Value of Quality Foot Radiographs and Their Impact on Practical Farriery

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1. Introduction

Radiographic evaluation of the horse's foot for the purpose of consultation with the farrier is becoming more popular but is still an underutilized use of radiographic imaging. In the absence of lameness, detailed radiographic evaluation of the horse's foot is very useful in preplanning and management of trimming and shoeing of a horse's foot and in the prevention of lameness. A horse's exhibiting poor foot conformation, imbalance, or abnormal patterns of growth can be clues to impending foot disease and lameness. Radiographic evaluation of a horse's foot gives tremendous insight into the relationship between the structures within the foot and between the foot and distal limb.

Digital photography has also been shown to be useful and accurate in the assessment of the horse's foot.[1] However, the relationship of the distal phalanx with the hoof capsule cannot be appreciated with photography alone.

The quality of information obtained from a radiographic study depends solely on the quality of the radiographs ("garbage in, garbage out"). Producing quality radiographs is dependent on the use of quality equipment, developing a proficiency at operating that equipment, and maintaining consistency when performing radiographic studies. A systematic approach should be taken when planning a radiographic study of the foot; the "point-and-shoot" approach is not always the best approach. Taking multiple standard views, although not always necessary, is important to avoid missing a diagnosis. Additional projections may be required to further investigate initial findings or confirm a diagnosis. There are a number of preplanning questions that must be asked before performing foot radiographs: (1) What is the purpose of the study: investigation of lameness or consultation with the farrier? (2) What do I expect to gain from the study: source of lameness or information useful in managing the foot? (3) What information do I need to obtain from the study: relationship of the hoof capsule and the distal phalanx? The answers to these questions will guide in planning the study with regard to the appropriate views to be taken, the appropriate technique, and the appropriate positioning of the foot and centering of the x-ray beam.

Taking the time to examine the foot and prepare it properly will avoid the need, risk, and expense of repeating images and will improve the quality and therefore the interpretation of your radiographic images. Before performing a full series of foot radiographs, it is common practice to recommend removing the shoes. However, when acquiring ra-

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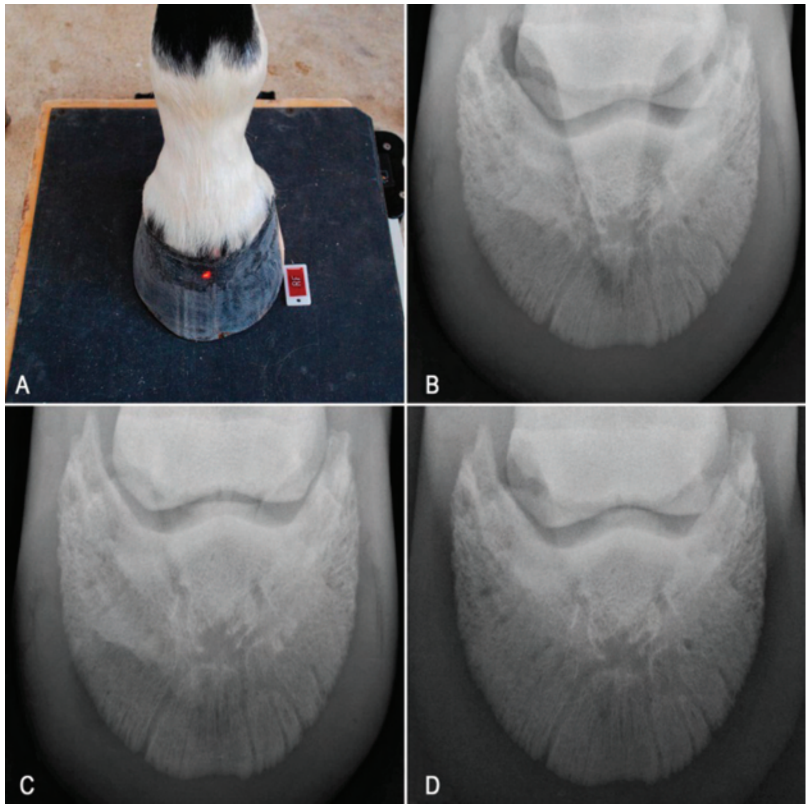

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Fig. 1. A, Dorsoproximal–45-degree–palmarodistal oblique view (DP-45-PDO). B, Radiographic image of a foot that has not been packed. Note the artifact associated with the sulci of the foot. C, Traditional packing with putty material (Play-Doh®) eliminates the majority of artifact; however, packing artifact can still be present. D, Foot is placed in a water bath, resulting in displacement of all gas and packing artifact.

diographs for the purpose of trimming and shoeing issues, leaving the shoes in place can be beneficial. Direct visualization of the weight-bearing surface and the position of the shoe in relation to the hoof capsule and distal phalanx can help in the planning process. This simplifies evaluation of break-over, sole depth, and balance of the foot. If a source of lameness has been localized to the foot, removal of the shoes may be necessary to obtain the additional views necessary to fully evaluate the foot. Proper shoe removal technique is a skill that the veterinarian must be comfortable with.

