OSTEOTOMY OF THE GREATER TROCHANTER, TENSION BAND FIXATION, AND FEMORAL CONFORMATION

by

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B.S., University of California, Davis 1973
D.V.M., University of California, Davis 1975

A MASTER'S THESIS

submitted in partial fulfillment of the

requirements for the degree

MASTER OF SCIENCE

Department of Surgery and Medicine

KANSAS STATE UNIVERSITY
Manhattan, Kansas

1978

Approved by:

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ACKNOWLEDGEMENTS

I would like to thank Dr. J. E. Mosier and the Department of Surgery and Medicine for the funding and support necessary to perform this thesis. Special thanks are due my major professor, Dr. H. C. Butler, for his continued support. Dr. Butler, through his guidance and expertise, has contributed greatly to my evolution as a surgeon.

I would also like to thank the other members of my committee, Dr. M. M. Guffy, for a better appreciation of the science of radiology, and Dr. H. W. Leipold, for a better understanding of the histology of bone.

I am most appreciative of the help given by Dr. A. M. Feyerherm, Department of Statistics, in the evaluation of my data, and Mr. Dick Lark, Kansas University Medical Center, in his assistance with and production of tetracycline photographs.

Ms. Karen Killough, Radiology Technician, assisted in the exposure of a multitude of radiographs, for which I am thankful. Thanks are also due to Ms. Nancy Taylor for a fine job of typing this thesis.

Last but by no means least, I acknowledge and most gratefully thank those who gave the most, my Beagle dogs, in the interest of the science of orthopedic surgery.

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CHAPTER I

INTRODUCTION

The potential of the epiphysis of the greater trochanter has been explored in many species at a young age, and characteristic deformities are known to occur when growth from this epiphysis is halted. After the time of natural cessation of growth, there is no potential for deformity following damage to this epiphysis. There is no published work concerning the effect of epiphyseodesis of the greater trochanter in the interim period of growth in the dog or other lower animal. There is little written in man on this subject.

The purpose of this thesis is to explore the potential of the epiphysis of the greater trochanter, and the effect of osteotomy of the greater trochanter with tension band fixation, in the growing dog at various ages.

CHAPTER II

DEVELOPMENT AND ANATOMY
Gross (Miller 1964) and Functional

The proximal femur consists of a head, neck, and three trochanters. The head is united to the shaft by the neck, which is reinforced by a ridge of bone that extends from the head to the greater trochanter. This ridge of bone acts as a tension band to transmit forces from the head to the shaft of the femur (Prieur 1978).

The greater trochanter is located lateral to the head on the proximal aspect of the femur and is the site of insertion of the middle and deep gluteals, and the piriformis. The trochanteric fossa lies between the head and greater trochanter, caudal to the connecting ridge of bone, and is the site of insertion of the gemellus, and internal and external obturator muscles.

The lesser trochanter is a small eminence on the caudomedial surface of the proximal end of the femur whereon the iliopsoas inserts. Distal to the apex of the greater trochanter lies the third trochanter on the lateral aspect of the proximal end of the femur. The superficial gluteal muscle inserts at this point. The lesser and third trochanters are traction epiphyses, contributing nothing to growth.

In the Beagle, ossification of the diaphysis is present at birth (Chapman 1965). The ossification center of the head appears at 18 days of age while the center of the greater trochanter doesn't appear until 59 days of age. This observation is in general agreement with other authors (Hare 1960, Riser 1973, Gustafsson 1972, Shively 1975, Carlson 1977.

The epiphyses of the head and greater trochanter are, in early life, joined into a single proximal epiphysis. In the human, the initial medial growth results in "infantile coxa valga" and elongation of the neck. Lateral growth, which occurs later, results in lessening of the femoral neck-shaft angle. The result of the two forces interacting determines the femoral neck-shaft angle (Morgan 1960).

These epiphyses become separate and distinct during the growth process. This has been reported to be as early as 12 days (Riser 1973). There is, in the author's opinion, connection between these two major proximal physes across the bony connecting ridge beyond 12 days of age (Figure 1). The exact age at which the physes of the greater trochanter and femoral head become distinct is undetermined.

The physes of the greater trochanter and femoral head begin closure and progress to complete union, in the Beagle, in 208-250 days (Chapman 1965). Other closure dates have been reported (Carlson 1977, Hare 1960, Riser 1973, Smith 1960, Sumner-Smith 1966).

The angle that the femoral head and neck make with the shaft of the femur, as viewed on the anteroposterior projection, is referred to as the femoral neck-shaft angle (Figure 2). The angle that the femoral head and neck make with a line drawn through the femoral condyles in a frontal plane is referred to as the anteversion angle (Figure 3).

Normal femoral head and neck angles have not been well determined in the dog. In a single Greyhound, a femoral neck-shaft angle of 135° was recorded that remained constant throughout the growth period (Riser 1973). Anteversion angles have been reported more frequently. In one study, angles ranged from 12°-40° (Nunamaker 1973). In another,

Figure 1a

Figure 1b

Figure 1 - Femur of a Seven-week-old Beagle

A frontal section through the bony connecting ridge (Figure 1a) demonstrates connection between the physes of the head of the femur and greater trochanter. A frontal section of the same bone in a more posterior plane (Figure 1b) does not demonstrate connection between these physes.

the angle at birth was 0^o and increased gradually with age to a maximum of 20^o (Riser 1973). This finding is consistent with another study in neonates that found the majority of anteversion angles to be 0^o (Riser 1966). In man, the anteversion angle decreases with age (Fabry 1973).

CHAPTER III

LITERATURE REVIEW

The alterations in conformation and growth of the femur following damage to the epiphysis of the greater trochanter have been explored by many authors.

Hoyt (1966) performed surgery in three to five-week-old dogs. Following total excision of the greater trochanteric epiphysis, a typical coxa valga was produced. He observed that the capital epiphysis was the only proximal femoral epiphysis responsible for longitudinal growth.

Ewald (1973) transferred the greater trochanter distally in 15 to 18-week-old Beagles. The dogs walked with the hip in abduction for two to three weeks before resuming a normal gait. He observed no change in the head to condyle femur length, and no change in anteversion. There was an eighteen percent decrease in the diameter of the femoral neck. Ewald noted the appearance of an increased femoral neck-shaft angle, but he drew no conclusions regarding the true angle of the femoral neck.

Hattori (1976) fused the epiphysis of the greater trochanter in dogs approximately three months of age. He observed a 5° increase in anteversion and femoral neck-shaft angles. He also noted a decrease in the femoral neck diameter. There was no change in femoral length.

Compere (1940) fused the greater trochanteric epiphysis in six-week-old goats. Coxa valga occurred in these animals. There was a twenty-two percent loss of the trochantericcondylar length.

Laurent (1959) removed the epiphysis of the greater trochanter in five-day-old rabbits. Coxa valga with a long slender neck developed. The femoral leg length was maintained.

Morgan (1960) discussed growth of the proximal end of the femur. He stated that closure of the trochanteric growth plate results in coxa valga.

Salenius (1970) performed epiphysiodesis of the greater trochanter in four to eight-week-old pigs. Utilizing tetracycline, he demonstrated a lack of growth in the region of the greater trochanteric physis, marked growth from the periosteum of the greater trochanter, and a cessation of the process of remodeling resorption on the lateral side. He showed that about one-half of the growth in length of the greater trochanter can be arrested by epiphyseodesis, the other half coming from the tip of the trochanter. Coxa valga was produced in all pigs.

Weissman (1974) resected the epiphysis of the greater trochanter in twelve-day-old rabbits. He found a decreased proximal femoral growth and a compensatory increase in distal growth. Thus, femoral leg length was maintained. No mention is made of neck-shaft angles.

Savastano (1975) ablated the epiphysis of the greater trochanter in weanling rats. He observed that the neck-shaft angle became more obtuse. There was no change in femoral leg length.

Epiphyseodesis of the greater trochanter is used in the human therapeutically for coxa plana (Legg-Perthes Disease), infantile coxa vara and coxa vara secondary to congenital dislocation of the hip. Langenskiold (1967) recommended its use whenever serial radiographs showed a marked reduction in the articulotrochanteric distance. This is done to prevent overgrowth of the greater trochanter, an abductor insufficiency, and a resultant limping gait. Edgren (1965) also used epiphyseodesis of the greater trochanter in the treatment of coxa plana, for the same reason.

Brandes-Dortmund (1929) resected the greater trochanter as a treatment for coxa vara. Mau (1955) also resected the greater trochanter to treat coxa vara in children aged three to thirteen years. He demonstrated an increase in femoral neck-shaft angle in all his cases.

Chigot (1962) treated children with congenital dislocation of the hip by open reduction and resection of the greater trochanter. He observed lengthening of the neck of the femur in forty-two percent, which was often associated with coxa valga. He recommended that section of the greater trochanter be discarded in young children.

Jani (1969) treated cases of congenital dislocation of the hip by section and distal reposition of the greater trochanter. He observed a 30^{o} increase in femoral neck-shaft angle in patients aged six to thirteen years (open epiphysis), a 10^{o} increase in patients aged twelve to fifteen years (small opening), and no change in patients aged thirteen to twenty-five years (closed epiphyses).

