THE PHALANGES

The radiographic views needed to evaluate the phalanges will depend on the area of interest. The views needed to evaluate the third phalanx are different than those needed to evaluate the pastern.
Proper labeling of all phalangeal radiographs is important. The structures of the fetlock joint and distal to it are symmetrical and provide no anatomic landmarks for orientation. As with all limb radiographs the markers will be placed along either the lateral or cranial aspect of the limb.

THIRD PHALANX
Routine evaluation of the third phalanx consists of 2 views
Lateromedial (Lateral)
Dorsal 65-degree Proximal-Palmarodistal Oblique (D65Pr-PaDiO)*
Optional views that may be used to evaluate the third phalanx include
Dorso 65-degree Proximal 45-degree Lateral-Palmarodistal Medial Oblique (D65Pr45L-PaDiMO)*
Dorso 65-degree Proximal 45-degree Medial-Palmarodistal Lateral Oblique (D65Pr45M-PaDiLO)*
Dorsopalmar (Horizontal Beam)*
* If the hind foot is radiographed substitute plantar for palmar.

LATEROMEDIAL VIEW

The lateromedial view (commonly referred to as a lateral view) is obtained with the horse standing on a block. The x-ray beam is centered on the foot, at the level of the coronary band.

The lateral radiographic projection allows evaluation of most of the 1st phalanx and the entire 2nd and 3rd phalanges. This is the same view that is used to evaluate the navicular bone.
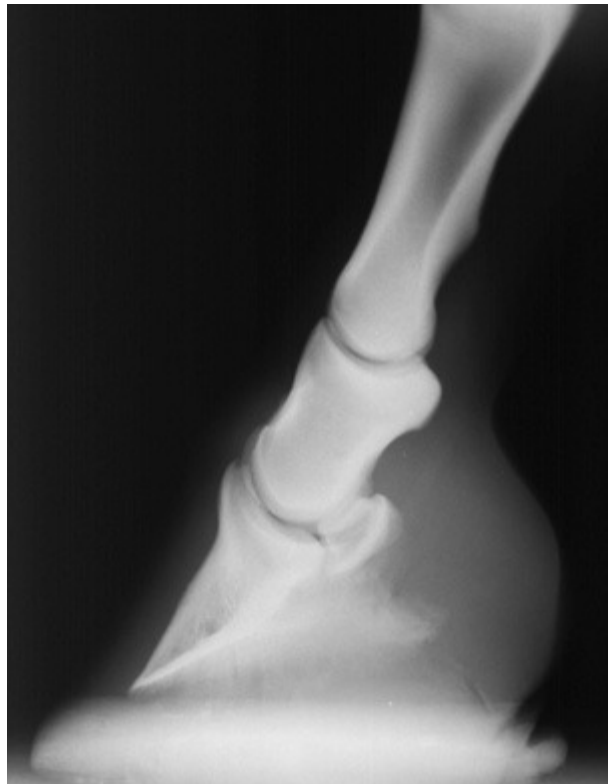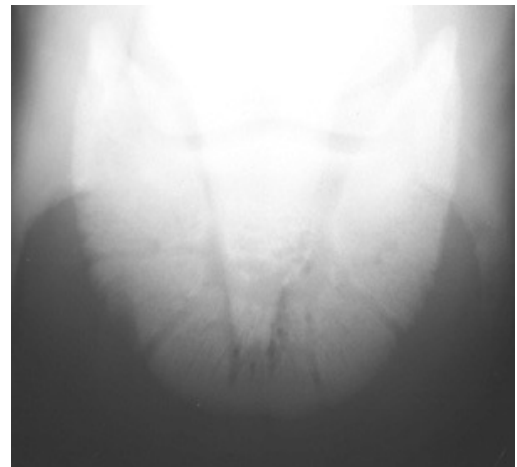
DORSAL 65-degree PROXIMAL -PALMARODISTAL OBLIQUE VIEW
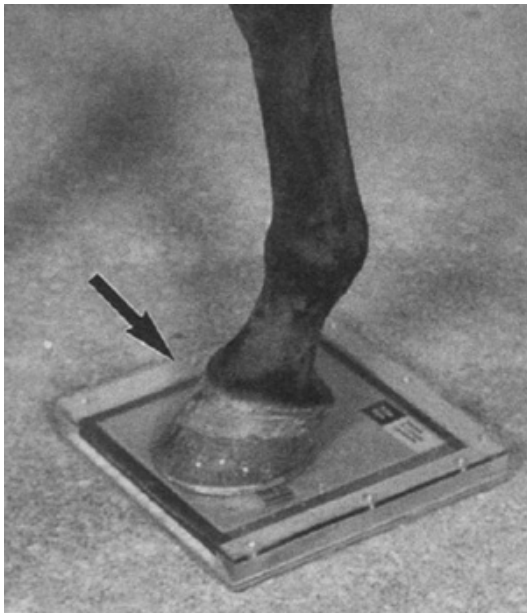
This view is obtained with the horse standing on the cassette (contained within a holder for protection). As with other oblique views the name of the view describes the direction of the x-ray beam. The beam is aimed from dorsoproximal to palmarodistal at a 65 degree angle to the supporting surface. The beam is centered on the foot and directed at the level of the coronary band. The name listed above is the proper designation for the radiographic projection. However, in the real world this view is generally referred to as the dorsopalmar view.

