be in controlling the rate of degeneration of the hip.[12] It has been noted in dogs with CHD that, on the standard hip-extended ventrodorsal pelvic radiographs, the shape of the DAE will become increasingly cupped or S-curved.[13] Likely this is a result of damage and/or underdevelopment of the DAR due to increased loading on this area by the subluxated femoral head. In the British hip classification scheme, alteration to the line of the DAE is

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FIG. 1. Ventrodorsal pelvic radiograph of a dog with increased depth of the dorsal acetabular edge (DAE) on the left hip (white arrows). For the two inserts, the contrast of the image was adjusted to improve visualization of the DAE. The black arrow identifies the location of the measurement of the width of the obturator foramen.

one of the features assessed when the hip is rated, with a subjectively deeper curve receiving a lower score.[14] On a good quality radiograph, the DAE traverses the femoral head almost vertically and extends a little beyond it cranially and caudally. The DAE on the radiograph represents the bony DAR on the actual pelvis. In a review of the British CHD grading scheme, it was stated that changes involving the DAE are not greatly affected by axial rotation of the pelvis.[14]

The aim of this project was to define the changes to the DAE that can be identified from radiographs made with the dog in the exact ventrodorsal position with the hind limbs extended, and to determine the effects of improper positioning of the pelvis on the shape and depth of the DAE. It was hypothesized that evidence of dorsal acetabular rim damage can be determined from changes in the profile of the DAE. It was further hypothesized that a relationship could be established between pelvic rotation and the ratio of the obturator foramina widths, and that this relationship could be used to determine if DAE depth and/or defect area were greater or less than measured.

To assist in the application of these findings to clinical radiographs, equations were derived that describe how the depth-to-width ratio of the DAE profile and DAE defect area change with rotation. A third equation was derived to calculate the degree of pelvic rotation based on the relative widths of the obturator foramina. By combining these results, the amount of DAR damage on a radiograph of a patient could be calculated.

## Materials and Methods

### *Determining the Normal Degree of Rotation of the Pelvis Over the Transverse Plane*

When a dog is positioned for a ventrodorsal pelvic radiograph with the hips extended, the pelvis is aligned at a certain angle to the cassette or imaging plate. As we wanted to position our cadaver pelves at this same angle, we measured it in nine dogs undergoing standard hip-extended ventrodorsal radiographs for hip dysplasia. The dogs were positioned for the ventrodorsal view and, without moving the patient, a horizontal-beam lateral radiograph of the pelvis was made.[6] A line from the dorsal most point on the ilial wing to the dorsal most point on the ipsilateral ischiatic tuberosity determined the ilial–ischial axis. The angle between the ilial–ischial axis and the tabletop (tilt) was measured. A tilt angle of $0^\circ$ was defined as having the ilial–ischial axis parallel to the tabletop. A positive angle was recorded if the dorsal surface of the ischium was higher than the dorsal surface of the ilial wing. A negative angle was recorded if the dorsal surface of the ischium was lower than the dorsal surface of the ilial wing.

### *Ex Vivo Radiographic Study*

An ex vivo radiographic study was conducted to evaluate the effect of pelvic rotation, and of simulated DAR remodeling, on the appearance of the DAE on a ventrodorsal radiographic image. The relationship between the maximum width of the left and right obturator foramina and the degree of pelvic rotation was determined from these same images. This phase of the study was conducted on eight cadaver specimens. Animals obtained from a local animal shelter. Animals were euthanized in accordance with shelter policy before consideration for the study. Criteria for cadaver selection were a body weight of 20–40 kg, and an age of approximately 1–2 years. No gender or breed criteria were used. After dissection of the pelves, the acetabula were inspected to insure that they were free of gross damage to the articular cartilage or labrum.

Of the 15 cadavers selected initially, eight were free of coxofemoral abnormalities. Of these eight, four were males and four were females. One appeared to be a purebred Labrador Retriever. The other seven mixed breed dogs appeared to be predominantly German Shepherd Dog (2), Chow (2), Golden Retriever, American Staffordshire Terrier, and a Chinese Shar-Pei. The cadavers ranged in weight from 19.5 to 23.5 kg.

