1. Running head:

Transarticular immobilization of the canine tibiotarsal joint

2. Title:

Biomechanical Evaluation of Six Transarticular Tibiotarsal Immobilization Methods in Canine Cadaveric Limbs

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Abstract:

Objective: To determine the effects of six types of transarticular immobilization techniques on tibiotarsal joint angles during stimulated weight-bearing.

Study Design: Canine *ex vivo* biomechanical study.

Sample population: Canine cadaveric pelvic limbs (n=15).

Methods: A validation study was conducted to determine tibiotarsal flexion before and after transection of the superficial digital flexor tendon in five canine cadaveric limbs without tibiotarsal joint immobilization. Six transarticular tibiotarsal immobilization techniques were tested sequentially in 10 canine cadaveric pelvic limbs. The tibiotarsal joint angles were measured from lateral projection radiographs before and during axial loading of 200N. Mixed linear models were applied to determine the effects of the immobilization techniques on change in tibiotarsal joint angle under loading.

Results: There was no change of tibiotarsal joint angle between extended digits and flexed digits under both unloaded and loaded conditions. Change in tibiotarsal joint angles did not differ between any of the immobilization techniques tested here (mean change 1.36 degrees, range 0-5 degrees). The main contributor to variance in angle explained by the final model was associated with the random effect for limb.

Conclusion: Changes in tibiotarsal joint angles during single static loading in canine cadaveric limbs for the six immobilization techniques were minimal.

Clinical significance: The six techniques appear equally effective at limiting tibiotarsal joint flexion during single axial loading of 200N. Cyclic mechanical testing of these techniques is recommended to support our findings and validate their clinical application.

Keywords:

Gastrocnemius Tendon, Common Calcaneal Tendon, Transarticular Immobilization, Canine

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Introduction:

Common calcaneal tendon (CCT) injuries occur in dogs as a result of acute, direct, sharp trauma or chronic degenerative injuries.^{1,2} CCT injuries can cause swelling at the affected area and significant functional impairment to the limb, such as hyperflexion of the tibiotarsal joint and a plantigrade stance. The injury can lead to different degrees of lameness due to pain and tibiotarsal joint instability.^{2,3} CCT injuries are classified into types 1, 2a-c or 3 based on chronicity, etiologies, and location of tendon pathology.⁴ The indication for surgical intervention depends on the type of injury, nature of injury (acute or chronic onset), closed or open (clean, contaminated, or dirty) and location of injury (muscular or tendinous part).¹

Surgical treatment by tenorrhaphy and temporary post-operative tibiotarsal joint immobilization has been recommended when all three tendon components are ruptured or increased flexion of the tibiotarsal joint is present during weight bearing.⁵⁻⁸ Some case reports have described successful outcomes in dogs with partial ruptures treated without tenorrhaphy.^{9,10}

Tendon healing is slow relative to many other tissues due to the relatively poor vascular supply of tendons.¹¹ Tendons never regain 100% of their pre-injury tensile strength after repair.¹² Temporary immobilization of the tibiotarsal joint in hyperextension is recommended for 3-6 weeks after tendon repair to decrease tendon strain and prevent gap formation during tendon healing.^{2,5,6} Gap formation can adversely affect the tensile strength and duration of tendon healing.¹³ The tendon gap heals with fibrous tissue, which is mechanically inferior to the original tendon structure. Transarticular immobilization, however, can cause significant morbidity of the joint, including articular cartilage atrophy and soft tissue complications.^{14,15}

Early controlled mobilization has been advocated in human patients to reduce articular cartilage atrophy and to provide appropriately controlled limited strain to the anastomosis site.¹⁶

A variety of postoperative tibiotarsal immobilization methods after CCT repair have been described in the veterinary literature including cranial cast application,⁶ calcaneotibial positional screw,³ calcaneotibial screw and cast,^{7,9} transarticular linear external skeletal fixation (ESF),^{5,8,17} transarticular circular ESF,¹⁸ and single circular ring.¹⁹ Nielsen and Pluhar observed better functional recovery in dogs treated with transarticular ESF compared to cast immobilization, although the difference was not statistically significant.⁸ Most complications after tenorrhaphy are considered to be related to the immobilization technique rather than to the method of tendon repair.⁸

The authors are not aware of any studies in the veterinary literature that directly compare the ability of transarticular immobilization techniques to limit tibiotarsal movement. Canine cadaveric limbs were used in this study as a model of the normal weight bearing pelvic limb to evaluate the ability of six transarticular immobilization techniques to tibiotarsal range of motion during axial loading. We hypothesized that the type II ESF would result in the least change in tibiotarsal joint angle under loading.