This is the same dorsopalmar view that is used to evaluate the navicular bone. However, much less penetration of the x-ray beam is required to produce adequate radiographs of the third phalanx. The exposure factors used are decreased to avoid overexposure of the margin of the third phalanx.

In this radiograph the technique used allows the margins of the third phalanx to be visualized but the area of the distal interphalangeal joint is underexposed. A second view of the area using higher exposure factors would be needed to evaluate the joint.

DORSO 65-DEGREE PROXIMAL 45-DEGREE LATERAL-PALMARODISTAL MEDIAL OBLIQUE (D65Pr45L-PaDiMO)

As with all radiographic projections this view is named by the direction of the x-ray beam. As with the dorsopalmar view the horse is standing on the cassette (within a protective holder). The x-ray beam is aimed from dorsoproximal to palmarodistal at a 65-degree angle to the supporting surface AND from lateral to medial at a 45 degree angle to the dorsal surface. The beam is directed at the level of the coronary band.

This view allows evaluation of the lateral aspect and palmar process of the third phalanx. Notice how well the lateral aspect of the coffin joint is visualized.
This view is most often used to evaluate for the presence of a fracture of P3 - there is a fracture visible in this radiograph - can you find it?

The dorso 65-degree proximal 45-degree medial-palmarodistal lateral oblique (D65Pr45M-PaDiLO) is the same view of the medial aspect of the third phalanx. In this case the x-ray beam is aimed from medial to lateral at a 65-degree angle to the dorsal surface.

DORSOPALMAR (HORIZONTAL BEAM)
As indicated by the name the x-ray beam travels from dorsal to palmar in a horizontal direction. The horse is made to stand on a block in order to place the coronary band at the level of the x-ray beam. The cassette is behind the limb, perpendicular to the x-ray beam.

Although it is relatively easy to obtain this view in the forelimbs it may be difficult to get a horse to place the hind feet on blocks.
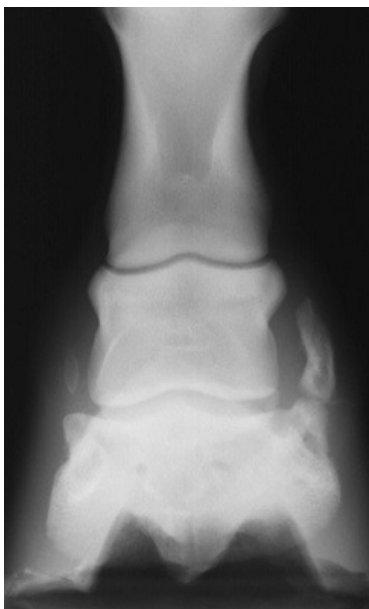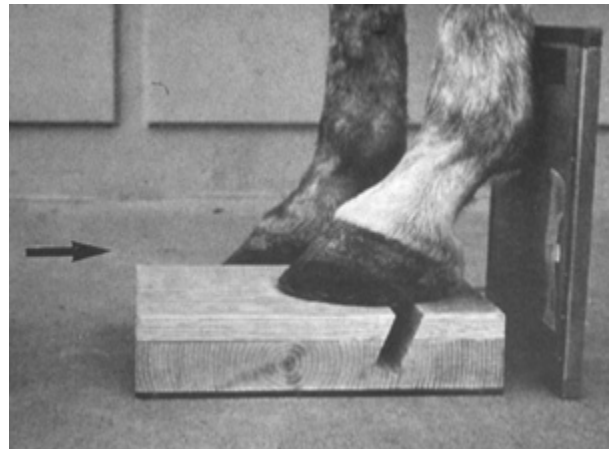
This view provides good evaluation of the proximal and distal interphalangeal and metacarpophalanageal joint spaces (the metacarpophalangeal joint has been "cropped" from the radiograph).