CHAPTER IV

MATERIALS AND METHODS

A. Experimental Design

Twelve registered Beagles, obtained from a commercial breeder[a], were utilized in this study. There were seven females and five males from two litters. The dogs were placed into three equal groups dependent on their sex and litter. The leg that was to be operated on was determined by the flip of a coin. (Table 1)

All dogs in all groups were given tetracycline HCl[b] (50 mg/kg) orally once a day for the five days up to and including the day of surgery. The experimental surgery was performed on group 1 at 14 weeks, group 2 at 20 weeks, and group 3 at 26 weeks of age.

Group 1 was radiographed on the day of surgery and at four week intervals thereafter. Group 2 was radiographed on the day of surgery and at two week intervals thereafter. Group 3 was radiographed at 14 weeks of age and at four week intervals thereafter, including the day of surgery. (Table 2)

Radiographs were taken in group 2 at two week intervals so that comparisons could be made within and between groups relative to age and time after operation. Radiographs were taken of group 3 prior to surgery to determine the normal growth of the femur to compare with the growth of the unoperated-control femur in the other groups.

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[a] Theracon Inc., Topeka, Kansas.

[b] Wolins Pharmacol Corporation, Melville, New York.

TABLE 1

OPERATIVE GROUPS

	Dog	Birthdate	Sex	Leg Operated
GROUP I	7101	2-11-77	male	right
	7103	2-11-77	female	right
14-week	7132	2-23-77	male	left
	7133	2-23-77	female	right
GROUP II	7102	2-11-77	male	right
	7104	2-11-77	female	right
20-week	7131	2-23-77	male	left
	7134	2-23-77	female	right
GROUP III	7105	2-11-77	female	left
	7106	2-11-77	female	right
26-week	7129	2-23-77	male	left
	7135	2-23-77	female	right

TABLE 2

RADIOGRAPHY (x) AND SURGERY (*)

							Weeks						
	14	16	18	20	22	24	26	28	30	32	34	36	38
14-Week Group	* x		x		x		x		x		x		x
20-Week Group				* x	x	x	x	x	x	x	x	x	x
26-Week Group	x		x		x		* x		x		x		x

All dogs were clinically evaluated for lameness at one week intervals post surgically. Evaluation was made utilizing the lameness classification proposed by Braden (1973).

The final radiographic and clinical evaluations were performed at 38 weeks of age. Euthanasia and necropsy were performed at 39-40 weeks of age.

Epiphyseal closure was determined radiographically, by evaluation of the growth curve, and finally, histologically.

Following euthanasia, a gross necropsy was performed. The femora and tibia were stripped of their soft tissue attachments and the remainder of the animal disposed. Gross photographs of the bones were taken.[a] The femora were then split with a band saw on the frontal plane, placing half of each femur in 10% buffered neutral formalin (for histologic study) and storing the other half, along with the tibiae, in the fresh state at -22°C (for tetracycline study).

B. Histology

The bones were removed from formalin and placed in a decalcifying solution[b], requiring 20 hours for decalcification. They were then routinely processed, embedded in paraffin, and sectioned at 6 microns. The sections were stained with hemotoxylin and eosin, and histologically examined.

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[a] B & W plus X 125 ASA.

[b] RDO, DuPage Kinetic Laboratories, Inc., Naperville, Illinois.

C. Tetracycline Photography

The split femora were placed side by side on black paper, their level and even position maintained with black paper strips and pieces of clay. Fluorescence was effected, in a dark room, with two 15-watt, 366 nm (3660 Å), Sylvania F15T 8-BLB ultraviolet bulbs[a] placed about one foot away at an approximate angle of 45°. Exposures were taken at f 5.6 for 1, 1½, 2, and 2½ seconds, utilizing 200 ASA Daylight film.[b] A Soligar K-1 yellow filter was used to photograph the femurs, care being taken to prevent UV light from directly striking the filter. A Coastar Y-2 yellow filter was used to photograph the tibia.

D. Surgical Procedure

The surgical procedure that was performed was a unilateral trochanteric osteotomy. The operative leg was routinely clipped and prepared for aseptic surgery.

A curved skin incision was made from antero-dorsal to the greater trochanter, around the trochanter posteriorly, and distally down the femur approximately one-half its length. Skin towels were placed on the skin edges. The biceps femoris was separated from the fascia lata along its anterior border the length of the incision. The sciatic nerve was identified at this time and throughout the surgery. The superficial gluteal muscle was separated from its tendinous attachment on the third trochanter and reflected dorsally. Forceps were passed under the distal bellies of the middle and deep gluteals so as to lie on the neck of the femur. An osteotome was placed at the level of the third trochanter, directed at the forceps, and the greater trochanter was osteotomized.

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[a] Ultra Violet Products, Inc., San Gabriel, California.

[b] Kodak Ektachrome, EPD 135-36.

The trochanter was then reflected dorsally, severing all soft tissue attachments as needed. The trochanter was then replaced to its anatomic position and fixed by means of two K-wires drilled through the epiphysis of the greater trochanter and into the shaft of the femur. Fixation was maintained utilizing the tension band principle. A cerclage wire was passed through a hole previously drilled in the shaft of the femur and figure-eighted around the proximal tips of the two K-wires which were bent medially 90°. The cerclage wire was then snugly tightened.

The superficial gluteal muscle was replaced to the third trochanter and fixed by means of surgical gut in an interrupted pattern. The biceps was sutured to the fascia lata and the skin was sutured. No special post operative procedures or precautions were undertaken.

E. Radiography, Technique and Measurements

Radiographs were taken with the dog anesthetized in dorsal recumbency. A ventrodorsal radiograph of the pelvis was obtained, as is done for hip dysplasia (Whittington 1961). The pelvis was centered and the stifle and hock joints extended with the legs parallel and the patellas superimposed over the midline of the femurs.

On the ventrodorsal radiograph, (Figure 2), the femur was bisected along its length and a line drawn connecting the lateral and medial femoral condyles. Two lines were then drawn perpendicular to the line bisecting the femur: 1) to the proximal-most tip of the head of the femur and 2) to the proximal-most tip of the greater trochanter.

The distance from the head of the femur to the condyles represents the femoral leg length and is referred to as the articulocondylar distance (ACD). The distance from the tip of the greater trochanter to the condyles is referred to as the trochantericcondylar distance (TCD). The distance from the tip of the trochanter to the head of the femur is the articulotrochanteric distance (ATD). The ATD plus the TCD equals the ACD.

The femoral neck-shaft angle was measured on the ventrodorsal radiograph by two methods. By the first method, two lines were drawn through the physis of the head of the femur in its "straight part". This "straight part" excludes that medial and lateral portion of the physis that may deflect distally, when viewed on the ventrodorsal radiograph. A line was drawn perpendicular to this physeal growth plate. The angle that this line makes with the femur represents the femoral neck-shaft angle by the epiphyseal line method.

In the second method, the femoral head was bisected along the physeal line. The femoral neck was bisected at its narrowest point on the control femur and at a similar point on the experimental femur. The angle formed by the line passing through these two points and intersecting the line bisecting the femur along its longitudinal axis is the femoral neck-shaft angle, obtained by bisecting the head and neck. This method of bisection of the neck will include a portion of the connecting ridge of bone between the femoral head and greater trochanter.

The anteversion measurement (Figure 3) was obtained with the dog still anesthetized in dorsal recumbency. The femur was positioned vertical to the radiography table by directly sighting down the shaft of the femur, utilizing fluoroscopy with image intensification. With the dog maintained in this position, the table was moved so that the femur came to lie under a standard X-ray tube. A routine radiograph was then exposed, utilizing a bucky.

Figure 2

Ventrodorsal Pelvis - Measurements

The following measurements are demonstrated:

1) Articulocondylar distance
2) Trochantericcondylar distance
3) Articulotrochanteric distance
4) Femoral neck-shaft angle - epiphyseal line method
5) Femoral neck-shaft angle - head and neck bisection method

Figure 3 - Anteversion - Measurement

The femoral head and neck were then bisected on the radiograph and a line drawn through these points. The angle that this line makes with a line drawn through the articular surfaces of the condyles in the frontal plane is the anteversion angle.

F. Evaluation of Data

The following radiographic measurements were obtained: 1) articulotrochanteric distance, 2) articulocondylar distance, 3) trochanteric condylar distance, 4) femoral neck-shaft angle, by the epiphyseal line method, 5) femoral neck-shaft angle, by head and neck bisection method, and 6) anteversion. The final values of these measurements (obtained at 38 weeks of age) were analyzed statistically utilizing the F-test, comparing the operated to the unoperated-control leg.

All other statistical comparisons were made utilizing the student's t-test. This included, as example, evaluation of the difference between gross femur and gross tibia lengths on the operated versus the unoperated leg. Also included was the evaluation of the normal femur up to 26 weeks of age compared to the unoperated-control femur at the same age.

CHAPTER V

EXPERIMENTAL RESULTS

A. General

There was no statistically significant difference between the normal femur and the unoperated-control femur. It appeared, therefore, that the unoperated leg served adequately as a control in this experiment.