Cleaning the foot of all particulate matter as well as removing any fragmented wall and overgrown sole and frog will reduce the potential for gas artifacts. Any flakiness of or accumulations of debris on the outer wall can be removed with either a rasp or a sanding block. Radiographs taken to guide trimming and shoeing do not require packing the foot; if additional films are required, packing the foot is recommended. Packing the sulci with appropriate putty material reduces the likelihood of radiographic artifact due to gas in the sulci. Liberal use of the packing material should be used to fill the depths of the sulci; however, overpacking will cause packing artifact along the margins of the packing. Traditional packing in horses that have deep center sulci or overgrown bars can be difficult in eliminating all gas artifacts. Placing the foot in a water bath is an effective method of displacing trapped gas deep within the sulci or wall (Fig. 1). The water depth should be at a level just proximal to the heel bulbs. Placing the cassette or digital sensor in a plastic protective cover (trash bag) prior to placement of the foot will reduce the potential for water damage. A 50% increase in technique is recommended when using digital radiography; when using film-screen radiography, a significant increase in milliamperes will also be necessary and will depend on whether a grid is used or not. F1

Digital radiography (DR) has become commonplace in equine practice and gives rise to a number of advantages over film/screen radiography when evaluating the foot. The advantages of DR over film/screen radiography include digital postprocessing, improved image quality, and improved archiving. Digital radiographs have tremendous exposure latitude compared with plain film radiography. With a single image from a single exposure, the clinician has the ability to adjust brightness and contrast, allowing for visualization of multiple tissue densities. Once captured, processed, and saved, the im-

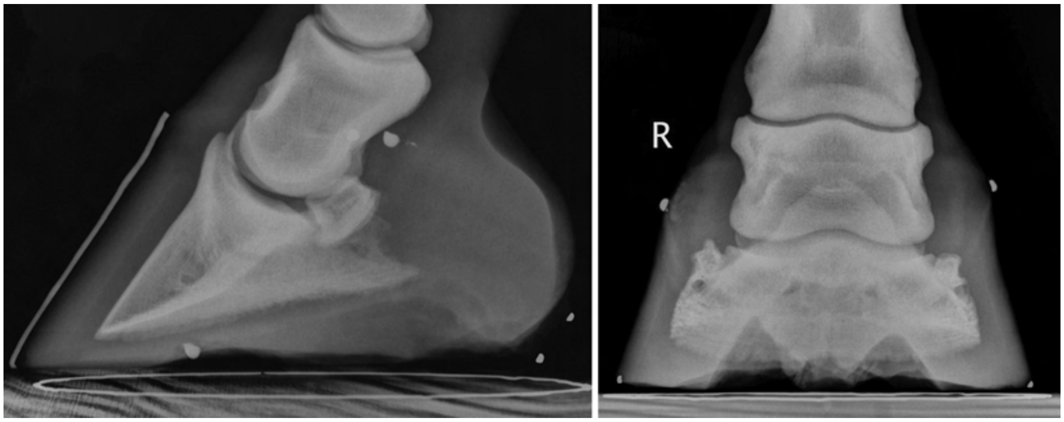

Fig. 2. Radiopaque markers (barium paste) placed at the appropriate locations aids in accurate identification of coronary band, dorsal hoof wall contour, and distal hoof wall.

ages can be archived electronically, resulting in easier storage and follow-up evaluation, comparison, and manipulation.[2] Despite the advantages of digital technology, like any imaging technology, it has its limitations. Furthermore, high-quality conventional radiographs are satisfactorily diagnostic for many purposes. However, because there is less exposure latitude with conventional film/screen radiography, it is important to establish standard technique charts, taking into consideration the view to be taken, what information is to be obtained from the particular view, and the size of the foot.[3] Additionally, because the same degree of detail and contrast is not as obvious on conventional film, establishing multiple techniques (soft tissue and bone) for each view is necessary to visualize and evaluate soft and osseous tissues.

Accurate identification of key points on the foot, allowing for evaluation of dorsal hoof wall and heel angles, sole depth, and medial and lateral wall height, is not always possible, depending on the technique used and the conformation of the foot. Digital radiography allows improved visualization of soft tissues; however, accurate identification of the coronary band and heels can still be difficult. Edge burn-through (saturation artifact) at the periphery of soft tissues is a common artifact with digital radiography.[4] This in particular can result in inaccurate assessment of hoof wall thickness. Rigid metallic markers are often used to identify the true border of the dorsal wall; however, accurate identification of the wall length and contour is impossible unless the marker equals the length of the toe and can be contoured to the true shape of the wall. Running a 2-mm bead of barium paste (can be easily stored in and applied from a 60-mL syringe) directly over the dorsal median hoof wall, extending from the coronary band to the tip of the toe, allows for accurate identification of the toe length, wall contour and border, and an appreciation of hoof wall distortion. Due to the increased beam attenuation of the barium paste, a halo artifact (Überschwinger) may be seen surrounding the barium, but this will not preclude accurate border identification.[5] Spot marking at (1) widest point of the proximal (coronary) and distal wall in the quarters, (2) proximal and distal wall in the heels, and (3) 2.0 to 2.5 cm dorsal to the apex of the frog will aid in the evaluation of quarter angles, quarter wall height, heel angle and height, sole depth, and toe-to-heel ratio (Fig. 2). Marking the dorsal hoof wall becomes very useful in horses with upright feet, the best example being the club-footed horse. As the foot grows out in these horses, there is a propensity for the dorsal wall to distort and flare, producing multiple angles to the dorsal wall. Radiographic evaluation of the dorsal wall with a conforming marker allows accurate assessment of the distortion of the wall and true angle of the foot.

It is crucial that the positioning of the patient, foot, and x-ray beam be flawless when evaluating the foot for the purposes of podiatry. True assessment and measurement of the dorsal hoof wall and heel angle, sole depth, joint congruity, medial to lateral balance, and toe-to-heel ratio is dependent on proper positioning. Slight abduction or adduction of the limb or shifting of weight can cause joint incongruity on the horizontal beam dorsal-palmar view. The horse should be placed on a firm, level footing, with the limbs squarely beneath the horse. Limb conformation should also be evaluated prior to taking radiographs. When placing the foot on the positioning blocks, it is important to allow the foot to position itself as dictated by the limbs conformation (toed-in, toed-out). To reduce magnification, the foot should be placed on the positioning block in such a way that the foot is as close as possible to the cassette or sensor plate.