This view also allows evaluation of the symmetry of the third phalanx. Poor foot care can result in a "hoof imbalance" over time. This is visible in the foot itself but may also be seen as asymmetry of the distal phalanx.

The projections of bone along each side of the distal interphalangeal joint are ossified accessory cartilages. The ossification along the right side is extreme. This is commonly referred to as "sidebone." The linear lucency that separates the ossified cartilage from the bone on each side is not a fracture, it is an area of cartilage that has not yet ossified.

PROXIMAL INTERPHALANGEAL JOINT

Routine evaluation of the second and third phalanges and proximal interphalangeal joint consists of 2 views

Lateromedial (Lateral)
Dorsopalmar (Horizontal Beam)*
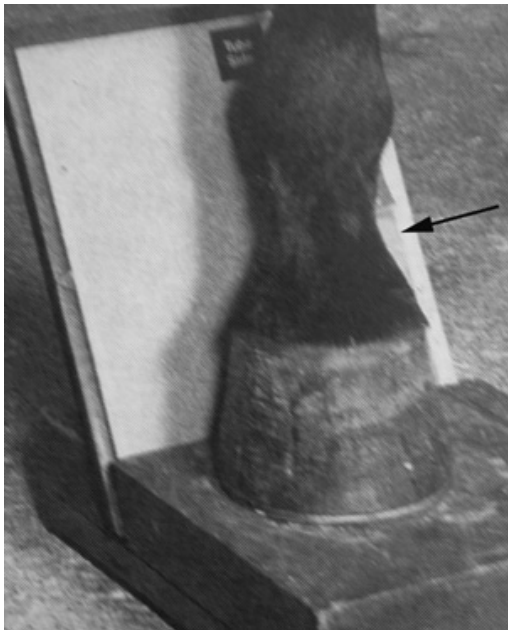These views are the same as those described above for the third phalanx.
Optional views that may be used to evaluate the pastern joint include
Dorsolateral-Palmaromedial Oblique*
Dorsomedial-Palmarolateral Oblique*
   *If the hind foot is radiographed substitute plantar for palmar.

DORSOLATERAL-PALMAROMEDIAL OBLIQUE

In this view the x-ray beam passes from the dorsolateral aspect of the limb (approximately 45 degrees lateral to the dorsal surface) to the cassette at the palmaromedial aspect of the limb. Notice that the cassette is parallel to the angle of the pastern and that the x-ray beam is perpendicular to the cassette. The x-ray beam is centered at the level of the proximal interphalangeal joint.

To include the distal interphalangeal joint and third phalanx in the image the horse is positioned with the foot elevated on a block. In this case the block is designed to hold the cassette - this limits radiation exposure to personnel.

This view allows the dorsomedial and palmarolateral margins of the phalanges and the interphalangeal joints to be evaluated. This may be helpful in cases of arthritic change and in defining fracture lines in the first and second phalanges.