All dogs were clinically lame for up to several days following surgery. A mild degree of lameness was observed nine times in seven dogs (Appendix A). These observations include those made one week post operatively. At the termination of the study, all dogs were normal and without any degree of lameness.[a]

B. Dogs Operated at 14 Weeks of Age

The tetracycline label (Figure 4) demonstrated there to be a minimal amount of growth occurring from the epiphysis of the greater trochanter in the proximo-distal direction. There was, however, a greater amount of growth that occurred in the lateral direction. Growth from the other femoral epiphyses was approximately the same. The delineation between labelled and unlabelled bone was not marked in all dogs of this group.

Radiographically (Figures 5 & 6), there was a marked increase in the articulotrochanteric distance and the appearance of an increased femoral neck-shaft angle. The anteversion angles were approximately the same. The radiographic measurements obtained in these dogs, throughout the

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[a] Observed also by Dr. Mark Guffy, Radiologist, Kansas State University.

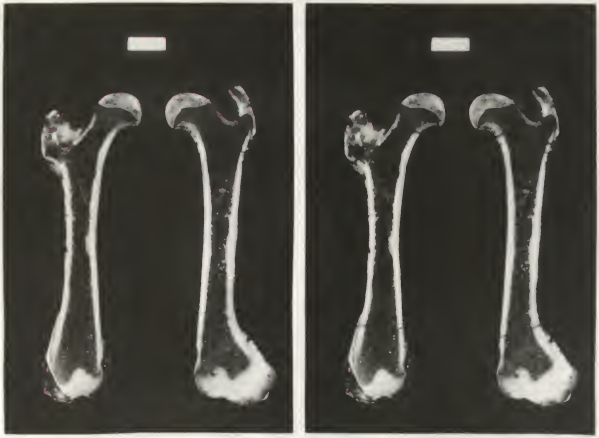

Figure 4a

Figure 4b

Figure 4 - Tetracycline Labelled Femur
From Dog Operated at 14 Weeks of Age

The epiphyseal-metaphyseal junction can be seen clearly, as the tetracycline labelled bone of the epiphysis appears very light while the unlabelled bone of the metaphysis is darker in color. The delineation between labelled and unlabelled bone in the diaphysis is not as clear. A line is drawn in Figure 4b to assist in this delineation. The bone between the epiphyseal-metaphyseal junction and the line drawn in the diaphysis is the bone that has grown since the tetracycline label.

Figure 5

Ventrodorsal Pelvis

Figure 6

Anteversion

Figures 5 and 6 are radiographs of a dog operated on at 14 weeks of age. There is a marked increase of the articulotrochanteric distance and the appearance of an increased femoral neck-shaft angle of the experimental femur. The anteversion angles are approximately the same.

experiment, were tabulated (Appendix A). The mean and standard deviation of the final radiographic measurements were also tabulated (Tables 3-8).

Grossly, the coxofemoral joints appeared normal. Histologically, (Appendix B) there was complete osseous union of the physeal growth plates of the heads and greater trochanters of both the experimental and control femurs on all dogs of this group, with one exception. On dog showed osseous union of the medial aspect of the physeal growth plate of the head of the control femur, while proliferating chondrocytes remained in the lateral aspect of the plate.

Foci of calcification were noted in the articular cartilage of the head of the control femur in one dog. No defects of articular cartilage were noted in the heads of the experimental femurs or in the heads of the remaining control femurs.

C. Dogs Operated at 20 Weeks of Age

Less growth occurred from the epiphyses of the femur in these dogs than those operated at 14 weeks of age (Figure 7). The growth from the capital and distal femoral epiphyses was approximately equal, with a marked retardation of growth of the greater trochanter. There was minimal proximo-distal and lateral growth, and some malformation of this epiphysis.

Radiographically (Figures 8 & 9), there was an increase in the articulotrochanteric distance, with the other parameters being approximately the same. The radiographic measurements obtained in these dogs throughout the experiment were tabulated (Appendix A). The mean and standard deviation of the final radiographic measurements were also tabulated (Tables 3-8).

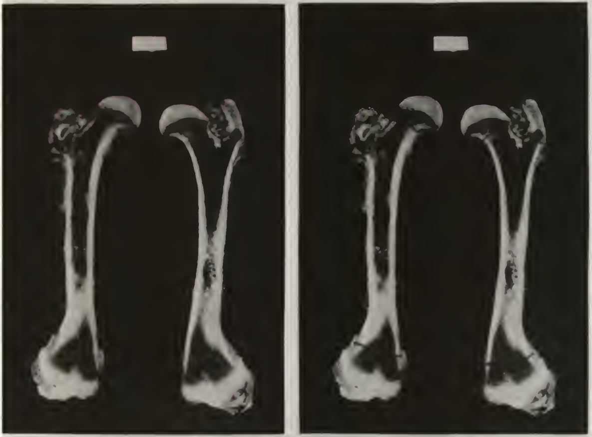

Figure 7a

Figure 7b

Figure 7 - Tetracycline Labelled Femur
From Dog Operated at 20 Weeks of Age

The epiphyseal-metaphyseal junction can be seen clearly, as the tetracycline labelled bone of the epiphysis appears very light while the unlabelled bone of the metaphysis is darker in color. The delineation between labelled and unlabelled bone in the diaphysis is not as clear. A line is drawn in Figure 7b to assist in this delineation. The bone between the epiphyseal-metaphyseal junction and the line drawn in the diaphysis is the bone that has grown since the tetracycline label.

Figure 8

Ventrodorsal Pelvis

Figure 9

Anteversion

Figures 8 and 9 are radiographs of a dog operated on at 20 weeks of age. There is a marked increase of the articulotrochanteric distance of the experimental femur. The femurs are otherwise very similar.

Grossly, the coxofemoral joints appeared normal. Histologically, (Appendix B) there was complete osseous union of the physeal growth plates of the heads and greater trochanters of both experimental and control femurs in three dogs of this group. In the remaining dog, proliferating cartilage cells were present in the physeal growth plates of the heads of both experimental and control femurs. There was osseous union of the greater trochanteric physis.

A fissure was present that extended one-third the depth of the articular cartilage of the head of the femur in the experimental leg of one dog. Foci of calcification were noted in the articular cartilage of the head of a control femur in another dog. No defects were noted of the articular cartilages of the heads of the remaining experimental or control femurs.

D. Dogs Operated at 26 Weeks of Age

There was little epiphyseal growth remaining in these dogs, as demonstrated with the tetracycline label (Figure 10). The growth from the epiphysis of the greater trochanter was not well delineated, but it appeared to be minimal to none.

Radiographically, the femurs appeared very similar (Figures 11 & 12). The radiographic measurements obtained in these dogs throughout the experiment were tabulated (Appendix A). The mean and standard deviation of the final radiographic measurements were also tabulated (Tables 3-8).

Grossly, the coxofemoral joints appeared normal. Histologically, (Appendix B) there was osseous union of the physeal growth plates of the heads and greater trochanters of both the experimental and control femurs in all dogs of this group. This union was complete in three dogs and incomplete in one dog.

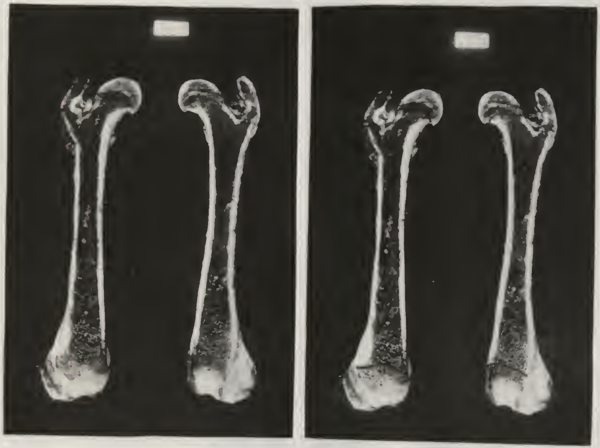

Figure 10a

Figure 10b

Figure 10 - Tetracycline Labelled Femur
From Dog Operated at 26 Weeks of Age

The epiphyseal-metaphyseal junction can be seen, as the tetracycline labelled bone of the epiphysis appears very light while the unlabelled bone of the metaphysis is darker in color. The delineation between labelled and unlabelled bone in the diaphysis is not as clear. A line is drawn in Figure 10b to assist in this delineation. The bone between the epiphyseal-metaphyseal junction and the line drawn in the diaphysis is the bone that has grown since the tetracycline label.

Figure 11

Ventrodorsal Pelvis

Figure 12

Anteversion

Figures 11 and 12 are radiographs of a dog operated on at 26 weeks of age. The experimental and control femurs are very similar.

A focal area of calcification was noted at the surface of the articular cartilage of one experimental femur. No defects were noted of the articular cartilage of the heads of the remaining experimental or control femurs.

E. Articulotrochanteric Distance (Table 3)

The mean of the twelve experimental femurs was approximately 7 mm greater than the mean of the twelve control femurs. This difference was highly significant ($p = .0001$). The greatest difference in ATD occurred in those dogs operated on at 14 weeks of age (11 mm). This difference was less in those dogs operated on at 20 weeks of age (7 mm), and even less in those operated on at 26 weeks of age (3 mm).