Materials and methods:

This study was approved by the Office for Research Ethics and Integrity at Melbourne Veterinary School, The University of Melbourne (Animal Ethics ID # 14003). Fifteen pelvic limbs were collected from clinically healthy greyhound dogs, weighing between 25kg and 35kg, that were euthanized for reasons unrelated to this project. Limbs were stored at -20°C. Skin was preserved as much as possible to prevent desiccation during the experiment. Limbs were thawed in air to room temperature 24 hours before the experiment. Lateral projection radiographs of the limbs were used to screen for pre-existing orthopaedic disease prior to the experiment.

Specimen preparation:

The stifle was rigidly immobilized at 135 degrees, the normal standing angle of the canine stifle,²⁰ using a transarticular type II ESF (small-medium SK linear ESF system, IMEX Veterinary Inc., TX). The stifle transarticular type II ESF was constructed with three centrally threaded positive profile 3.2mm shaft diameter transfixation pins (centerface pin IMEX Veterinary Inc., TX) placed parallel to each other in the proximal, middle and distal part of the femur, and three pins placed in the proximal half of the tibia. These transfixation pins were connected to 6mm-diameter titanium and/or carbon fiber connecting rods using small-medium SK clamps (IMEX Veterinary Inc., TX). Another connecting rod was attached using double clamps between the existing two rods to form a triangle-shaped reinforcement of the stifle transarticular ESF construct at both medial and lateral sides of the stifle (**Figure 1**).

Validation phase:

Validation studies were performed in five limbs to study the effect of the intact CCT on the tibiotarsal joint without immobilization. The stifle was fixed at 135 degrees as described

above and was placed vertically in a custom jig without any tibiotarsal joint immobilization with normal standing stance of the digits. Lateral radiographs of the limb were taken with a horizontal beam (**Figure 2A**) before and during axial loading of 200N, and the tibiotarsal joint angles during both conditions were recorded.

A second validation study was performed to evaluate the influence of the superficial digital flexor tendon (SDFT) on tibiotarsal joint flexion (**Figure 2B**). Digit flexion produced laxity in the SDFT minimizing the contribution of the SDFT to tibiotarsal joint stability. A padded cast (7.5cm Soffban Natural, 7.5cm Handyband Conforming Bandage, and 7.5cm Delta-Lite Plus, BSN medical Inc., NC) was applied to the metatarsals and distally to the digits with the digits placed in natural flexion. Lateral view radiographs with horizontal beam were taken again before and during axial loading of 200N, and the tibiotarsal joint angles were recorded.

The tibiotarsal joint angles before and during loading were compared between the two validation studies.

Experimental phase:

Tibiotarsal joint immobilization techniques:

The tibiotarsal joint of each limb was immobilized sequentially by each of the six different types of immobilization methods in the following order: (1) single circular ring, (2) calcaneotibial screw, (3) calcaneotibial screw plus cranial cast, (4) cranial cast, (5) type IA linear ESF and (6) type II linear ESF. The sequence of the testing was selected to minimize the potential for mechanical damage to the limb and to optimise the experimental workflow. For single circular ring fixation, an 84mm inner diameter full ring (IMEX Veterinary Inc., TX) was applied to the tibiotarsal joint using a 1.6mm stopper fixation wire (IMEX Veterinary Inc., TX) through the caudal surface of the proximal calcaneus to the distal tibia in