Cadaver pelves were harvested, sacrum intact, boiled and cleaned of all remaining soft tissues. Epoxy adhesive was used to reassemble sacroiliac joints ($n = 8$) and/or pubic symphyses ($n = 5$) as needed. Intramedullary pins* (3.175 mm diameter) were placed through the pelves, one through both illia and one through both tuber ischii. The pelves were mounted in a frame constructed of external fixator components* for consistent positioning. An inclinometer,† accurate to 1/2 of $1^\circ$, was used to position each specimen at the desired position. For this study, tilt of the pelvis was defined as rotation around the transverse axis. The rotation positions studied occurred around the longi-

*IMEX Veterinary Inc., Longview, TX.
†Angle Finder, Dasco Pro Inc., Rockford, IL.

tudinal axis. As there was no body attached to the specimens, their position relative to the vertical axis was not relevant.

Pelves were mounted in the angle of rotation around the transverse axis (tilt) defined in the first portion of the study. The pelves were then radiographed at 0°, 5°, and 10° of left and right rotation around their longitudinal axis. Rotation was achieved by lifting the frame of the opposite side of the pelvis off of the table until the inclinometer read the desired degree of rotation. The right DARs of the eight pelves were sequentially modified by removing 2 mm increments of bone (2, 4, and 6 mm depths), with a high-speed burr,‡ to simulate the progressive damage that occurs over time in the lax hip. The shape and position of the defect was based on previous observations of acetabula with natural damage. The maximum depth of the defect was centered at the most dorsal aspect of the DAR when the pelvis was positioned in a normal standing position (an illio-ischial angle of 40° relative to the ground). This was designated as the 12 o'clock position on the acetabular "face." The depth at 11 and 1 o'clock was 50% of the maximum, and, by the 10 and 2 o'clock positions, it was tapered back to the normal rim. Pelves were radiographed in five positions of rotation (−10°, −5°, 0°, +5°, +10°) around their longitudinal axis after each level of damage simulation.

The radiographs were digitized for analysis using a radiograph scanner§ and measurements were acquired from the digital radiographs using imaging software.¶ Measurements were calibrated to a known linear length on each film. The distance "AB" was determined by drawing a line from point "A" at the cranial aspect of the acetabulum to point "B" at the caudal aspect of the acetabulum. The distance "CD" was determined from a line drawn from the point of maximum DAE depth, point "D", to its perpendicular intersection of the line drawn from "A" to "B," point "C." The DAE depth to acetabular width ratio was calculated using CD/AB. The relative point of maximum DAE depth was determined using AC/AB. The defect area was calculated by the software after manually outlining the perimeter of the area demarcated by the line AB and the DAE (Fig. 2). The maximum width of the left and right obturator foramina were measured on each radiograph (Fig. 1), and the percent difference between the left and right measurements calculated.

To assist in the application of these findings to clinical radiographs, equations were derived that describe how the depth-to-width ratio of the DAE profile and DAE defect area change with rotation. A third equation was derived to calculate of the degree of pelvic rotation based on the relative width of the obturator foramina. By combining

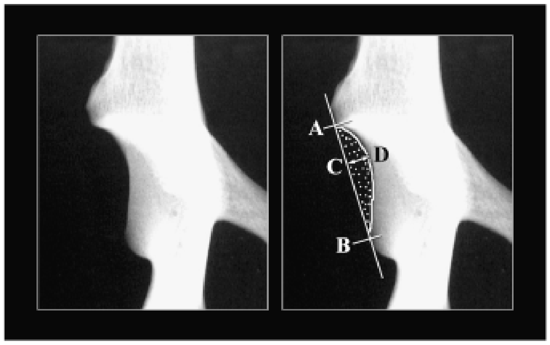


FIG. 2. Ventrodorsal radiograph of right acetabulum. Note the cranial aspect of the acetabulum (A), caudal aspect of the acetabulum (B), point of maximum dorsal acetabular edge (DAE) depth (D), and the point of perpendicular intersection of a line from D to line AB (C). The lengths AB and CD were measured and expressed as a ratio. The acetabular defect area is the shaded region between the line AB and the DAE.

these results, the amount of DAR damage on radiograph of a clinical patient could be calculated.