F. Articulocondylar Distance (Table 4)

The twelve experimental legs were, radiographically, 1.75 mm longer than the control legs. This difference was consistent and, though small, was significant with $p = .03$.

Grossly, the experimental femurs were again slightly longer than the control femurs, the difference being slightly more than 1 mm (Appendix A). Evaluating this difference with the student's t-test, a t value of 1.97 was obtained. This t value corresponded to an approximate $p = .07$.

The greatest difference in experimental femur length occurred in dog 7102, operated on at 20 weeks of age. This difference can be visualized from a picture of the gross specimen (Figure 13). With the tetracycline label, a couple millimeters more growth from both the capital and distal femoral epiphyses can be visualized (Figure 14).

TABLE 3

ARTICULOTROCHANTERIC DISTANCE - ATD
(p = .0001)

	Control	Experimental
Mean N=12	0.1 SD 1.4	7.08 SD 3.7
14-Week	0.25 SD 2.0	11.0 SD 1.4
20-Week	0.0 SD 1.2	7.25 SD 2.0
26-Week	0.0 SD 1.4	3.0 SD 0.8

TABLE 4

ARTICULOCONDYLAR DISTANCE - ACD
(p = .03)

	Control	Experimental
Mean N=12	130.5 SD 7.2	132.25 SD 8.2
14-Week	132.75 SD 3.8	133.0 SD 5.0
20-Week	129.25 SD 12.4	133.0 SD 13.8
26-Week	129.5 SD 3.7	130.75 SD 4.9

Figure 13

Gross Femur

Figure 13 demonstrates the experimental femur to be longer than the control femur. The greatest increase in femoral length occurred in this dog (7102), operated at 20 weeks of age.

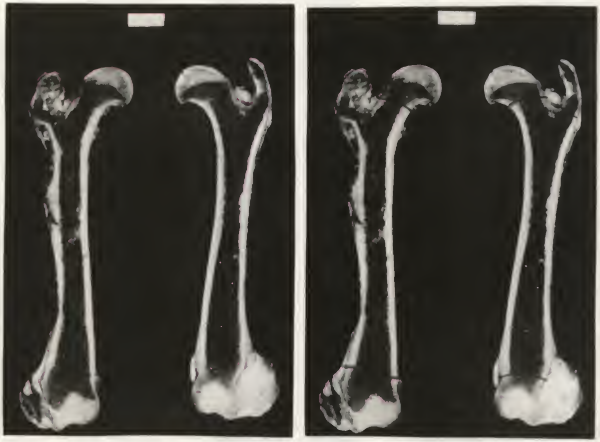

Figure 14a

Figure 14b

Figure 14 - Tetracycline Labelled Femur From Dog 7102, Operated at 20 Weeks of Age

This dog showed the greatest increase in length of the experimental femur. The epiphyseal-metaphyseal junction can be seen clearly, as the tetracycline labelled bone of the epiphysis appears very light while the unlabelled bone of the metaphysis is darker in color. The delineation between labelled and unlabelled bone in the diaphysis is not as clear. A line is drawn in Fibure 14b to assist in this delineation. The bone between the epiphyseal-metaphyseal junction and the line drawn in the diaphysis is the bone that has grown since the tetracycline label.

G. Trochantericcondylar Distance (Table 5)

The experimental legs were always shorter than the control, the mean length of the twelve experimental legs being 5.2 mm less than the mean of the twelve control legs. This difference was highly significant ($p = .0007$). The greatest difference occurred again in those dogs operated on at 14 weeks (10.5 mm) and the least in those dogs operated on at 26 weeks (1.75 mm).

H. Femoral Neck-Shaft Angle - Epiphyseal Line Method (Table 6)

The femoral neck-shaft angle obtained by the epiphyseal line method was approximately 145°. There was no significant difference between experimental and control legs ($p = .81$).

I. Femoral Neck-Shaft Angle - Head and Neck Bisection Method (Table 7)

The femoral neck-shaft angle of the experimental legs was always greater than the angle of the control legs; the difference between the twelve experimental and control legs being highly significant ($p = .0002$). The greatest difference again occurred in those dogs operated on at 14 weeks (7.75°) and the least in those dogs operated on at 26 weeks (3°).

J. Anteversion (Table 8)

The anteversion angle of those dogs operated on at 14 weeks of age was 3.25° less than the control. When the operation was performed at 20 weeks, this difference was 2°. In those dogs operated on at 26 weeks, the experimental legs exhibited 6° more anteversion. The mean of the twelve experimental legs was 36.1°, and the mean of the twelve control legs was 35.8°. There was no significant difference between experimental and control legs ($p = .87$).

TABLE 5

TROCHANTERICCONDYLAR DISTANCE - TCD
(p = .0007)

	Control	Experimental
Mean N=12	130.4 SD 7.0	125.2 SD 8.6
14-Week	132.5 SD 4.5	122.0 SD 5.9
20-Week	120.25 SD 11.8	125.0 SD 13.6
26-Week	129.5 SD 3.7	127.75 SD 5.5

TABLE 6

FEMORAL NECK-SHAFT ANGLE - EPIPHYSEAL LINE METHOD
(p = .81)

	Control	Experimental
Mean N=12	146.0 SD 4.2	146.3 SD 4.4
14-Week	145.0 SD 5.7	146.5 SD 4.0
20-Week	147.0 SD 2.3	146.75 SD 3.4
26-Week	146.0 SD 4.9	145.75 SD 6.6

TABLE 7

FEMORAL NECK-SHAFT ANGLE - HEAD AND NECK BISECTION METHOD
(p = .0002)

	Control	Experimental
Mean N=12	123.6 SD 5.0	128.75 SD 4.3
14-Week	125.0 SD 7.3	132.75 SD 4.8
20-Week	122.0 SD 3.6	126.75 SD 1.0
26-Week	123.75 SD 4.5	126.75 SD 3.3

TABLE 8

ANTEVERSION
(p = .87)

	Control	Experimental
Mean N=12	35.8 SD 3.6	36.1 SD 4.5
14-Week	36.0 SD 2.8	32.75 SD 4.2
20-Week	38.0 SD 2.9	36.0 SD 3.3
26-Week	33.5 SD 4.2	39.5 SD 3.8

K. Tibial Length

The tibias on the experimental side were greater in length than the control tibias, the mean difference being 1.9 mm (Appendix A). Utilizing the student's t-test, a t-value of 3.44 was obtained. As $t_{.01} = 3.106$, this difference, though small, was highly significant.

The greatest increase in tibial length occurred in dog 7106, operated on at 26 weeks of age. This difference can be seen on the gross photograph (Figure 15). The 7 mm of increased growth could not be demonstrated, however, on the tetracycline section (Figure 16).

Figure 15

Gross Tibia

Figure 16

Tetracycline Labelled Tibia

Figure 15 demonstrates the tibia on the experimental side to be longer than the tibia on the control side. The greatest increase in tibial length occurred in this dog (7106), operated at 26 weeks of age. The increased growth could not be demonstrated on the tetracycline section (Figure 16).

CHAPTER VI

DISCUSSION

There existed in these dogs an increase in the femoral neck-shaft angle as measured by the head and neck bisection method. However, minimal to no increase in the true femoral neck-shaft angle is felt to have existed in these experimental legs. Using, as example, those dogs operated on at 14 weeks of age, four reasons are cited.

Initially, the femoral neck-shaft angle obtained by the epiphyseal line method showed there to be a 1.5° more obtuse angle on the experimental side compared to the control (Table 6). This difference was, however, insignificant.

Secondly, the ventrodorsal radiograph of the pelvis gave the appearance of an increased femoral neck-shaft angle. If one covered up the trochanteric region of the experimental and control femurs, however, they were visually identical (Figure 17).

Thirdly, if one cut the ventrodorsal radiograph of the pelvis in half, and superimposed the femoral heads and capital epiphyseal lines (Figure 18), the experimental femoral shafts were on the mean, at a 1.5° more obtuse angle than the control femoral shafts. The results of this procedure agreed with, and substantiated, the difference in the femoral neck-shaft angle obtained by the epiphyseal line method.

Finally, bisection of the "neck", in the bisection method of measuring femoral neck-shaft angle, measured not simply the neck, but also the connecting ridge between the femoral head and greater trochanter.

Figure 17a

Figure 17b

Figure 17 - 14 Week Ventrodorsal Pelvis,
With (17b) and Without (17a) Trochanters Covered

On this ventrodorsal radiographs of a dog operated on at 14 weeks of age, there is the appearance of an increased femoral neck-shaft angle. With the trochanteric regions covered, however, the experimental and control femurs are visually identical.

Figure 18

14 Week Superimposed Ventrodorsal Radiograph

A ventrodorsal radiograph of a dog operated at 14 weeks of age is cut in half and the femoral heads and capital epiphyseal lines are exactly superimposed. The experimental shaft is seen to be at a slightly more obtuse angle with the femoral head and neck than the control shaft.

With this experiment, the bony ridge appeared to be reduced and the bony contribution to the dorsal femoral neck was smaller. Consequently, it could be seen that even if the angles formed by the ventral femoral head and neck and the medial femoral shaft were identical (comparing experimental to control), the femoral neck-shaft angle obtained by bisecting the head and "neck" would be greater on the experimental side, as, in fact, it was.