the caudodistal-cranioproximal direction. Two divergent 1.6mm smooth fixation wires (IMEX Veterinary Inc., TX) were placed in the distal tibia to stabilize the ring (**Figure 3**) as described by Norton *et al.*¹⁹ Then, the single ring construct was removed and a hole was drilled using a 2.5mm drill bit (Depuy Synthes Companies, PA) from the caudal aspect of the proximal calcaneus into the distal tibia with the tibiotarsal joint in hyperextension. For calcaneotibial positional screw immobilization, a positional 3.5mm self-tapping cortical screw (DePuy Synthes Companies, PA) was inserted through the drill hole from the caudal surface of the proximal calcaneus to the distal tibia. The calcaneotibial screw plus cranial cast construct was created by adding a cranial cast to the screw construct (**Figure 4**). The cranial cast was prepared by bivalving a full cast made using fiberglass casting material (7.5cm Delta-Lite Plus, BSN medical Inc., NC). The cranial cast was applied to the level of the digits, so that the digits were naturally flexed and completely covered by the cast, following orthopaedic padding dressings described by Guerin *et al.*⁶ To evaluate cranial cast construct without screw, the calcaneotibial screw was removed via a 10mm longitudinal incision at the caudal aspect of the bandage. The Type IA and Type II ESF tibiotarsal fixations were constructed using two centrally threaded positive profile 3.2mm shaft diameter transfixation pins (IMEX Veterinary Inc., TX) engaged in the distal tibia and two centrally threaded positive profile 2.0mm shaft diameter transfixation pins (IMEX Veterinary Inc., TX) inserted in the proximal and mid-metatarsal bones. The proximal pin was inserted to engage all metatarsal bones and the distal pin engaged the third and fourth metatarsal bones.¹⁷ The fixation pins were connected with single clamps to 6mm diameter carbon fiber connecting rods (IMEX Veterinary Inc., TX) (**Figure 5**).

Evaluation of constructs before and during axial loading:

Each immobilized limb was placed in a custom jig with the phalanges extended in a normal standing stance on the experiment floor or, with the digits in flexion for the immobilization

methods incorporating a cranial cast. A lateral projection radiograph of the limb, including metatarsals, tibia, and distal femur was taken before loading.

An axial load of 200N was applied to the top of the limb by means of a 20Kg weight, and a second lateral projection radiograph was taken immediately after the load application. The load of 200N was selected for this study based on the following assumptions and calculations. The peak vertical force to the pelvic limb of dogs is reported to be between 35% and 75% of the body weight during walking and trotting, respectively.^{21,22} We assumed the mean body weight of the dogs was 30kg. Based on **Equation 1**, the calculation resulted in an approximate load of 200N.

$$\text{Load required} = \text{MBW} * \text{PVF} * 9.8 \text{ m/s}^2$$

Equation 1: Determination of load applied. MBW: mean body weight, PVF: peak vertical force

The process was repeated with each limb (n=10) for all six of the immobilization methods with radiographs taken before and during loading so that a total of 12 tibiotarsal joint angles were recorded for each limb.

Measurement of the tibiotarsal joint angle:

The tibiotarsal joint angles were measured from the radiographs with a commercially available DICOM viewing software (SYNAPSE PACS v3.1 Fuji Film Holdings Corporation, Tokyo Japan). The tibiotarsal joint angle was measured between the mechanical axis of the tibia and a line connecting the center of the talus and the center point of the distal diaphysis

of the third metatarsal bone. The mechanical axis of the tibia was drawn as a line from the midpoint between the medial and lateral intercondylar tubercles to the center of the talus²³ (Figure 6). All measurements were made in triplicates (at least 24 hours apart) by a single observer, and combined in the arithmetic mean. Intra-observer variability was assessed with the relative standard deviation of the triplicate measures.

Statistical analysis:

Data analysis was conducted in MATLAB 2015 (The Mathworks, Inc., MA). The final data set comprised 120 angle observations (10 observations for each of 6 treatments, before and during loading).

The statistical analysis was conducted via a general linear model, of the form;

$$\text{Equation 2: } Y = \beta X + c + \eta_i + \varepsilon$$

Where 'Y' is the response (dependent) variable, X is a vector of predictor (independent) variables, β is a vector of coefficients, c is the y-axis intercept, η_i is the random effect for the i th subject, and ε is the residual error, which is assumed to be normally distributed with mean zero; $N(0, \sigma^2_\varepsilon)$. The parameters to be estimated from the data are therefore the coefficient values β (effect size), the random effects η (the between-subject variability), the y-axis intercept c, and the standard deviation of the residual error σ^2_ε .

Candidate predictor variables in the models were the presence of loading (LOADING), and the two-way interaction of loading and immobilization methods (LOADING*TREATMENT). Assuming that treatments had no effect on the measured angle in the absence of loading, treatment alone was not considered as a predictor in the models.

Limb was included as a random effect. The parameters were estimated by maximum likelihood estimation, using the 'fitlme' function in MATLAB.

Candidate predictors were sequentially added and removed to determine the optimum model.