## Statistical Analysis

The obturator foramen widths were compared using the general linear models procedure with a post hoc least squares means test.|| The difference between the obturator foramen widths was correlated to the degree of rotation. Changes in CD/AB, AC/AB, and defect area with each change in rotational position, and with each change in defect depth (right acetabula only), were evaluated using a post hoc least squares means test. The data for all left (unaltered) acetabula were pooled. Statistical significance was set at $P<0.05$.

## Results

### *Determining the Normal Degree of Rotation of the Pelvis Over the Transverse Plane*

Mean angle of the pelvis relative to the cassette was −0.33° (range: −6° to +6°).

### *Radiographic Study*

The width of the left and right obturator foramina of the non-rotated pelves were different (mean difference $0.14 \pm 0.11$ mm, range −0.38 to 0), with the left being slightly bigger than the right ($P=0.03$). The percent difference between the widths changed with pelvic rotation over the longitudinal axis, with the descriptive equation being:

‡Dremel®, Emerson Electric Co., Racine, WI.
§Lumiscan 75, Eastman Kodak Co., Rochester, NY.
¶Adobe® Photoshop® 5.0, Adobe Systems Inc., San Jose, CA.
||SAS 6.2, SAS Inc., Cary, NC.

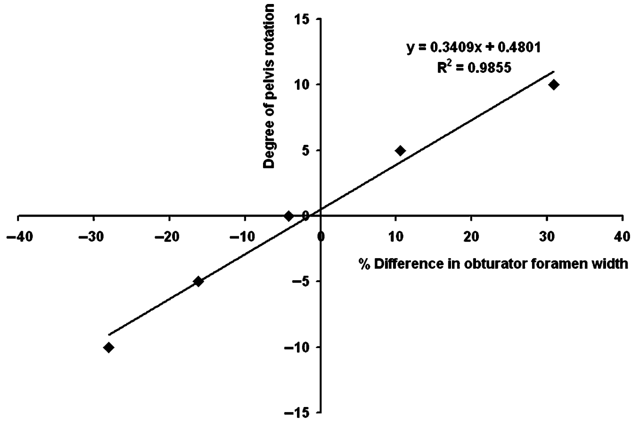


FIG. 3. Line graph of the change in percent difference between obturator width with varying degrees of axial pelvic rotation over the longitudinal axis. Negative numbers represent rotation to the dog's right. Positive numbers represent rotation to the dog's left. After measurement of the width of both obturator foramen, and calculation of the percent difference, this equation can be used to determine the amount of rotation present in the pelvis.

$$\text{Degrees } (^\circ) \text{ of rotation over the longitudinal axis} = 0.3 \times (\% \text{ Difference between obturator widths}) + 0.5 (R^2 = 0.986; \text{ Fig. 3})$$

The shape of the DAE on the unaltered left side changed with rotation of the pelvis (Fig. 4). Every 5° increment of pelvic rotation had a significant effect on the measurement of CD/AB (depth to width ratio) (for the pooled data of the left, unaltered DAE, $n = 32$, $P \leq 0.007$).

Following removal of 2 mm of bone on the right DAR, rotation caused a significant CD/AB difference between the neutral position and −10°, and +5°, or +10° of rotation ($P \leq 0.05$; Fig 5). Following removal of 4 mm of bone from the right DAR, rotation caused a significant CD/AB difference between the neutral position and +5° or +10° of rotation only ($P \leq 0.04$). There was also a significant CD/AB difference between −5° and +5° of rotation ($P = 0.02$). There were no differences between CD/AB after removal of 6 mm of bone from the right DAR for any amount of pelvic rotation.