Commercial positioning blocks and stands are available that aid in standardizing focal distance, foot placement, and alignment of the x-ray beam. Wood blocks of the appropriate size and height work well; commercial blocks are available, but they are also simple to fabricate to the practitioner's desired

Fig. 3. Rotating positioning block. A, Note copper metal insert used for identification of weight-bearing surface. B, Rotation of the block allows for accurate placement of the limb due to variations in conformation. C, Lateromedial (L-M) radiograph demonstrating identification of weight-bearing surface.

specifications. A variation of the standard block and one that the author uses is one that has been adapted from one originally described by Caudron.[4] It is composed of two independent circular blocks connected in such a way that allows rotation of the two halves. A cooper wire is embedded in the surface of the block, forming a 15-cm circle; this acts as a radiographic marker for the weight-bearing surface. Regardless of the beam angle with the surface of the block, a line drawn from the two apices of the ellipse will be parallel to the weight-bearing surface (Fig. 3). The rotational component of the block works well for horses that exhibit abnormal conformation such as a toed-in or toed-out conformation. When the foot is placed on the block, the rotation of the block allows the foot to position itself naturally, influenced by the horse's conformation, thereby alleviating the possibility of positional artifacts such as joint space asymmetry. When designing or purchasing a positioning block, it is important to take into consideration the height of the block and the center of the x-ray beam of your particular x-ray machine. Incorporating some type of metallic marker within the surface of the block is useful in aiding accurate identification of the ground surface, thus improving the accuracy of foot measurements.

The lateromedial and horizontal dorsopalmar projections are the most useful views to perform when evaluating the foot for conformation and balance. Consideration of the area of interest as well as having solid anatomical knowledge of the horse's foot is important when performing these radiographic views.

The lateromedial (L-M) projection is performed with the horse standing squarely on a flat, level surface with each foot on a positioning block of equal height. It is important that the cannon bone be perpendicular to the floor in both the medial-to-lateral and dorsal-to-palmar planes. Keeping the horse's head and neck straight is also important to reduce the influence of uneven loading of any one limb. Focal-film distance usually ranges between 24 and 28 inches; it is important to be consistent and that once the technique is established, the focal-film distance remains constant. Once the horse is positioned squarely, proper beam alignment and posi-

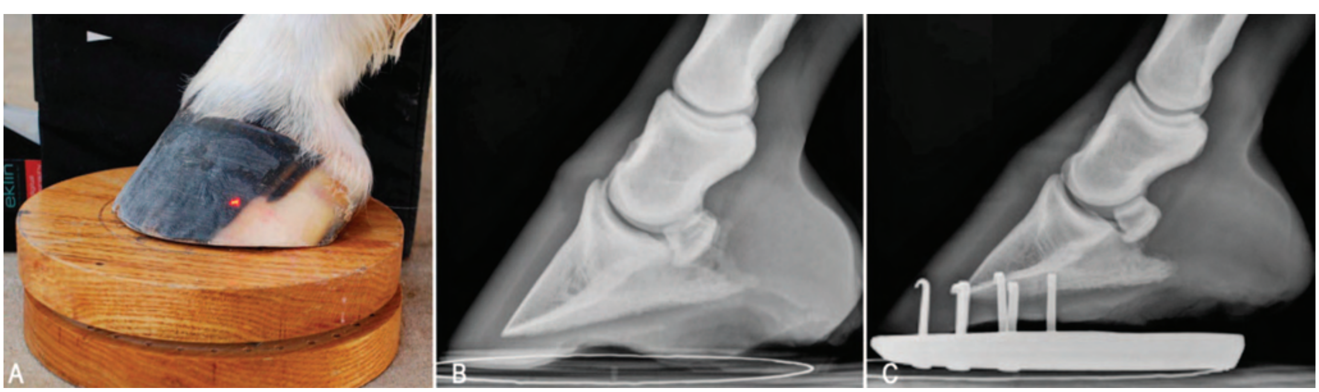

Fig. 4. Lateromedial view (L-M). A and B, Beam orientation is perpendicular to the dorsopalmar plane of the foot. Parallel alignment with the heel bulbs is useful in proper alignment of the x-ray machine. The beam is centered at a point halfway between the toe and the heels and 1.5 to 2 cm proximal to the weight-bearing surface. C, Shoe placement and point of break-over can be evaluated with L-M projection taken with the shoe on.

Fig. 5. Proper alignment of the x-ray beam demonstrating uneven alignment of the solar margins of the distal phalanx in a horse with poor conformation. Evaluation of the horizontal dorsopalmar/plantar (HD-P) projection confirms the presence of poor hoof conformation.

tioning is the next step in obtaining a workable image. If the area of interest is the distal phalanx and the purpose of the study is evaluating foot balance and symmetry, the center of the beam should be aimed 1.5 to 2.0 cm proximal to the weight-bearing surface and midway between the toe and the heel; the beam angle should be parallel with the heel bulbs and the ground surface.[3,6] This beam alignment will produce a film that shows the medial and lateral solar margins and palmar processes of the distal phalanx superimposed on one another (in the
F4 “normal” foot) (Fig. 4). Any obliquity in the image can be corrected by raising or lowering the central beam to adjust for variation in sole depth, or adjusting the beam angle in relation to the heel bulbs. Any adjustment in the height of the central beam should be done with spacers, thereby eliminating the possibility of hand-held errors.

The lateromedial projection is useful in evaluating the relationship of the distal phalanx with the hoof capsule and distal limb (hoof-pastern axis), location of break-over, shoe placement, and quantitative parameters. Malalignment of the foot and pastern is seen in 72.8% of horses with forelimb lameness.[7] Malalignment of the medial and lateral solar margins is common with imbalance or poor conformation, though many normal horses have some asymmetry of the distal surface of the distal phalanx. Additionally, resorption and remodeling of the distal phalanx can alter the dorsal contour, solar margins, and length of the distal phalanx as well as alter the shape and angle of the solar margin, com-
F5 plicating interpretation (Fig. 5). These changes are seen with laminitis, pedal osteitis, and other sources of chronic inflammation (heel bulb avulsions, osteomyelitis, etc). Investigation with the orthogonal view (HD-P) will help to clarify any solar margin asymmetry seen in the L-M view.