The relative quality of the candidate models was assessed using the log-likelihood and the Akaike's information criterion, histograms and q-q plots of the residuals, and 95% confidence intervals of the parameter estimates.

Results:

All limbs used in the study were normal on radiographic evaluation.

Validation phase:

The mean intra-observer variation for each measurement in the tibiotarsal joint angle was 0.8% (range 0-2.5%). In the first validation study, the mean tibiotarsal joint was 127 degrees (range 114-133 degrees) before loading and 101 degrees (range 94-111 degrees) during loading, respectively. In the second validation study, the mean preload tibiotarsal joint angle with digits flexed in the cast was 127 degrees (range 117-135 degrees), and the angle during loading was 102 degrees (range 94-113 degrees). The mean change in tibiotarsal joint angle was 26 degrees with digit extension (normal stance) and 25 degrees with digit flexion (cast).

Evaluation of six immobilization techniques:

The mean relative standard deviation across measurements at preloading was 0.8% (range 0-2.6%), and at loading was 0.9% (range 0-2.9%). All immobilization techniques evaluated in this study effectively limited movement of the tibiotarsal joint during static loading of 200N. There was no significant difference in the change in tibiotarsal joint angles between all immobilization techniques. The final model did not provide evidence that the ESF type II was superior to any other immobilization method. Therefore, our hypothesis was rejected. The results are summarized in **Table 1**. The single ring construct, the baseline effect in the model, had the greatest change in tibiotarsal joint angle during loading. The calcaneotibial screw construct had a positive effect ($\beta = 3.8$) and was the only significantly different technique (95% CI: 0.153-7.45) compared to the single ring construct. However, the magnitude of the difference was small (**Figure 7**). Distal displacement of the stifle during axial loading was

observed in the single ring, calcaneal screw, and ESF immobilization techniques. No change in stifle angle was observed during loading.

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Discussion:

All of the immobilization techniques tested were similarly effective at limiting tibiotarsal joint movement during single static loading of 200N.

The tibiotarsal joint angles across immobilization methods varied minimally, and intra-observer variability was small (0.8% or 1.36 degrees). Therefore, immobilization techniques and intra-observer variability were not considered as contributing factors for the variance in the data. The magnitude of the within-limb variability (STD = 6.37 degrees) and the error variability (STD = 4.12 degrees) both exceeded the effect size of all the immobilization methods. The effect of immobilization methods very weakly explained the observed data variance in the absence of the limb-level random effect ($R^2 = 0.0147$), but the model with random effect was highly explanatory ($R^2 = 0.720$), demonstrating relatively large variability between limbs regardless of immobilization methods. This observation may be clinically important as a contributor to between-patient response to the tibiotarsal immobilization.

The single ring construct had the largest change in the tibiotarsal joint angle during loading and greatest variability between limbs. However, the magnitude of the difference was very small. The final model indicated that the effects of the immobilization methods under loading were positive compared to the single ring technique (**Table 1**). This indicates that the single ring technique was associated with the largest change in the tibiotarsal joint angle during loading. Only the effect of the screw construct was significant ($p = 0.04$). It is reasonable to assume that greater joint movement during loading may be associated with adverse effects on tendon healing and a higher chance of implant failure. The small effect sizes observed in this study suggest that the difference between immobilization methods may be of limited clinical significance. Further evaluations, such as cyclic loading, would be required to determine if

the observed difference in effect for the single ring technique and screw construct is clinically relevant.

The tibiotarsal joint angle during loading was not different between the first and second validation study (101 and 102 degrees, respectively). The validation studies demonstrated that the intact CCT would not be subject to strain with the immobilized tibiotarsal joint in hyperextension (>150 degrees). For this reason, transection of the CCT was not performed for the subsequent experiments. The second validation study showed that the SDFT did not have an effect on the change in the tibiotarsal joint angle before and during loading with either the digits flexed in the cast or with hyperextension of the metatarsophalangeal joints (normal standing stance).

The sequence of testing was selected to minimize the potential for mechanical damage to the limb and to optimise the experimental workflow. Each radiograph was assessed for fracture or failure of the construct. There was no radiographic or palpable construct failure before and during loading.

During loading, the stifle joint angle did not visually change, but the location of the stifle joint was transposed distally during axial loading in the single ring, calcaneotibial screw, and ESF immobilized limbs. This displacement was due to extension of the metatarsophalangeal joint and compression of the footpad to the floor, absorbing the applied load (**Figure 8**). This distal stifle displacement was not observed in the cast only and screw plus cast immobilization methods.