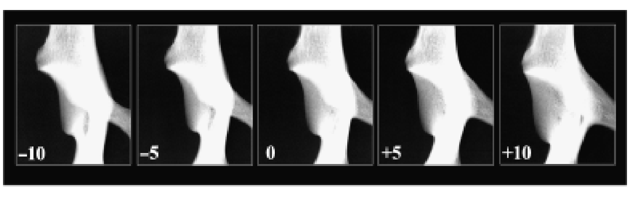


FIG. 4. Ventrodorsal radiographs of the right acetabulum. Note the change in shape of the dorsal acetabular edge (DAE) with varying degrees of axial rotation. Zero is true ventrodorsal. Negative numbers represent degrees rotation to the dog's right (achieved by lifting the left side of the pelvis). Positive numbers represent degrees rotation to the dog's left (achieved by lifting the right side of the pelvis).

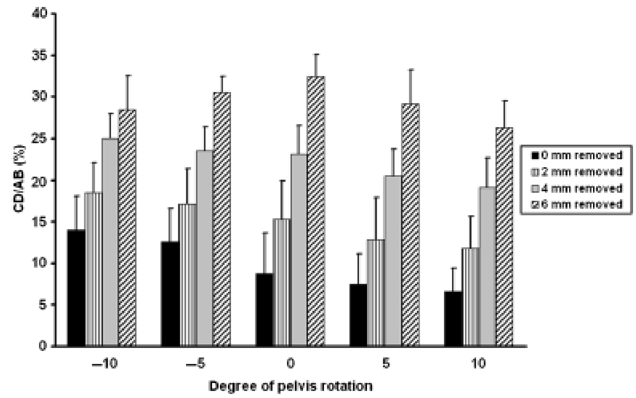


FIG. 5. Change in the mean (±SD) ratio of acetabular width to depth to the dorsal acetabular edge (CD/AB) with axial rotation and simulated DAR damage ($n = 8$)

The shape of the DAE changed with simulated damage to the DAR (Fig. 6). The linearity of the relationship between CD/AB and the amount of damage to the DAR changed with the amount of rotation ($P \leq 0.006$; Fig 7). The constants "a" and "b" for the linear descriptive equation:

$$\text{Amount of DAR damage (mm)} = a \times (\text{CD/AB}) + b$$

for each rotation position are given in Table 1.

The position of the AC/AB point (point of maximum profile depth) of the unchanged left acetabulum differed only at −10° pelvic rotation. This caused the point to move caudally. The position of the AC/AB point of the modified right acetabulum did not differ at any of the described degrees of pelvic rotation.

Every 2 mm of DAR removed had a significant positive effect on acetabular defect area ($P < 0.003$). With 0, 2, and 4 mm of bone removal, there was a significant difference in defect area for every 5° of pelvic rotation away from neutral ($P \leq 0.04$; Fig. 8). For 6 mm of bone removal, a difference was only significant with +10° of rotation ($P < 0.01$). The relationship between defect area and DAR damage changed with different degrees of rotation (Fig. 9).

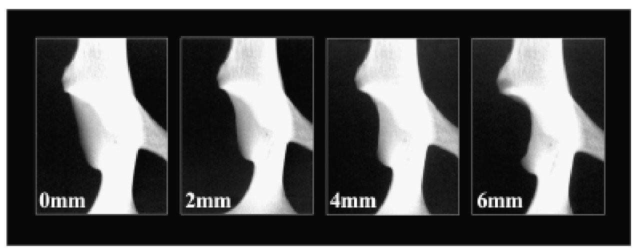


FIG. 6. Ventrodorsal radiographs of the right acetabulum (0° rotation). Note the change in shape of the dorsal acetabular edge (DAE) with varying amounts of simulated dorsal acetabular rim (DAR) damage. Numbers represent maximum depth (millimeters) of bone removed at the most dorsal aspect of the DAR.