If the navicular bone is the area of interest, the x-ray beam should be centered at a point halfway between the dorsal and palmar coronary band and approximately 1 cm distal to the coronary band. For the distal interphalangeal joint, the x-ray beam is centered on the coronary band at the junction of the dorsal and middle one-third of the coronary band.

Additional radiographic abnormalities commonly identified in the L-M projection include osteophyte or enthesophyte formation associated with the distal interphalangeal (DIP) joint and navicular bone and small focal irregularities at the insertions of the deep digital flexor tendon and the distal sesamoidean impar ligament.[6]

The horizontal dorsopalmar/plantar (HD-P) view is also performed with the horse standing squarely on two positioning blocks with the foot placed toward the back of the block. The cassette is placed on the palmar/plantar surface perpendicular to the ground surface. The beam orientation is parallel to the dorsal-palmar/plantar long axis of the foot on the median plane of the foot. For consistency, the x-ray beam is also centered 1.5 to 2 cm above the weight-bearing surface of the foot. Depending on the block surface and the horse's conformation, using the dynamic rotary block may add additional accuracy to the interpretation of this image by alleviating any artifact produced by poor conformation or foot placement. Placement of a small dot of barium paste at the hairline on the medial and lateral coronet will result in accurate identification of the proximal-most extent of the medial and lateral coronet. This beam alignment will produce a film that projects of the extensor process of the distal phalanx on the median plane of the second phalanx (Fig. 6). Re- F6
gardless of whether a unilateral or bilateral study is being performed, both feet should be placed on

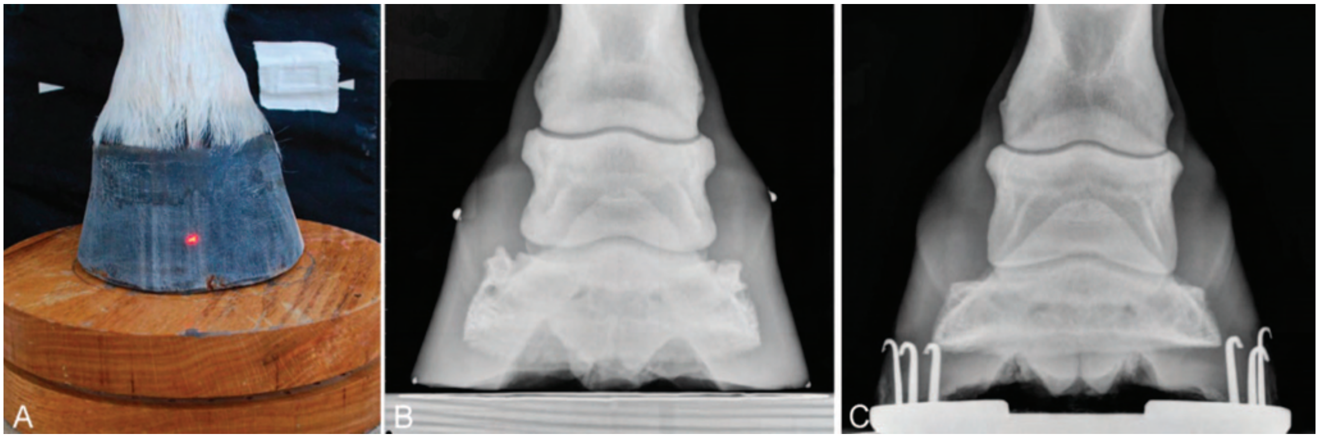

Fig. 6. Horizontal dorsopalmar view (HD-P). A, Beam orientation is parallel to the dorsopalmar plane of the foot and bisecting the axial plane of the foot. As with the L–M projection, the x-ray beam is aimed 1.5 to 2 cm above the weight-bearing surface of the foot or 7 cm distal to the dorsal coronary band on a line perpendicular to the weight-bearing surface. B, Placement of a radio-opaque marker on the axial-dorsal surface of the wall helps in accurate identification of the extent of the hoof capsule. C, Shoe placement and accurate assessment of distal medial and lateral aspect of the wall can be evaluated with L-M projection taken with the shoe on.

blocks of equal height. Correct positioning reduces the likelihood of artifactual changes to the joint space that might otherwise be interpreted as joint asymmetry and foot imbalance.

This projection allows evaluation of medial to lateral balance and conformation of the foot with observation and measurement of the medial and lateral wall length and angle, and the orientation of the distal phalanx within the hoof capsule. Orientation of the distal phalanx can be assessed by measuring the distance from the articular surface of the distal phalanx to the ground surface; the solar canal can also be used as a reference point, but it is less consistent. Using the solar margin as a point of reference can be variable due to changes that can occur in the bone.[8] In horses with "ideal" conformation, the articular surface of the distal phalanx is parallel to the ground, as is a line between the medial and lateral coronary band and, the medial and lateral walls are of equal thickness, and the distance from the medial and lateral solar margins to the ground are similar.[8] In horses with significant rotation or angulation in the distal limb, the relation of the distal phalanx with the ground may not be as symmetrical. Furthermore, the distal interphalangeal joint space should be approximately even across its width regardless of angulation of the phalanges. It is normal for the medial quarter wall to be at a slightly steeper angle and subsequently measure shorter in length.[8] However, caution in overinterpretation of joint incongruency is recommended, because any malpositioning of the limb or