The opposite oblique view (dorsomedial - palmarolateral) is very similar in appearance. Again, correct markers and marker placement are needed for correct interpretation of the radiograph.
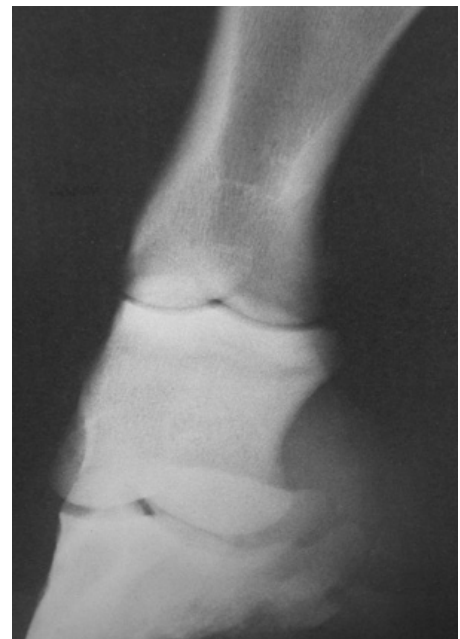
REFERENCES
Morgan JP. Techniques of Veterinary Radiography 5th ed. Iowa State University Press. 1993
Smallwood JE et al. A standardized nomenclature for radiographic projections used in veterinary medicine. Veterinary Radiology 26(1), 1985;pp 2-9.
Shively MJ. Synonym equivalence among names used for oblique radiographic views of distal limbs. Veterinary Radiology 29(6), 1988;pp 282-284.

RADIOGRAPHIC ANATOMY OF THE PHALANGES

A brief review of the normal radiographic appearance and important anatomic structures of the phalanges is indicated prior to any discussion of radiographic abnormalities.

Let us begin our discussion of the normal radiographic appearance with the dorsal 65-degree proximal - palmarodistal oblique view (referred to as the dorsopalmar view for purposes of simplicity). Below are a labeled diagram and a radiograph of this view.
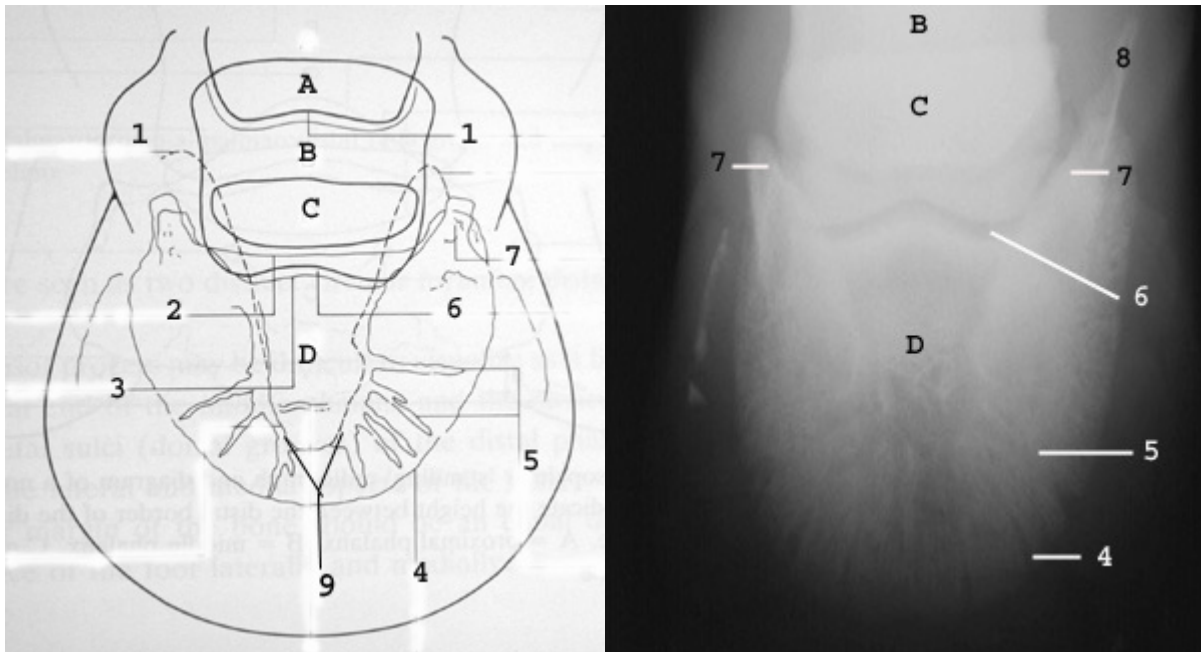
A = Proximal phalanx (P1)
B = Middle phalanx (P2)
C = Navicular bone
D = Distal phalanx (P3)
1 = Angle of the heel and the frog
2 = Palmar margin of the distal interphalangeal joint
3 = Dorsal margin of the distal interphalangeal joint
4 = Solar margin
5 = Vascular channels
6 = Distal interphalangeal joint
7 = Palmar process
8 = Ossifying accessory cartilage of P3
9 = Solar canal