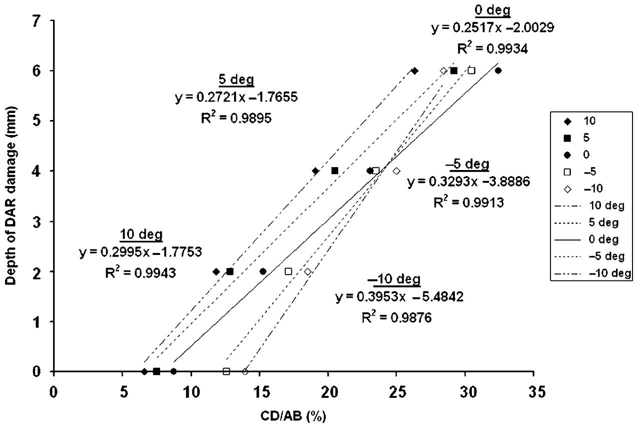


FIG. 7. Line graph depicting the relationship between the ratio of DAE depth/width in the right acetabulum (CD/AB) and the depth of damage to the DAR with varying degrees of axial pelvic rotation. Negative numbers represent degrees rotation to the dog's right (achieved by lifting the left side of the pelvis). Positive numbers represent degrees rotation to the dog's left (achieved by lifting the right side of the pelvis). The equations can be used to estimate the depth of DAR damage. After measurement of the acetabular width and the depth of the DAE from the line connecting the cranial and caudal acetabular rims, the ratio, CD/AB, is calculated. The appropriate equation is chosen based on the degree of pelvic rotation estimated from the equation in Fig. 3, and the depth calculated.

The constants "a," "b," and "c" for the second-order polynomial equation

$$\text{Amount of DAR damage(mm)} = a \times (\text{defect area})2 + b \times (\text{defect area}) + c$$

for each rotation position are given in Table 2.

## Discussion

Proper positioning and optimal exposure technique are essential prerequisites for radiographs of diagnostic quality that allow accurate assessment of the hip joints. This study shows that pelvic rotation affects the shape of the DAE. The profile of the DAE of an acetabulum elevated off the table will have less depth, while, the depth of the DAE of the contralateral side will be exaggerated. Qualitative assessment of the DAE uses a combination of line shape and defect area and both of these parameters are affected by rotation. Because the DAE is often used to subjectively assess coverage of the femoral head, errors in positioning will also affect this parameter.

TABLE 1. Constants "*a*" and "*b*" from the Equations Determined by Fitting a Linear Line to the CD/AC Data for Each Amount of Rotation

| Rotation (deg.) | *a* | *b* |
|---|---|---|
| 10 | 0.2995 | −1.7753 |
| 5 | 0.2721 | −1.7655 |
| 0 | 0.2517 | −2.0029 |
| −5 | 0.3293 | −3.8886 |
| −10 | 0.3953 | −5.4842 |

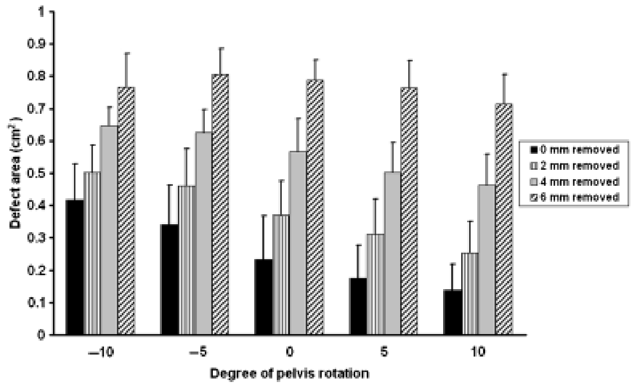


FIG. 8. Change in mean acetabular defect area (± SD) with axial rotation and simulated DAR damage to the right acetabulum ($n = 8$).

The relationship between CD/AB (maximum distance of the DAE from the line joining the cranial and caudal aspects of the acetabulum) and damage to the DAR changed with different degrees of rotation. This is likely because the DAE is a two-dimensional representation of a three-dimensional object. As the amount of damage increases and/or the degree of rotation increases, other portions of the acetabulum may contribute to the DAE. This was particularly true for the 6 mm defect group, where the ventral aspect of the acetabulum became visible. This changing relationship makes the calculation of DAR damage less accurate. However, 10° of rotation is obvious and would likely lead to the patient being re-positioned and a better quality radiograph made.