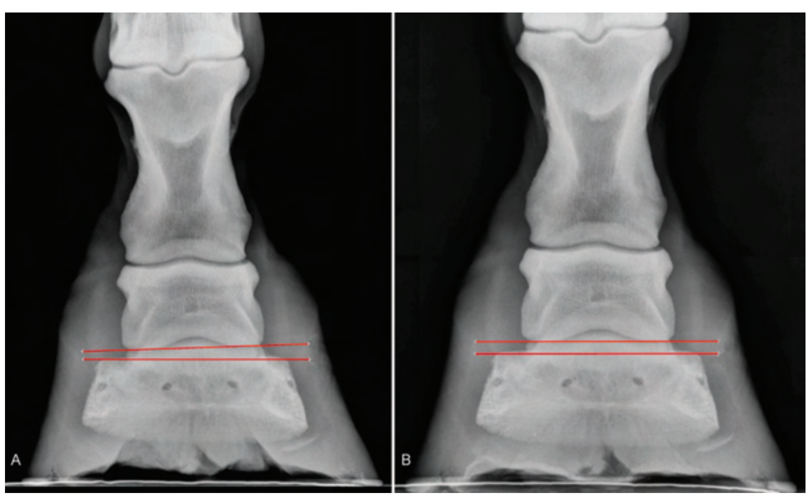

Fig. 7. HD-P view showing abnormal and normal distal interphalangeal joint symmetry in the same horse. A, The limb is slightly abducted and the horse's weight is shifted to the contralateral limb. B, The horse is positioned squarely with both front limbs directly underneath him and standing on identical positioning blocks.

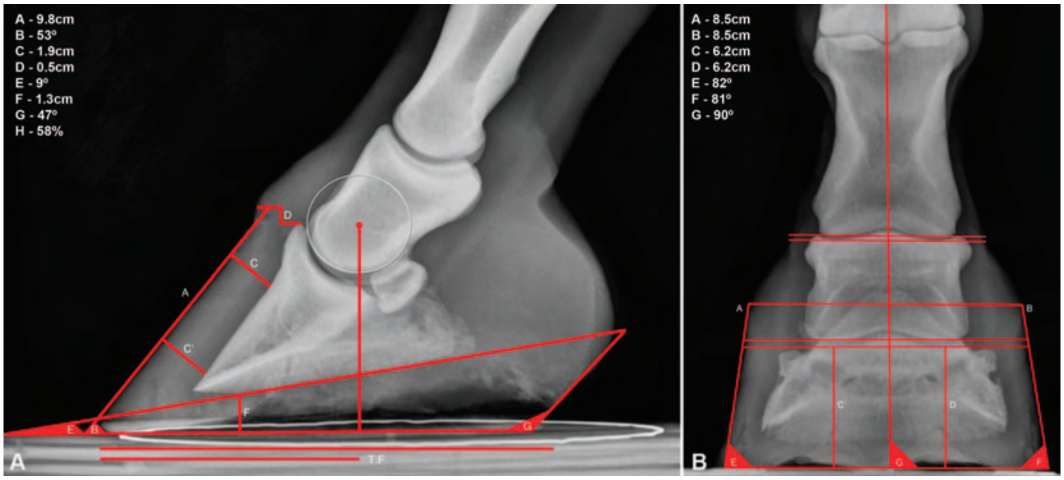

Fig. 8. A, Measured lateromedial view (L-M). Quantitative assessment of the horse's foot. A, dorsal hoof wall length (DHWL); B, dorsal hoof wall angle (DHWA); C and C′, H-L zone, dorsal hoof wall thickness (DHWT); D, coronet to extensor distance (CED); E, solar angle (SA); F, sole depth (SD); G, heel angle (HA); H, toe-to-foot ratio (T:F). B, Measured horizontal dorsopalmar view (HD-P). Quantitative assessment of the horse's foot. A, lateral hoof wall length (LHWL); B, medial hoof wall length (MHWL); C, lateral P3 height (LP3H); D, medial P3 height (MP3H); E, lateral hoof wall angle (LHWA); F, medial hoof wall angle (MHWA); G, median angle (MA).

foot can create the appearance of medial to lateral imbalance (Fig. 7). F7

Quantitative methods of evaluating the horse's foot have been developed.[9] Measurements obtained from the L-M and HD-P radiographic images have been used to evaluate the effects of trimming and shoeing,[7,10,11] the stresses delivered to the deep digital flexor tendon when hoof angle is changed,[12,13] the relationship between foot conformation and lameness,[1,14,15] and, in Thoroughbreds, the relationship between solar angle and deep digital flexor tendon injuries.[12]

Quantitative parameters that should be evaluated include (1) the dorsal hoof wall angle (DHWA), (2) the heel angle (HA), (3) the solar or palmar angle (SA), (4) the dorsal hoof wall length (DHWL), (5) the dorsal hoof wall thickness (DHWT), (6) the sole depth (SD), (7) the distance between the dorsal coronary band and the apex of the extensor process (CED), and (8) the distribution of the dorsal and palmar portions of the foot (toe-to-foot ratio, T:F), separated by a line extending from the center of rotation of the distal interphalangeal joint, perpendicular to the weight-bearing surface (Fig. 8 and Table 1). F8 T1 Subjective assessment of a well-taken radiograph is frequently adequate for evaluating the horse's foot; quantitative assessment is useful in documenting changes in a foot over time and when comparing feet on the same horse.

Changes in the DHWA, SA, and disproportionate distribution of foot mass in relation to the center of rotation can be appreciated on the L-M projection and can be used to assess the dorsopalmar balance of the foot. There is a wide range in what is considered normal for the SA (2 to 8 degrees).[1,7,10,12,16,17] Minimal decreases or flattening of the SA and DHWA have been associated with lameness.[1] An increase in the solar angle decreases the deep digital flexor tendon force, and therefore the force on the navicular bone; a 1-degree increase in solar angle increases the pressure on the navicular bone by 6%.[14] At the same time, changes in the SA or DHWA will result in changes in the hoof-pastern axis. The center of rotation (COR) separates the foot mass into dorsal and palmar/plantar proportions. The COR is located midway