Notice that the structures of the distal interphalangeal joint and the navicular bone are not as clear in the radiograph as they are in the diagram. As noted above an exposure adequate to evaluate the solar margin of P3 results in underexposure of the thicker areas such as the joint and the navicular bone. Proper exposure of the distal interphalangeal joint would create significant overexposure of the margin of the third phalanx (burn-out!).

The soft tissue structures are normal in the radiograph. The thin band of mineral opacity along the left side of the third phalanx is opaque material on the solar surface of the foot. This is quite common in radiographs of the feet and should not be mistaken for pathology. Packing material (usually Playdough) is often placed into the sulci of the frog - if this is not done the air within the frog shows up as linear lucent bands. The packing material is usually of soft tissue opacity and may be seen superimposed over the third phalanx. This should not be mistaken for pathology.

The accessory cartilages of the third phalanx have varying degrees of ossification. This radiograph is from the same horse as the horizontal beam dorsopalmar view above. Notice the assymmetry between the palmar process regions (7). The palmar process on the left side is normal; on the right the palmar process is surrounded by a large area of bone proliferation which extends abaxially and palmar to the process. This is the ossified accessory cartilage.

The vascular channels (5) arise from the solar canal (9) and extend to the solar margin of P3 (4). These structures actually are vascular channels (unlike those in the navicular bone) and provide the blood supply to the bone. The vascular channels can be mistaken for fracture lines. In general, fracture lines are more straight and distinct and do not tend to travel toward the center of the bone. The vascular channels may appear widened and irregular if inflammation of the third phalanx is present. However, this change can be quite subtle. Causes of inflammation include laminitis, pedal osteitis and osteomyelitis.

Notice that both the palmar (2) and dorsal (3) margins of the distal interphalangeal joint are visible in the radiograph. This is the result of the angle at which the x-ray beam intersects the joint.

Below are a labeled diagram and radiograph of the lateromedial view. This is typically referred to as the lateral view.
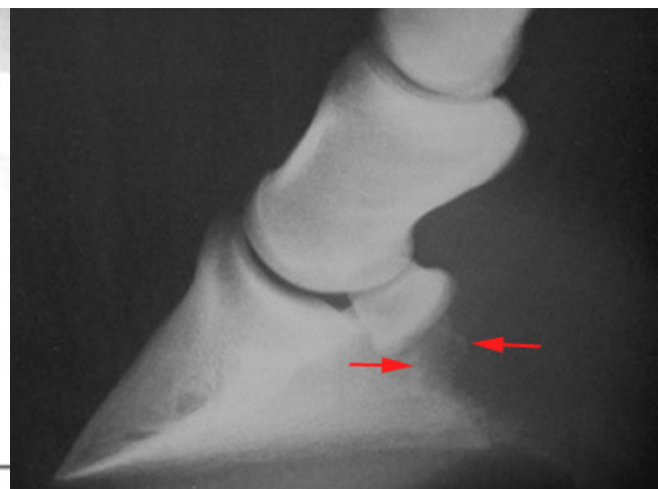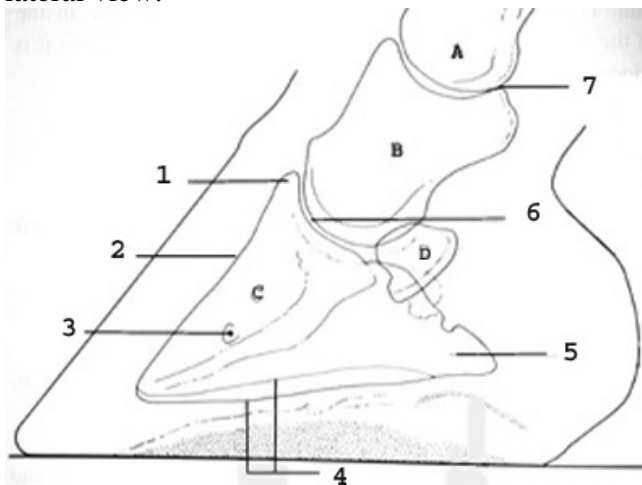
A = Proximal phalanx (P1)
B = Middle phalanx (P2)
C = Distal phalanx (P3)
D = Navicular bone