The single ring construct had the greatest variance in tibiotarsal joint angle change during loading. In the single circular ring fixation, hyperextension of the tibiotarsal joint is maintained by the small stopper on the fixation wire at the caudal aspect of the calcaneus and tensioning of the wire on the ring. The ring is secured to the distal tibia with two divergent

smooth fixation wires.¹⁹ Therefore, all the force in the tibiotarsal joint concentrates at the stopper part of the fixation wire at the caudal surface of the calcaneus. The balance of adequate tension and movement of the calcaneus can be difficult to adjust. Elongation of the stopper wire and slippage between the wires, ring and fixation bolts could contribute to less stability compared to other immobilization methods.

We hypothesized that the type II ESF immobilization technique would be the stiffest construct and therefore provide the greatest resistance to change in tibiotarsal joint angle under loading. However, the results did not provide evidence that the ESF type II was superior to the other immobilization methods. The difference between the type IA and the type II ESF was not significant. Because the diameter of the metatarsal bones are much smaller compared to the tibia, smaller diameter transfixation pins need to be used in the metatarsal bones. The load of 200N caused deformation of the 2.0mm diameter transfixation pins in the metatarsals that resulted in a changed tibiotarsal joint angle despite no change in the angle of the ESF construct. The measurement between the connecting clamps did not change from unloaded and loaded radiographs indicating that the stiffness of the connecting bars and clamps was appropriate. A slight deformity of the most distal transfixation pin was observed by direct visualization during loading, but the dorsopalmar projection radiographic measurement of the change in length between transfixation pins was less than 0.1mm (**Figure 9**). Although this may not be a significant problem in the clinical scenario, we suspect that the weakness caused by thinner pins could increase the risk of implant failure in cyclic loading due to micromotion. It is difficult to improve the construct stiffness since smaller pin insertions and limited numbers of pins dictate the stiffness of the linear ESF. Increasing the numbers of pins in the metatarsals may increase the risk of fracture due to small metatarsal bone diameter. A circular or hybrid ESF fixation using tensioned fine wires in the metatarsals

may provide more effective metatarsal bone purchase without increasing the risk of metatarsal fractures.¹⁸

There are several limitations to this study. The results of this study must be interpreted cautiously due to the use of cadaver limbs and single static loading testing and should not be used to make clinical recommendations.

The reported normal standing angle of the tibiotarsal joint in dogs is 140 degrees.²⁰ The standing angle of the tibiotarsal joint without loading in limbs used in this study without tibiotarsal joint stabilization was approximately 130 degrees. Spontaneous isometric contractions of muscles maintain normal posture in live standing animals. The difference of 10 degrees between reported normal and cadaver limbs may be explained by muscle relaxation and lack of isometric contraction in the cadaveric limbs. The contribution of active or isometric muscle contraction to the stability of the tibiotarsal joint is ignored in cadaveric studies.²⁴ The pelvic limb was disarticulated at the coxofemoral joint, and therefore some muscles including the semitendinosus and quadriceps muscle group had to be separated from their origin. This does not fully replicate the *in vivo* clinical situation, such as the contribution and effect of muscle contraction on tibiotarsal joint stability. However, this study was designed to test the ability of various immobilization techniques to limit changes in tibiotarsal joint angle in limbs under static loading conditions.

The failure to detect differences between immobilization methods may result from the sample size, but the estimated effect sizes in this study suggest an absence of clinically meaningful differences between immobilization methods other than single ring construct. The change in angles was assessed by a single observer with angle measurement performed on three occasions on different days. The study could not be blinded because implants were visible at the tibiotarsal joint and easy to recognize during assessment. The variability was minimal,

and the repeatability was excellent. The variability of the angles was minimal (0.8-0.9%), which was equivalent to or even better than the other study for comparison of goniometry and radiographic measurement.²⁵

A load of 200N was selected for the experiment, based on calculations by Moores *et al.* in which peak vertical force of 399N for a 30Kg dog at a trot was estimated.²⁶ In our study samples, the body weight varied between 25 and 35Kg, and a load of 200N would represent approximately 57 to 80% of individual body weight. 200N would be well above the peak vertical force during walking. Because the limbs were supplied individually separated from dogs, a particular limb of the body weight of the dog was unknown. To standardize the data, we used the tibial mechanical axis length as a variance, but it did not demonstrate significant correlation with the results. Ideally, cyclic fatigue testing with lower loading would represent a more clinically relevant evaluation to compare tibiotarsal joint movement and implant stability with different immobilization techniques. However, this was not financially or technically feasible for this study. Single static loading with 200N was selected as an appropriate model to evaluate and compare the immobilization methods.