The control neck was therefore bisected and a value obtained. This value was then applied to the experimental neck. The lack of bony contribution to the dorsal femoral neck was therefore accounted for and negated. The results of this procedure demonstrated the experimental femoral neck-shaft angles to be 3^{o} greater than the control, a difference that was insignificant as demonstrated by the student's t-test.

The head and neck bisection method was, therefore, not felt to be an accurate measurement of the true femoral neck-shaft angle in these experimental dogs. A more accurate representation of the femoral neck-shaft angle was obtained by the epiphyseal line method. There was, therefore, no significant difference between the true femoral head and neck angles of the experimental and controls femurs.

The only real change in femoral conformation that resulted from this experiment was an increase in the articulotrochanteric distance. Since the gluteal musculature inserts on the greater trochanter, the insertion of the gluteals becomes relatively more distal and the gluteals become relatively less of an extensor of the hip. It can be theorized that this biomechanical change will result in coxarthropathy.

Histologically, there was change in the articular cartilage of two experimental and two control femurs. There were no defects noted in the articular cartilages of the experimental femurs of those dogs operated on at 14 weeks of age. Since 14 weeks was the youngest age at which a trochanteric osteotomy was performed in this experiment, it is suspected that if the experimental procedure were to precipitate a change, it would have done so in the 14-week group. It is therefore felt that the minimal changes observed in the articular cartilages of experimental and control femurs were unrelated to the experiment.

The possibility, however, that histologic, radiographic, or clinical coxarthropathy could develop several years later in these hips cannot be excluded by this experiment. To do so would require that these dogs be maintained, for example, three years after the experiment. At that time they could be evaluated again histologically, radiographically, and clinically. The possibility that femoral deformity, coxarthropathy, or clinical lameness could occur in a larger breed of dog, for example the Greyhound, cannot be excluded by this experiment.

It is emphasized that, in this experiment, changes in femoral conformation were primarily limited to an increase in the articulotrochanteric distance of about one centimeter. There was no evidence of coxarthropathy radiographically, histologically, or clinically. In the end result then, this surgical procedure was performed in the growing Beagle dog without any adverse effects.

CHAPTER VII

SUMMARY AND CONCLUSIONS

Osteotomy of the greater trochanter, with tension band fixation, did have some effect on femoral conformation when performed in the young dog. There was some malformation of the greater trochanter and, though growth from the physis was not arrested, it was markedly retarded. Up to two millimeters of measured growth in the proximo-distal direction occurred, with sometimes slightly greater growth occurring in the lateral direction.

The experiment resulted in a significant and marked increase in the articulotrochanteric distance. It did not result in any significant change in anteversion angle and there was minimal to no change in the true femoral neck-shaft angle. There was no shortening of the leg. In fact, there resulted a mild increase in femoral and tibial lengths. This is felt to be due to the phenomenon of stimulation of growth.

The experiment did not result in any degree of lameness, nor did it result in radiographic or histologic evidence of coxarthropathy. It was concluded that osteotomy of the greater trochanter with tension band fixation, performed in the growing Beagle dog, could be safely performed without any adverse effects.

CHAPTER VIII

APPENDIX

APPENDIX A

WEEKLY CLINICAL EVALUATION OF FUNCTIONAL LIMB USAGE

I Nonuse; no functional use of the limb; carries the limb most of the time
II Slight use; some functional use; will set limb down at a stand or walk; carries limb when running; bears no weight on limb
III Limp; functional use of limb; partial weight bearing
IV Normal; full function at standing, walking, running; full weight bearing

	Age In Weeks																								
I.D.	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36	37	38
7101	IV	IV	IV	IV	IV	IV	IV	IV	IV	IV	IV	IV	IV	IV	IV	--	IV	IV	--	IV	IV	IV	--	--	IV
7103	IV	III	IV	IV	IV	IV	IV	IV	IV	III	IV	IV	IV	IV	IV	--	IV	IV	--	IV	IV	IV	--	--	IV
7132	IV	IV	--	IV	IV	IV	IV	IV	IV	IV	IV	IV	IV	--	IV	IV	IV	IV	--	IV	IV	--	IV	--	IV
7133	IV	IV	--	IV	III	IV	IV	IV	IV	IV	IV	IV	IV	--	IV	IV	IV	IV	--	IV	IV	--	IV	--	IV
7102							IV	III	IV	IV	IV	IV	IV	IV	IV	--	IV	IV	IV	IV	IV	IV	IV	--	IV
7104							IV	IV	IV	III	IV	IV	IV	IV	IV	--	IV	IV	IV	IV	IV	IV	IV	--	IV
7132							IV	IV	III	IV	IV	IV	IV	--	IV	IV	IV	IV	IV	IV	IV	--	IV	--	IV
7134							IV	III	IV	IV	IV	IV	IV	--	IV	IV	IV	IV	IV	IV	IV	--	IV	--	IV
7105													IV	III	III	--	IV	IV	--	IV	IV	IV	--	--	IV
7106													IV	IV	IV	--	IV	IV	--	IV	IV	IV	--	--	IV
7129													IV	--	IV	IV	--	IV	--	IV	IV	--	IV	--	IV
7135													IV	--	IV	IV	IV	IV	--	IV	IV	--	IV	--	IV

ARTICULOTROCHANTERIC DISTANCE
(in millimeters)

I.D.	Leg	Age In Weeks												
		14	16	18	20	22	24	26	28	30	32	34	36	38
7101	*R	3		6		7		8		9		10		9
	L	3		0		–1		–1		–1		–1		–2
7103	*R	3		8		7		12		12		12		12
	L	3		0		0		1		1		1		2
7132	R	5		3		2		1		–1		–1		–1
	*L	4		9		10		10		10		11		11
7133	*R	5		7		9		9		13		12		12
	L	6		3		1		3		2		2		2
7102	*R				1	3	4	6	5	7	6	6	6	7
	L				0	0	1	1	0	1	0	2	0	1
7104	*R				0	5	6	9	8	9	9	10	9	10
	L				0	0	1	2	0	1	1	2	0	1
7131	R				0	1	–2	–1	–1	–1	–2	–1	–1	–1
	*L				0	2	4	3	5	6	5	6	6	7
7134	*R				0	2	2	5	4	4	4	5		5
	L				–1	0	0	0	0	–1	–2	–2		–1
7105	R	2		0		–1		0		–2		–2		–1
	*L	2		0		0		0		1		2		4
7106	*R	3		1		1		1		2		4		3
	L	3		1		0		0		0		0		0
7129	R	4		3		1		1		0		–1		–1
	*L	5		4		1		1		3		3		3
7135	*R	6		3		3		2		1		2		2
	L	6		3		3		2		1		1		2

* = Operated leg

ARTICULOCONDYLAR DISTANCE
(in millimeters)

I.D.	Leg	Age In Weeks												
		14	16	18	20	22	24	26	28	30	32	34	36	38
7101	*R	93		111		119		128		135		139		139
	L	93		109		119		127		134		137		137
7103	*R	95		109		115		123		130		131		132
	L	95		107		114		122		128		130		132
7132	R	82		98		110		117		124		127		128
	*L	81		96		110		118		124		126		127
7133	*R	91		105		115		125		132		134		134
	L	91		104		115		125		131		134		134
7102	*R				126	131	137	139	144	147	150	150	150	152
	L				124	130	134	137	140	141	144	145	144	144
7104	*R				110	114	119	122	124	127	128	128	129	129
	L				108	113	120	121	124	125	126	127	128	127
7131	R				106	112	115	119	123	125	128	130	132	132
	*L				105	111	115	120	124	126	128	130	131	132
7134	*R				96	102	105	108	113	116	117	119		119
	L				94	99	103	107	110	112	113	115		114
7105	R	89		105		112		121		125		126		128
	*L	90		103		113		121		126		128		127
7106	*R	91		104		112		119		123		125		126
	L	88		105		112		119		123		123		125
7129	R	83		100		114		123		129		133		133
	*L	84		99		111		120		128		134		135
7135	*R	88		103		116		121		130		133		135
	L	85		102		114		121		127		130		132

* = Operated leg

TROCHANTERICCONDYLAR DISTANCE
(in millimeters)

I.D.	Leg	Age In Weeks												
		14	16	18	20	22	24	26	28	30	32	34	36	38
7101	*R	90		105		112		120		126		129		130
	L	90		109		120		128		135		138		139
7103	*R	92		101		108		111		118		119		120
	L	92		107		114		121		127		129		130
7132	R	77		95		108		116		125		128		129
	*L	77		87		100		108		114		115		116
7133	*R	86		98		106		114		119		122		122
	L	85		101		114		122		129		132		132
7102	*R				125	128	133	133	139	140	144	144	144	145
	L				124	130	133	136	140	140	144	143	144	143
7104	*R				110	109	113	113	116	118	119	118	120	119
	L				108	113	119	119	124	124	125	125	128	126
7131	R				106	111	117	120	124	126	130	131	133	133
	*L				105	109	111	117	119	120	123	124	125	125
7134	*R				96	100	103	103	109	112	113	114		114
	L				95	99	103	107	110	113	115	117		115
7105	R	87		105		113		121		127		128		129
	*L	88		103		113		121		125		126		123
7106	*R	88		103		111		118		121		121		123
	L	85		104		112		119		123		123		125
7129	R	79		97		113		124		129		134		134
	*L	79		95		110		119		125		131		132
7135	*R	82		100		113		119		129		131		133
	L	79		99		111		119		126		129		130