Table 1. Common Measurements of the Equine Foot Found in Sound and Lame Horses

	Dyson, 2011; 300 Mixed Breed Lame	Kummer, 2009; 40 Warmblood Sound	Cripps, 1999; 25 Mixed Breed Sound	Eliashar, 2004; 31 Irish Draught Sound	Mansmann; 108 Mixed Breed Sound
DHWA	52.27 Degrees	54.7 Degrees	50.52 Degrees	50.5 ± 3.6 Degrees	
HA				39 ± 7.3 Degrees	
SA	5.63 Degrees	5.7 Degrees	8.0 Degrees	2.5 ± 2.2 Degrees	2.35 Degrees
DHWL (cm)		9.6			
CED (cm)		1.1 ± 0.35	0.41		
SD (cm)		1.3–1.4			1.4
T:F		64.2%			59%

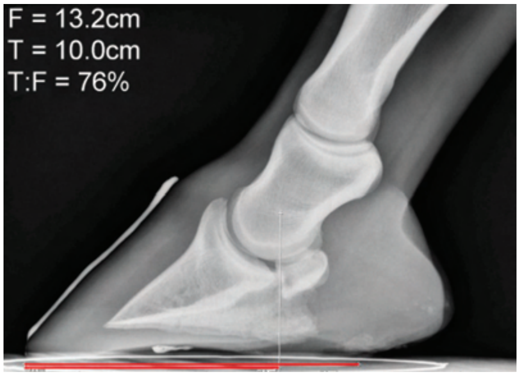

Fig. 9. Image demonstrating long-toe/low-heel syndrome, resulting in an abnormal distribution of sole mass in relation to the center of rotation (COR). Seventy-six percent of the sole mass is dorsal to the COR.

between the dorsal and palmar/plantar aspects of the distal articulation of the middle phalanx; a line dropped from this point and perpendicular to the weight-bearing surface divides the dorsal and palmar/plantar foot mass. In the "normal" foot the T:F should be between 50% and 67%.[7,18] If viewed from the solar surface, the widest point of the foot should correspond to the COR. Horses with long-toe, low-heel syndrome usually have a low dorsal hoof wall and solar angle, a long, narrow frog, and disproportionate foot mass with excessive mass dorsal to the center of rotation (>67%) (Fig. 9). A solar angle of less than 2 degrees is usually associated with a dorsopalmar imbalance; the center of rotation of the DIP joint is displaced toward the heels, resulting in an increase in the T:F ratio.[8]

The DHWA, HA, SA, DHWL, SD, and T:F are changed or potentially changed when the foot is trimmed and shod and results in an overall change in the equilibrium and balance of the foot. Repeating the L-M projection after trimming and shoeing the foot is useful in evaluating the effects of the trim.

Radiography of the foot remains the most practical, economical, and informative imaging modality in the field. Having said that, the quality of the information gained from a radiograph is only as good as the quality of the radiograph itself. Using high-quality equipment, maintaining that equipment, and mastering radiographic technique and image acquisition are imperative to obtaining quality information. Depending on the information desired from a radiographic study, a limited number of views are required. Based on the information gained from the standard study and the clinical presentation of the case, there are numerous other specialty views and techniques that can be performed to gain additional information. As stated previously, a detailed lameness examination is also required to guide the practitioner in deciding what radiographic views should be taken. Radiography is also very useful in more thorough evaluation of the sound horse's foot for consultation with the farrier with respect to trimming and shoeing protocols. Although DR has improved the ability to visualize and evaluate some of the soft tissue structures within the foot, there remain great limitations to imaging most soft tissue structures within the foot.

Clinical Examples

Using radiographs to assess the relationship between the hoof and the underlying osseous structures as an aid in assessing foot balance is about developing an understanding of the relationships between the position of the hoof capsule, the angle of the distal phalanx within the hoof capsule, the symmetry of the interphalangeal articulations, and the alignment of the phalangeals. It should be mentioned as a caveat at the outset that there isn't a comprehensive scientific study to document all of these relationships, but between the studies that are available and clinical experience, there is enough information to entertain a fruitful discussion on the subject.

Dorsopalmar balance is primarily related to two factors: the length of the toe and the alignment of the foot-pastern axis. Radiographs are a very useful adjunct because they convey information about both the relationship between the hoof capsule and the distal phalanx, and the relationship between the phalanges. The potentially most useful estimates of balance that can be derived from a lateral radiograph are the depth of sole, the angle of the solar margin of the distal phalanx, and the position between the center of rotation of the distal interphalangeal joint and the ground surface of the foot. The angle of the dorsal hoof wall, the horizontal distance between the dorsal margin of the toe and hoof capsule, and the angles formed by the interphalangeal joints may also be evaluated. However, as this information is related to the former variables, it is supplemental rather than additive. Ad-

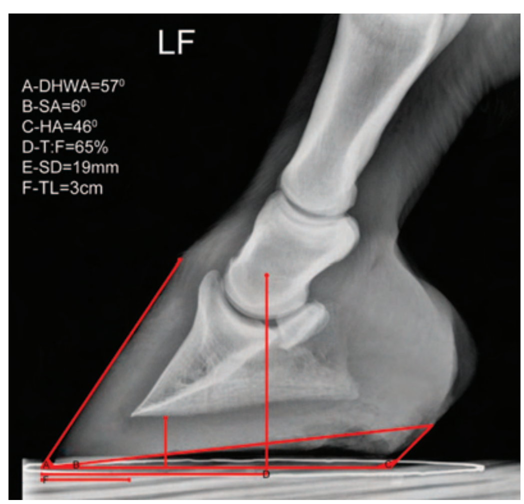

Fig. 10. Lateral to medial radiograph of a normal foot.