The constants for the equation may need to be interpolated from those presented here. For example, if the percent difference between the obturator foramen widths was 20%,

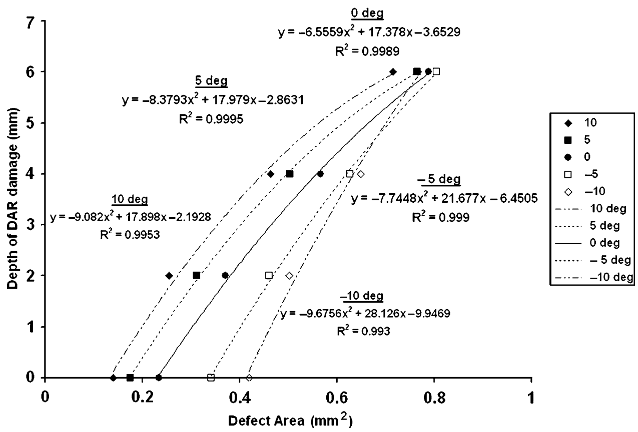


FIG. 9. Line graph depicting the relationship between defect area and depth of dorsal acetabular rim (DAR) damage with varying degrees of axial pelvic rotation. Negative numbers represent rotation to the dog's right. Positive numbers represent rotation to the dog's left. The equations can be used to estimate the depth of DAR damage. After measurement of the defect area, and selection of the appropriate equation based on the degree of pelvic rotation estimated from the equation in Fig. 3, the depth is calculated.

TABLE 2. Constants "*a*," "*b*," and "*c*"from the Equations Determined by Fitting a Second-Order Polynomial Line to the Defect Area Data for Each Amount of Rotation

| Rotation (deg.) | *a* | *b* | *c* |
|---|---|---|---|
| 10 | −9.082 | 17.898 | −2.1928 |
| 5 | −8.3793 | 17.979 | −2.8631 |
| 0 | −6.5559 | 17.378 | −3.6529 |
| −5 | −7.7448 | 21.677 | −6.4505 |
| −10 | −9.6756 | 28.126 | −9.9469 |

this suggests that the pelvic rotation is 7.3° (Fig. 3). The constants needed to calculate the amount of DAR damage would be half way between those for 5 and those for 10 degrees of rotation. In this example, "a" would be approximately 0.2858 and "b" would be approximately 1.7704.

As would be expected, the size of the change in the DAE defect area was not linearly related to the degree of pelvic rotation. The second order-polynomial equation more accurately represented the data. However, the constants have less meaning using this type of equation when compared with a linear equation. As with CD/AB, the overlap of the curves suggests that structures other than the DAE are affecting this measurement if the pelvis is rotated. In general, lifting the pelvis off of the table on one side diminishes the DAE defect area on the ipsilateral side and accentuates it on the contralateral side.

One unexpected finding was that the difference in maximum obturator foramen width between the left and right obturator foramina was significantly different. Although it is unlikely that this difference would remain significant if a larger number of pelves were measured, it does suggest a source of error in the equation generated. If there was not a significant difference between the widths, the intercept (constant "b") would be 0. The variability in the pelves studied suggests that rotation calculated using the obturator foramen width will have an error of 0.5° to 1°.

Computer measurements were made of the digital radiographs for data collection and analysis in this study. This degree of mathematical precision of DAE assessment cannot be achieved with visual evaluation of a radiograph in a clinical setting. Some of the statistically significant differences noted in our analysis may be of little or no clinical significance. A future study, evaluating DAE by simple subjective judging is warranted. In addition, a future study should include dogs with dysplastic hip joints to prove relevance of such type of analysis.

## Conclusion

The radiographically visible depth of curvature of the DAE, and the defect of the acetabular roof defined by the DAE, increase with increasing damage to the DAR. Rotation of the pelvis over its longitudinal axis affects assessment of the DAE. Degree of pelvic rotation can be quantified by comparison of the widths of the obturator foramina. Once known, its affect on the DAE can be accounted for.

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