* = Operated leg

FEMORAL NECK-SHAFT ANGLE - EPIPHYSEAL LINE METHOD
(in degrees)

I.D.	Leg	Age In Weeks												
		14	16	18	20	22	24	26	28	30	32	34	36	38
7101	*R	138		135		143		144		149		153		143
	L	136		134		137		141		145		148		139
7103	*R	137		135		127		140		145		148		143
	L	139		131		136		140		146		141		147
7132	R	136		136		143		145		145		149		142
	*L	139		141		145		150		148		150		150
7133	*R	143		132		134		151		154		153		150
	L	144		144		146		156		155		154		152
7102	*R				140	146	146	148	147	150	149	146	147	148
	L				142	146	149	149	148	149	146	150	151	145
7104	*R				137	140	141	146	144	147	145	143	142	147
	L				137	140	149	150	144	146	147	144	145	149
7131	R				140	141	144	144	151	151	153	152	150	149
	*L				131	135	140	139	142	143	140	143	146	142
7134	*R				136	142	147	148	151	149	146	149		150
	L				130	141	146	145	147	147	144	147		145
7105	R	137		132		136		144		144		137		140
	*L	142		131		145		147		141		144		138
7106	*R	146		141		146		149		147		150		146
	L	141		144		141		148		149		144		146
7129	R	130		140		142		145		152		148		146
	*L	143		145		140		149		149		146		145
7135	*R	144		139		145		150		151		150		154
	L	142		137		147		149		149		146		152

* = Operated leg

FEMORAL NECK-SHAFT ANGLE - HEAD AND NECK BISECTION METHOD
(in degrees)

I.D.	Leg	14	16	18	20	22	24
				Age In Weeks			
7101	*R	$^{A}126$		$^{BM}129$		$^{A}133$	
	L	$^{A}123$		$^{BM}120$		$^{A}118$	
7103	*R	$^{BM}126$		$^{BM}132$		$^{CM}128$	
	L	$^{A}132$		$^{CM}120$		$^{CM}122$	
7132	R	$^{A}126$		$^{A}127$		$^{A}131$	
	*L	$^{A}126$		$^{A}130$		$^{BL}132$	
7133	*R	$^{A}133$		$^{BM}127$		$^{BM}130$	
	L	$^{A}132$		$^{A}128$		$^{BM}131$	
7102	*R				$^{BM}124$	$^{A}131$	$^{A}130$
	L				$^{A}123$	$^{A}127$	$^{BL}127$
7104	*R				$^{A}123$	$^{BM}125$	$^{BM}124$
	L				$^{A}123$	$^{BM}123$	$^{A}135$
7131	R				$^{BM}122$	$^{BM}122$	$^{BM}122$
	*L				$^{CM}119$	$^{BM}124$	$^{BM}127$
7134	*R				$^{CM}123$	$^{BM}127$	$^{A}130$
	L				$^{CM}118$	$^{BM}124$	$^{A}132$
7105	R	$^{A}130$		$^{CM}121$		$^{BM}123$	
	*L	$^{A}128$		$^{CM}118$		$^{A}132$	
7106	*R	$^{A}129$		$^{BM}126$		$^{A}129$	
	L	$^{A}128$		$^{A}129$		$^{BM}122$	
7129	R	$^{BM}125$		$^{A}128$		$^{BM}126$	
	*L	$^{A}129$		$^{A}135$		$^{BM}124$	
7135	*R	$^{A}134$		$^{BM}129$		$^{BM}132$	
	L	$^{A}131$		$^{BM}128$		$^{A}129$	

A = Excellent Positioning
B = Mild Femoral Rotation
C = Excessive Femoral Rotation
M = Medial Femoral Rotation
L = Lateral Femoral Rotation

* = Operated leg

FEMORAL NECK-SHAFT ANGLE - HEAD AND NECK BISECTION METHOD
(in degrees)

I.D.	Age In Weeks						
	26	28	30	32	34	36	38
7101	^{A}135 ^{A}125		^{A}133 ^{A}125		^{BL}136 ^{BL}125		^{BM}127 ^{BM}116
7103	^{A}135 ^{A}128		^{BL}137 ^{BL}135		^{A}137 ^{A}129		^{A}135 ^{A}131
7132	^{A}133 ^{BL}136		^{A}131 ^{A}135		^{A}129 ^{A}131		^{A}122 ^{A}131
7133	^{A}141 ^{A}140		^{A}141 ^{A}138		^{A}139 ^{A}133		^{A}138 ^{A}131
7102	^{A}131 ^{A}128	^{A}133 ^{A}126	^{BL}133 ^{A}126	^{A}130 ^{A}125	^{A}130 ^{BL}128	^{A}126 ^{A}122	^{A}126 ^{A}122
7104	^{BL}133 ^{BL}135	^{A}131 ^{A}127	^{BL}131 ^{A}123	^{A}130 ^{A}131	^{A}130 ^{A}131	^{A}126 ^{BM}126	^{A}128 ^{A}124
7131	^{BM}127 ^{BM}125	^{A}127 ^{A}132	^{A}126 ^{A}131	^{A}130 ^{BM}126	^{A}127 ^{A}128	^{A}123 ^{A}128	^{A}125 ^{A}126
7134	^{A}135 ^{A}129	^{BL}133 ^{A}127	^{A}130 ^{A}123	^{A}126 ^{BM}120	^{A}126 ^{BM}120		^{A}127 ^{BM}117
7105	^{A}129 ^{A}132		^{A}123 ^{BM}126		^{BM}125 ^{BM}126		^{A}120 ^{BM}126
7106	^{BL}136 ^{A}127		^{A}128 ^{A}122		^{BL}133 ^{A}126		^{A}127 ^{A}124
7129	^{A}129 ^{A}131		^{BL}130 ^{A}132		^{A}123 ^{BM}126		^{BM}121 ^{BM}123
7135	^{A}133 ^{A}133		^{A}135 ^{BM}128		^{BM}134 ^{BM}125		^{A}131 ^{A}130

A = Excellent Positioning
B = Mild Femoral Rotation
C = Excessive Femoral Rotation
M = Medial Femoral Rotation
L = Lateral Femoral Rotation

* = Operated leg

ANTEVERSION
(in degrees)

I.D.	Leg	Age In Weeks												
		14	16	18	20	22	24	26	28	30	32	34	36	38
7101	*R	32		35		35		39		39		34		34
	L	28		32		36		35		39		31		34
7103	*R	35		39		34		38		36		33		33
	L	38		40		39		39		40		39		40
7132	R	28		35		38		38		39		36		34
	*L	29		29		32		31		29		34		37
7133	*R	28		28		34		35		32		30		27
	L	31		34		37		38		41		40		36
7102	*R				41	42	42	34	39	41	39	40	38	40
	L				37	35	40	38	36	44	37	36	38	36
7104	*R				37	42	41	40	38	42	35	37	41	36
	L				37	37	39	42	40	42	36	37	39	41
7131	R				38	37	39	41	38	37	42	39	40	40
	*L				31	35	37	36	34	35	35	33	34	32
7134	*R				38	37	35	40	35	31	32	36		36
	L				37	38	37	38	37	39	36	35		35
7105	R	32		37		33		36		41		38		34
	*L	36		42		38		40		46		41		45
7106	*R	29		34		30		33		35		34		37
	L	28		32		27		31		29		34		29
7129	R	33		38		36		36		34		33		32
	*L	42		38		40		40		39		37		37
7135	*R	29		34		40		37		42		34		39
	L	38		34		38		39		39		37		39

* = Operated leg

FEMUR - GROSS LENGTH
(in millimeters)

	Operated	Control
7101	134	133
7102	140	134
7103	125	125
7104	122	121
7105	127	125
7106	115	114
7129	123½	123½
7131	123½	123½
7132	120	122
7133	122	123
7134	110	108
7135	126	124
Mean	124.125	123

TIBIA - GROSS LENGTH
(in millimeters)

	Operated	Control
7101	124	122
7102	131	129
7103	113	111
7104	118	117
7105	114	114
7106	110	103
7129	119	117
7131	117	115
7132	115	113
7133	121	118
7134	113	112
7135	114	115
Mean	117.4	115.5

B. Histology

7101 - There was complete osseous union of the physeal growth plates of the heads and greater trochanters of both experimental and control femurs. No defects were noted of the articular cartilage of the heads of either experimental or control femurs. A defect of bone was noted in the greater trochanter of the experimental femur. This defect contained some fibrous tissue and cellular debris. It represents where a K-wire had been inserted.

7102 - There was complete osseous union of the physeal growth plates of the heads of the greater trochanters of both experimental and control femurs. No defects were noted of the articular cartilage of the head of the control femur. A fissure that extended from the surface of the articular cartilage for one-third of the depth of the articular cartilage was noted on the experimental femur. A tract was noted, where a K-wire had been inserted, in the experimental greater trochanter.