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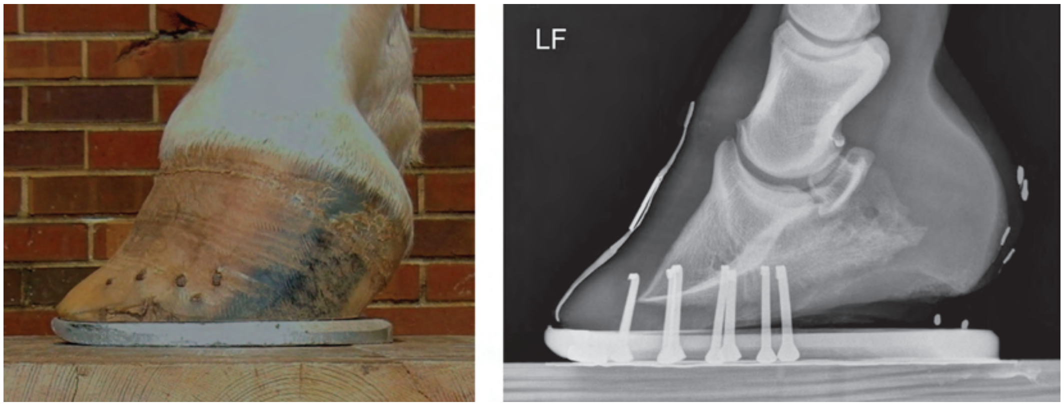

Fig. 11. Case 1.

ditionally, the angles at the interphalangeal joints vary with weight bearing and posture of the horse.

Lateral Radiograph - Normal

In Figure 10, the depth of the sole is 19 mm, the angle of the solar margin is 6° and the horizontal distance between the center of rotation and the toe is 65% of total ground surface length. Additionally, angle of the dorsal hoof wall is 57° and the horizontal toe to distal phalanx distance is 3 cm.

F11

Case 1. LF Distal Interphalangeal Joint Flexural Deformity

In Figure 11, there is asymetric hoof wall growth as indicated by the asymetric growth pattern. There is growth narrowing at the toe which widens as it extends to the heels. Note the two different DHWA's caused by the flaring of the mid-distal dorsal hoofwall. Radiographically, the depth of the sole is 10 mm; this is less than normal, though in other horses it may be closer to normal. The angle of the solar margin of the distal phalanx is 19°, which is markedly greater than that of the normal foot. Note that the dorsal 1/3 of the solar margin has under gone significant remodeling due to the deformity resulting in a solar angle of 0° in that portion of the distal phalanx. The horizontal distance between the center of rotation and the toe as a percentage of overall ground surface length is 58%, which is significantly reduced compared to the normal lateral. Additionally, the angle of the dorsal wall is markedly steeper (61°) than the normal lateral. Also note that the significant distortion of the distal dorsal hoof wall which is more accurately highlighted with the radiopaque marker. The horizontal distance from the toe of the capsule to the dorsal margin of the distal phalanx is also reduced. Furthermore, the foot-pastern axis is clearly broken forward.

Case 2. Distal Interphalangeal Joint Dorsiflexion (Negative Solar Margin Angle) F12

In Figure 12, there is significant asymetry in the growth pattern throughout the foot. Note the ventral divergence of the growth pattern in the heels and the widening of the growth pattern at the toe. The toe takes on a bulging or "bull nosed" appearance. Clinical experience has shown that this foot conformation is consistently predictive for horses having negative solar margin angles when radio-

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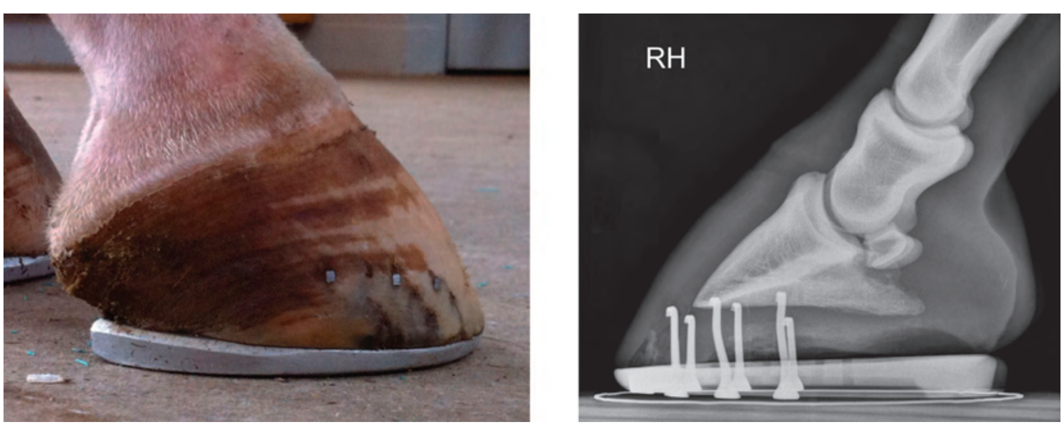

Fig. 12. Case 2.

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Fig. 13. Dorsal to palmar/plantar radiograph of a normal foot.

graphed. Radiographically, the bulging appearance of the DHW can be appreciated as well as the dorsal margin of the distal phalanx. The distal interphalangeal joint is dorsiflexed causing a broken-back hoof-pastern axis. The depth of the sole is 24 mm at the dorsal margin of the distal phalanx; at the plantar aspect this measurement is 18 mm. In the hind foot it is common to see a significant increase in the sole depth whereas in the front foot sole depth may be consistent with normal and have a reduced sole mass at the plantar aspect. The angle of the solar margin of the distal phalanx is -2° in the shod foot; if the foot was unshod the solar angle would be -4°. The horizontal distance between the center of rotation and the toe as a percentage of overall ground surface length is 68%; this is greater than it would be should the same foot have a normal solar margin angle. As seen in horses with flexural deformity the DHW exhibits multiple DHWA's but due to convexity of the wall verses concavity of the wall, the proximal DHWA measures 44° whereas the distal angle measures 62°.

Dorsopalmar Radiograph - Normal F13

In Figure 13, the articular and solar margins of the distal phalanx are parallel to the ground and perpendicular to the axis of the proximal phalanges. The distal interphalangeal joint space is even. The coronary band when marked shows mediolateral symmetry.