1 = Extensor Process
2 = Dorsal surface
3 = Solar canal
4 = Solar margin
5 = Palmar processes (superimposed)
6 = Distal interphalangeal joint (coffin joint)
7 = Proximal interphalangeal joint (pastern joint)

The lateral radiographic projection allows good evaluation of the margins of the proximal interphalangeal joint (7) and distal interphalangeal joint (6). These joints may be referred to by horsemen as the pastern joint and coffin joint, respectively. The width of the joint spaces can be evaluated in the lateral view - however, the appearance of the joint spaces can be greatly affected by the way the animal is standing and the angle of the x-ray beam, so should not be overinterpreted.

Evaluation of the lateral view is more straight-forward than some of the other views used to evaluate the phalanges. One area of confusion is the superimposition of the ossifying accessory cartilages and the navicular bone. This may create an impression of bony proliferation along the flexor surface of the navicular bone (red arrows). This degree of bony proliferation would be highly unusual on the navicular bone and if this were actually bony proliferation it should be visible in the palmaroproximal-palmarodistal view (aka flexor skyline view) of the navicular bone.

The soft tissue structures of the heel are prominent and are often confused with soft tissue swelling. Examination of the foot of the horse should help to confirm that there is normally a large amount of soft tissue in this region.

The oblique views of the third phalanx (D65Pr45L-PaDiMO and D65PrM-PaDiLO)are used to evaluate the palmar processes of the third phalanx and the margins of the distal interphalangeal joint. These views are included in a full radiographic series of the third phalanx, usually when a fracture is suspected.
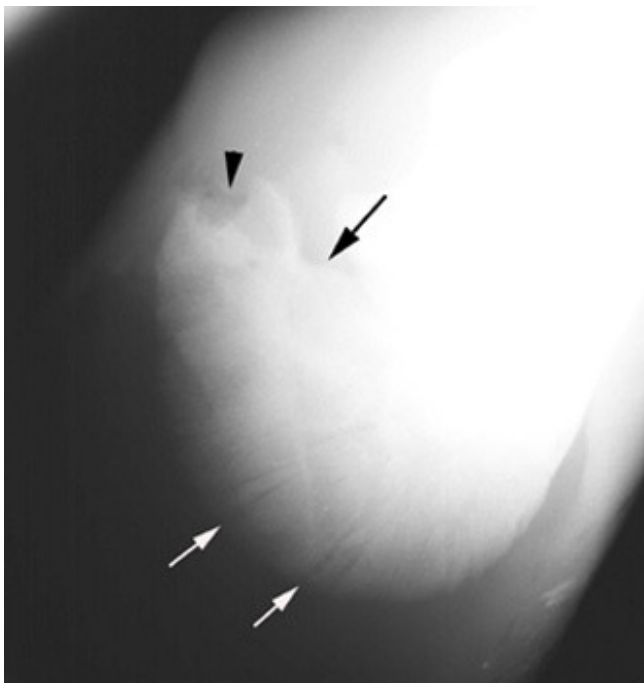

In this radiograph the palmar process is clearly visible (black arrowhead). The lucent area adjacent to the palmar process is gas within the sulcus of the foot. The articular surface of the distal phalanx is indicated by the black arrow.

Many vascular channels are visible radiating from the articular surface of the bone to its solar margin (white arrows). With experience it becomes easier to differentiate vascular channels from fracture lines.

Proper exposure of the margin of the third phalanx causes the central area (including most of the distal interphalangeal joint) to be under-exposed.