7103 - There was complete osseous union of the physeal growth plates of the heads and greater trochanters of both experimental and control femurs. No defects were noted of the articular cartilage of the heads of either experimental or control femurs.

7104 - There was complete osseous union of the physeal growth plates of the heads and greater trochanters of both experimental and control femurs. No defects were noted of the articular cartilage of the heads of either experimental or control femurs. A tract, containing a large amount of fibrous tissue, was noted in the experimental greater trochanter.

7105 - There was complete osseous union of the physeal growth plates of the greater trochanters of both experimental and control femurs. Though some cartilage cells remained in the physeal growth plates of the heads of both experimental and control femurs, osseous union was present across the majority of the plate. No defects were noted of the articular cartilage of the heads of either experimental or control femurs. A fibrous tract was noted in the experimental greater trochanter.

7106 - There was complete osseous union of the physeal growth plates of the heads and greater trochanters of both experimental and control femurs. No defects were noted of the articular cartilage of the heads of either experimental or control femurs.

7129 - There was complete osseous union of the physeal growth plates of the heads and greater trochanters of both experimental and control femurs. No defects were noted of the articular cartilage of the head of the control femur. A focal area of calcification was noted at the surface of the articular cartilage of the experimental femur. The cellular elements appeared normal throughout the cartilage.

7131 - There was complete osseous union of the physeal growth plates of the greater trochanters of both experimental and control femurs. Proliferating cartilage cells were present in the physeal growth plates of the heads of both experimental and control femurs. Foci of calcification were noted in the articular cartilage of the head of the control femur. No defects of the articular cartilage of the head of the experimental femur were noted.

7132 - There was complete osseous union of the physeal growth plates of the greater trochanters of both experimental and control femurs and the head of the experimental femur. There was osseous union of the physeal growth plate of the head of the control femur medially, while proliferating chondrocytes remained in the lateral aspect of the plate. No defects were noted of the articular cartilage of the heads of either experimental or control femurs.

7133 - There was complete osseous union of the physeal growth plates of the heads and greater trochanters of both experimental and control femurs. Foci of calcification were noted in the articular cartilage of the head of the control femur. No defects were noted of the articular cartilage of the head of the experimental femur.

7134 - There was complete osseous union of the physeal growth plates of the heads and greater trochanters of both experimental and control femurs. No defects were noted of the articular cartilage of the heads of either experimental or control femurs. A fibrous tract was present in the greater trochanter of the experimental femur.

7135 - There was complete osseous union of the physeal growth plates of the heads and greater trochanters of both experimental and control femurs. No defects were noted of the articular cartilage of the heads of either experimental or control femurs. A fibrous tract was present in the greater trochanter of the experimental femur.

C. Stimulation of Growth

Stimulation of growth following fractures or epiphyseal injuries has been observed clinically, in man, for many years (Cassidy 1958, Edvardsen 1976). An increase in tibial length following distal femoral fracture has been observed in the dog (Alcantara 1975).

An increase in blood supply to the physeal growth plate has been observed experimentally following periosteal stripping and destruction of the nutrient artery (Yabsley 1965). It was suggested that this increase in blood supply was secondary to an increase in plate thickness and not the cause of any overgrowth (Harris 1968). Minor and inconsistent increases in limb length have been observed following this stripping procedure, however (Jenkins 1975).

Clinically, periosteal stripping of the femur and tibia has been used in children with a shortened extremity secondary to poliomyelitis. A definite increase in growth occurred in 31 of 45 patients (Chan 1970).

The insertion of an ivory peg in the epiphysis has resulted in an increase of growth (Bachynski 1974). On the other hand, various metals placed from epiphyses to metaphysis, in an attempt to stimulate growth, did not result in any significant change (Ford 1960).

Stapling of the proximal tibial physis has resulted in a reduction in the normal deceleration of growth in the distal tibial physis of rabbits. Following removal of the staples, the rate of epiphyseal growth returned to normal (Hall-Craggs 1969).

Following wedge osteotomy and experimental angulation of the tibia, a mild insignificant increase in epiphyseal growth occurred. More significantly, an asymmetrical epiphyseal growth occurred that resulted in straightening of the tibia (Karaharju 1976).

An increase in growth of a non-fractured bone in an extremity has been documented experimentally. In the rat, an increase in proximal tibial epiphyseal growth has occurred following fracture of the femur, tibia, and metatarsals (Hansson 1976).

Finally, an increase in length of the extremity has been observed following damage to the growth plate of the greater trochanter (Langenskiold 1967, Chigot 1962). A compensatory increase in distal femoral growth has been observed in the rabbit following ablation of the trochanteric epiphysis (Weissman 1974).

I feel, therefore, that this phenomenon of "stimulation of growth" did result in the observed mild increases in femoral and tibial lengths in this experiment. The exact mechanism of stimulation, however, remains elusive at this time.

D. Tetracycline

Tetracycline, when administered to an animal, is known to become fixed to bone and fluoresce under ultraviolet light. It is probably bound, structurally unaltered, with Ca^{++} (Karaharju 1967).

Any tetracycline, independent of route given and precise dose, will result in fluorescence. There is a relationship between intensity of fluorescence and age (Milch 1958). Fluorescence can be seen with doses as low as 0.3 mg/kg (Milch 1057). Doses greater than 50 mg/kg may result in diffuse labelling. That is, the label will exist in bone other than that actively growing (Harris 1962).

Tetracycline will initially label all tissue. Two to three days are necessary to clear the excess drug, leaving only the tetracycline bound to bone (Skinner 1975). The tetracycline fluorescence will persist *in vivo* for long periods, subject to remodeling and resorption. In man, observations have been made up to six years later (Frost 1960).

Following harvest of the bone, it should be stored in the fresh state at approximately -10°C (Milch 1958). If the bone is kept in EtOH, the fluorescence may be gradually lost over many weeks (Frost 1960).

The technique previously described in this paper appears adequate for the labelling of bone and photography of gross sections. A tetracycline dose of 20 mg/kg/day for three to six days has been recommended for the sharp labelling of forming mineralized tissue in adult animals (Skinner 1975). A long wave ultraviolet light, emitting approximately 3600 Å, is best to induce fluorescence. This light may come from either an ultraviolet light bulb or a white light bulb with filter. (I have successfully fluoresced, and photographed, tetracycline-labelled bone with a Wood's lamp.) The yellow filter utilized for photography is essential. Though I have found the Soligar K-1 and Coastar Y-2 to be good, personal preference and trial and error may dictate another filter.

E. Effect of Anteversion

The measured femoral neck-shaft angle is influenced by the anteversion angle of the femoral head and neck. The greater the anteversion angle, the greater the measured femoral neck-shaft angle will be. For example, the measured femoral neck-shaft angle of a femoral head and neck with an anteversion angle of 40° will be greater than if the anteversion were only 10°.

There is a trigonometric formula that will correct the anteversion angle to 0°. It is referred to as Webber Formula No. 2[a] (Dunlap 1953). As an example, at a measured femoral neck-shaft angle of 130° and an anteversion of 30°, the true femoral neck-shaft angle equals 126°.

An artifactual increase in femoral neck-shaft angle is produced when the femur is externally rotated on the ventrodorsal projection. It can be seen that externally rotating the femur is essentially the same as increasing the anteversion angle. As an example, this is demonstrated (Figure 19).

All femoral neck-shaft angles reported herein are the measured angles. Correction was not made utilizing Webber Formula No. 2, since all anteversion angles were approximately 35°. If corrections were made, all femoral neck-shaft angles would be, consistently, approximately 5° more varus.

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[a] $\text{Cot } B = \text{Cot } B_2 \times \text{Cos } \theta$ where
B = The true angle of inclination (femoral neck-shaft)
B_2 = The measured angle of inclination
θ = The true angle of torsion (anteversion)
Dunlap presents this formula in graph form in his article.

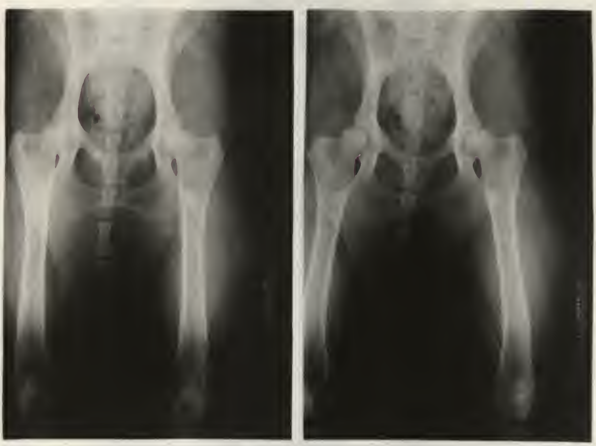

Figure 19a

Figure 19b

Figure 19 - Ventrodorsal Pelvis, With (19b) and Without (19a) External Femoral Rotation

The femurs are correctly positioned in Figure 19a. In Figure 19b, they are externally rotated, as evidenced by the fact that the patellas are lying laterally. This external femoral rotation will increase the femoral neck-shaft angle.

REFERENCES

Alcantara, P. V. and Stead, A. C.; (1975): Fractures of the Distal Femur in the Dog and Cat. J. Small Animal Pract., 16: 649-59.