In conclusion, the six different immobilization techniques evaluated in this study all provided similar immobilization of the tibiotarsal joint during single static loading of 200N.

Mechanical testing using repetitive cyclic loading is recommended. Selection of a tibiotarsal joint immobilization technique after CCT repair should be based on consideration of patient, client, and environmental factors, surgeon preference and the reported advantages and disadvantages of each immobilization technique.

Table 1. Statistical comparison of immobilization techniques.

Parameter	Estimate (degrees)	Lower CI (degrees)	Upper CI (degrees)	<i>p</i> -value
RING (baseline effect)	163.13 (0)	159 (-4.13)	167.26 (4.13)	<10 ⁻¹⁰
SCREW	3.8	0.15323	7.4468	0.041266
SCREW+CAST	2.4667	-1.1801	6.1134	0.18291
CAST	0.73333	-2.9134	4.3801	0.69109
ESF TYPE I	1.5	-2.1468	5.1468	0.41684
ESF TYPE II	2.9	-0.74677	6.5468	0.11794
1:ID	6.3742*	4.0501	10.032	
ERROR	4.1159†	3.6065	4.6974	

RING (Single ring) is the baseline effect with estimate (effect size) of zero. ERROR is the model's residual error. Lower CI and upper CI are the lower and upper bounds of the 95% confidence interval for the parameter estimates, respectively. 1:ID is the random effect for limb. The *p*-value is the probability of the null hypothesis, a coefficient value of zero for the parameter. * estimate is the standard deviation of the intercept for the random effect. † estimate is the standard deviation of the residual error.

Abbreviations:

CCT: Common calcaneal tendon

ESF: external skeletal fixation

SDFT: superficial digital flexor tendon

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Figure 1. A photograph of a limb with the stifle transarticular type II ESF before attaching to a jig for testing.
Note no immobilization was applied to the tibiotarsal joint in this case.

154x400mm (180 x 180 DPI)

AI

Figure 2A. A lateral projection radiograph of extended digits during normal standing stance.

148x220mm (96 x 96 DPI)

AU

Figure 2B. A lateral projection radiograph of flexed digits protected in a cranial cast.

155x233mm (96 x 96 DPI)

AU

Figure 3. Lateral projection radiograph of a single ring construct.

138x234mm (96 x 96 DPI)

AU

Figure 4. A lateral projection radiograph of a tibiotarsal joint immobilization technique using a calcaneotibial screw and cranial cast combination.

93x131mm (96 x 96 DPI)

Auth

Figure 5. A dorsopalmer projection radiograph of the tibiotarsal joint immobilized using a type II ESF.

89x167mm (96 x 96 DPI)

AU

Figure 6. An example of radiographic tibiotarsal joint angle determination. Note a type II ESF was used in this radiograph.

98x254mm (96 x 96 DPI)

AI

Figure 7: box-plot of the angle data; the data points are the mean of triplicate observations. For each treatment, the left box is the pre-loading angle ($n = 10$), and the right box is the post-loading angle ($n = 10$). An apparent outlier is marked as an open circle. The mean change in angle for the ring, screw, screw and cast, ESF type I, and ESF type II were 3.67, 1.47, 1.17, 1.9, and 1.23 degrees, respectively.

219x132mm (96 x 96 DPI)

Author N

Figure 8A. A photograph of a distal limb without loading.

819x1456mm (72 x 72 DPI)

Au

Figure 8B. A photograph of a distal limb during loading. Note the angle of the metatarsophalangeal joint is narrower and the paw is more compressed into the floor, compared to the limb shown in Figure 8A.

819x1456mm (72 x 72 DPI)

AI

Figure 9A. A dorsopalmar view radiograph of a limb using type II ESF before loading.

102x257mm (96 x 96 DPI)

AU

Figure 9B. A dorsopalmar radiograph of the limb during loading shown in Figure 9A. Note no radiographic changes were detected.

97x251mm (96 x 96 DPI)

AI

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