Case 3. LF Medial to Lateral Hoof Capsule Asymmetry

In Figure 14, the clinical features of this foot when F14
viewed from the dorsal aspect include a flare in the medial wall and growth ring compression on the medial side compared to the lateral side. These features suggest increased stress/weight bearing by the medial wall compared to the lateral wall. Additionally, the horizontal distance between the pastern joint and the coronary band appears less on the medial side than the lateral side; personal experience suggests that this indicates that the medial side of the hoof has been displaced proximally. Interestingly, the coronary band appears to be approximately parallel to the ground. Radiographically, one might expect the distal phalanx to be tilted distolaterally and the medial side of the joint space to be narrower laterally than it is medially. However, radiographs show that the distal phalanx is tilted distomedially. If this were the sole criteria for farriery intervention, the intuitive solution would be to trim the lateral side of the foot to restore a "normal" horizontal alignment of the distal phalanx. Examining the articulation of the distal interphalangeal joint, however, shows it to be approximately even medially and laterally, which is

Fig. 14. Case 3.

COLOR

COLOR

Fig. 15. Case 4.

considered normal. Additionally, the angle of the pastern, is tilted laterally from the fetlock distally (difficult to appreciate from this radiograph) so that the axis of the pastern is at right angles to the articular surface of the distal phalanx. Therefore, in contrast to the initial intuitive position above, these facts suggest that the alignment of the distal phalanx in the hoof capsule is normal for this horse. Therefore, the physical appearance of the foot and the radiographs cannot be interpreted in isolation of each other, and in this instance, the physical appearance of the foot provides more information about the balance of this limb than the radiographs.

Case 4. RF Medial to Lateral Hoof Imbalance

F15 The foot in Figure 15 demonstrates a marked flare of the medial hoof wall and considerable asymmetry in the growth pattern of the wall. There is a rise in the growth rings at the toe and widening of the rings on the medial quarter. The coronary band also takes on an undulating appearance. These features suggest decreased loading/weight bearing by the medial wall compared to the lateral wall and increased loading or jamming at the toe. This horse had severe White Line Disease and marked lameness. Radiographically, the distal phalanx is tilted distolaterally. Both the distal and proximal interphalangeal joints show asymmetry between the medial and lateral sides. Lastly, the distal phalanx has displaced medially in the frontal plane in relation to the middle phalanx. This pattern of observations is almost conclusive of mediolateral imbalance. Some of these findings may be present in other circumstances in isolation which can lead to misinterpretation if they are not all evaluated collectively. For example, the tilting of the distal phalanx and asymmetry of the interphalangeal joints may occur in horses with uniaxial laminitis, but with uniaxial laminitis, the medial wall should be thicker than the lateral wall (not to mention different clinical signs). Also, the distal phalanx may occur tipped to one side in horses that have under-

COLOR

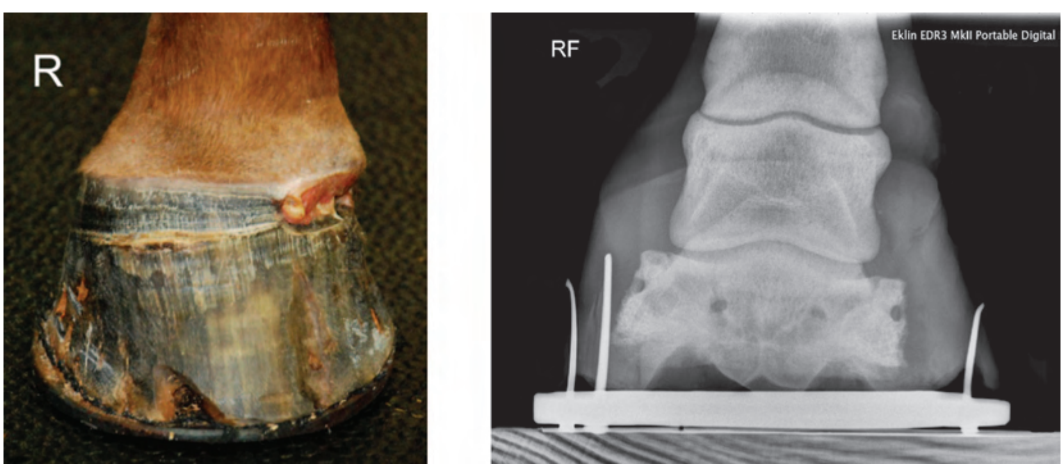

Fig. 16. Case 5.

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gone uniaxial cartilage loss in one of the two distal articulations secondary to a degenerative process; the affected side will show joint narrowing and may be accompanied by tilting of the distal phalanx distally on the other side, but the unaffected joint should either not appear uneven or compressed on the opposite side. Any ambiguity in interpretation is likely to be cleared up by taking into account the clinical signs.

Case 5. RF Medial Uniaxial Laminitis

F16 The foot in Figure 16 demonstrates marked asymmetry. Firstly, the center of the pastern does not appear to be aligned with the center of the coronary band; the coronary band appears to have shifted laterally in relation to the coronary band. Additionally, the medial wall has grown very little in relation to the lateral wall as evidenced by the divergence of the growth rings yet there is very little disparity in medial and lateral wall length. The separation that has occurred at the coronary band is obvious because of the presence of granulation tissue. Radiographically, there is marked tilting of the distal phalanx. The interphalangeal joints are asymmetrical, demonstrating narrowing laterally and widening medially. Additionally, the distance between the distal phalanx and the hoof wall is increased. Furthermore, due to the displacement of the medial distal phalanx the medial sole thickness is also decreased. Also note that with relatively similar medial and lateral wall length the distance between the medial eminence of the distal phalanx and the coronary band is increased in a comparable manner to that seen between the extensor process and the dorsal coronary band in horses with classic dorsal rotational displacement. The difference between this horse and the horse with mediolateral imbalance is that the thickness of the medial wall is significantly greater in this horse. This radiographic appearance is almost pathognomonic for laminitis with uniaxial distal displacement of the distal phalanx.

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