Bachynski, B. and Diaz, F., (1974): Leg Length equalization by Epiphyseal Stimulation. J. Bone Joint Surg., 56B: 588.

Braden, T. D. and Brinker, W. O., (1973): Effect of Certain Internal Fixation Devices on Functional Limb Usage in Dogs. JAVMA, 162: 642-46.

Brandes-Dortmund, (1929): Behandling der Coxa vara mit Resektion des Trochanter Major. Verh. Deutsche Orthop. Gesellsch, 24: 80-83.

Carlson's Veterinary Radiology, (1977): Lea and Febiger, Philadelphia, Pennsylvania.

Cassidy, R. H., (1958): Epiphyseal Injuries of the Lower Extremities. Surg. Clinics No. Am., 38: 1125-35.

Chan, K. P. and Hodgson, A. R., (1970): Physiologic Leg Lengthening. Clinical Orth. and Related Research, 68: 55.

Chapman, W. L., (1965): Appearance of Ossification Centers and Epiphyseal Closures as Determined by Radiographic Techniques. JAVMA, 147: 138-41.

Chigot, P. L. and Labbe, G., (1962): Allongements Cervicaux Apres Section du Grand Trochanter Chez l'enfant. Revue de Chirurgie Orthopédique, 48: 199-207.

Compere, E. L. et al, (1940): Deformities of the Femur Resulting from Arrestment of Growth of the Capital and Greater Trochanter Epiphyses. J. Bone Joint Surg., 22: 909-15.

Dunlap, K. et al, (1953): A New Method for Determination of Torsion of the Femur. J. Bone Joint Surg., 35-A: 289-311.

Edgren, W., (1965): Coxa Plana. Acta Orthop. Scand., Supplementum 84.

Edvardsen, P. and Syversen, S. M., (1976): Overgrowth of the Femur After Fracture of the Shaft in Childhood. J. Bone Joint Surg., 58-B: 339-42.

Ewald, F. C. and Hirohashi, K., (1973): Effect of Distal Transfer of the Greater Trochanter in Growing Animals. J. Bone Joint Surg., 55-A: 1064-67.

Fabry, G. et al, (1973): Torsion of the Femur. J. Bone Joint Surg., 55-A: 1726-38.

Ford, L. T. and Canales, G. M., (1960): A Study of Experimental Trauma and Attempts to Stimulate Growth of the Lower Femoral Epiphysis in Rabbits - III. J. Bone Joint Surg., 42-A: 439-46.

Frost, H. M. et al, (1960): Measurement of Bone Formation in a 57-year-old Man by Means of Tetracyclines. Henry Ford Hosp. Med. Bulletin, 8: 239-54.

Gustafsson, P. et al, (1972): Skeletal Development and Sexual Maturation in German Shepherds, Greyhounds and Their Crossbreed Offspring. Acta Radiologica, Supplementum 319: 187-90.

Hall-Craggs, E. C. B. and Lawrence, C. A., (1969): The Effect of Epiphyseal Stapling on Growth in Length of the Rabbit's Tibia and Femur. J. Bone Joint Surg., 51B: 359-65.

Hansson, L. I. et al, (1976): Effect of Fracture on Longitudinal Bone Growth in Rats. Acta Orthop. Scand., 47: 600-606.

Hare, W. C. D., (1960): Canine Pelvic Limb, Part II. JAVMA, 136: 603-11.

Harris, W. H. et al, (1962): The In Vivo Distribution of Tetracyclines in Canine Bone. J. Bone Joint Surg., 44-A: 1308-20.

Harris, W. R., (1968): The Effect of Rickets - And Procedures Known To Stimulate Growth - On the Blood Supply to the Epiphyseal Plate. J. Bone Joint Surg., 50B: 435.

Hattori, A.. (1976): Effect of Epiphysiodesis of the Greater Trochanter on the Growth of the Femur of Dog. J. Jap. Orthop. Ass., 50: 185-89.

Hoyt, W. A. et al, (1966): The Proximal Femoral Epiphyses: Experimental and Correlated Clinical Observation of Their Potential. J. Bone Joint Surgery., 48-A: 1026.

Jani, L., (1969): Die Entwicklung des Schenkelhalses mach der Trochanterversetzung. Arch. Orthop. Unfall-Chir., 66: 127-32.

Jenkins, D. H. R. et al, (1975): Stimulation of Bone Growth by Periosteal Stripping. J. Bone Joint Surg., 57-B: 482-84.

Karaharju, E. O., (1967): Deformation of Vertebrae in Experimental Scoliosis. Acta. Orthop. Scand., Supplementum 105.

Karaharju, E. O. et al, (1976): Remodelling by Asymmetrical Epiphyseal Growth. J. Bone Joint Surg., 58-B: 122-26.

Langenskiold, A. and Salenius, P., (1967): Epiphyseodesis of the Greater Trochanter. Acta Orthop. Scand., 38: 199-219.

Laurent, L. E., (1959): Growth Disturbances of the Proximal End of the Femur in the Light of Animal Experiments. Acta Orthop. Scand., 28: 255-61.

Mau, H., (1955): Die Trochanterresektion als Physiologische Behandlung der Coxa Vara. Zeitschr. f. Orthop., 85: 48-62.

Milch, R. A., et al, (1957): Bone Localization of the Tetracyclines. J. Nat'l Cancer Institute, 19: 87-93.

Milch, R. A., et al, (1958): Fluorescence of Tetracycline Antibiotics in Bone. J. Bone Joint Surg., 40-A: 897-910.

Miller, M. E., (1964): Anatomy of the Dog. W. B. Saunders, Co., Philadelphia, Pennsylvania.

Morgan, V. D. and Somerville, E. W., (1960): Normal and Abnormal Growth of the Upper End of the Femur. J. Bone Joint Surg., 42-B: 264-72.

Nunamaker, D. M. et al, (1973): Femoral Neck Anteversion in the Dog: Its Radiographic Measurement. J. Am. Vet. Rad. Soc., Vol. 14, No. 1: 45-48.

Prieur, Dieter, (1978): Personal communication.

Riser, W. H. and Shirer, J. F., (1966): Hip Dysplasia: Coxafemoral Abnormalities in Neonatal German Shepherd Dogs. J. Sm. Animal Pract., 7: 7-12.

Riser, W. H., (1973): Growth and Development of the Normal Canine Pelvis, Hip Joints and Femurs from Birth to Maturity. J. Am. Vet. Rad. Soc., Vol. 14, No. 2: 24-34.

Salenius, P. and Videman, T., (1970): Growth Disturbances of the Proximal End of the Femur. Acta. Orthop. Scand., 41: 199-212.

Savastano, A. A. and Bliss, T. F., (1975): Contribution of the Epiphyses of the Greater Trochanter to the Growth of the Femur. Int. Surg., 60: 280-81.

Shively, M. J., (1975): Selected Morphological Parameters of the Developing Canine Coxofemoral Joint. Ph.D. Thesis, Purdue Univ.

Skinner, H. C. W. and Nalbandian, J., (1975): Tetracyclines and Mineralized Tissues: Review and Perspectives. Yale J. of Biol. and Med., 48: 377-97.

Smith, R. N. and Allcock, J., (1960): Epiphyseal Fusion in the Greyhound. Vet. Record, 72: 75-79.

Sumner-Smith, G., (1966): Observations on Epiphyseal Fusion of the Canine Appendicular Skeleton. J. Small Animal Pract., 7: 303-11.

Weissman, S. L. et al, (1974): Growth of the Upper End of the Femur Acta. Orthop. Scand., 45: 225-34.

Whittington, K. et al, (1961): Report of Panel on Canine Hip Dysplasia. JAVMA, 139: 791-98.

Yabsley, R. H. and Harris, W. R., (1965): The Effect of Shaft Fractures and Periosteal Stripping on the Vascular Supply to Epiphyseal Plates. J. Bone Joint Surg., 47-A: 551-66.

OSTEOTOMY OF THE GREATER TROCHANTER, TENSION BAND FIXATION, AND FEMORAL CONFORMATION

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AN ABSTRACT OF A MASTER'S THESIS

submitted in partial fulfillment of the

requirements for the degree

MASTER OF SCIENCE

Department of Surgery and Medicine

KANSAS STATE UNIVERSITY
Manhattan, Kansas

1978

Osteotomy of the greater trochanter with tension band fixation was performed on Beagle dogs at the ages of 14, 20, and 26 weeks. The procedure markedly retarded growth from the physis of the greater trochanter as determined by the tetracycline label. This retardation of greater trochanteric epiphyseal growth resulted in a decrease in the trochanteric-condylar distance and an increase in the articulotrochanteric distance. There was no shortening of femoral leg length. In fact, mild increases in length of the femurs and tibias on the experimental side occurred. This is felt to be due to the phenomenon of stimulation of growth.

Femoral neck-shaft and anteversion angles were also measured. The experimental procedure resulted in minimal to no changes in these angles. There was no evidence of coxarthropathy histologically, radiographically, or clinically in these dogs. All dogs were clinically normal at the termination of the study. It was concluded that osteotomy of the greater trochanter with tension band fixation, performed in the growing Beagle dog, could be safely performed without any adverse effects.