Horizontal beam dorsopalmar views are not considered a part of the routine radiographic evaluation of the phalanges. However, this view may be used when complete evaluation of the distal interphalangeal joint is needed.
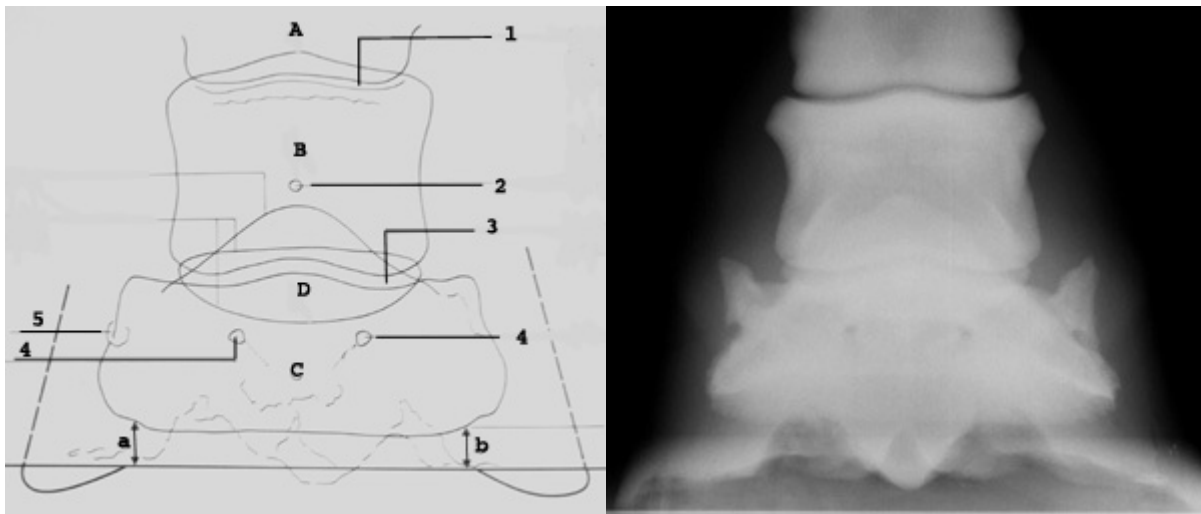
A = Proximal phalanx (P1)
B = Middle phalanx (P2)
C = Distal phalanx (P3)
D = Navicular bone
1 = Proximal interphalangeal joint (pastern joint)
2 = Nutrient foramen of the middle phalanx
3 = Distal interphalangeal joint (coffin joint)
4 = Solar canal
5 = Parietal sulcus of the distal phalanx
a and b = the height between the distal border of the distal phalanx and the ground surface

The distal interphalangeal, proximal interphalangeal and metacarpophalangeal joints are visible in a dorsopalmar horizontal beam view (the metacarpophalangeal joint has been "cropped" from the image above). The joint spaces decrease in width from distal to proximal - i.e. the distal interphalangeal joint is the widest and the metacarpophalangeal joint the narrowest.

Each joint space should be of equal width across its' entire surface. Remember that the appearance of a joint space is created by the articular cartilage and fluid within the joint, it is not actually a space. Symmetrical widening of a joint space suggests an increase in synovial fluid; symmetrical narrowing suggests loss of cartilage.

Asymmetry of the joint space may be the result of positioning or pathology. If it is the result of positioning all 3 of the joint spaces will demonstrate similar asymmetry. If it is the result of pathology only the affected joint space will be asymmetrical.

If the dorsopalmar horizontal beam is well-positioned it can be used to evaluate balance of the hoof. If a hoof is properly balanced the distances between the distal border of the distal phalanx and the ground surface will be symmetrical across the bone ("a" and "b" above will be equal). A diagnosis of hoof imbalance is generally made based on the appearance of the foot but can be substantiated with radiographs.

A routine series of the proximal interphalangeal joint consists of dorsopalmar and lateral views. Oblique views (DLPMO / DMPLO) may be added to provide additional information about the margins of the joint and the bone surfaces.

Correct labeling of these radiographs is imperative as there is no anatomic landmark to help differentiate the lateral and medial surfaces of the bones.

Small areas of roughened bone are present on the dorsomedial and dorsolateral margins of the middle phalanx. These are the areas of attachment of the collateral ligaments of the navicular bone (syn. suspensory ligaments of the navicular bone). This close-up view of the dorsolateral aspect of P2 shows this area (red arrow). This normal appearance may be mis-diagnosed as an area of proliferative periosteal response.

Figure 1
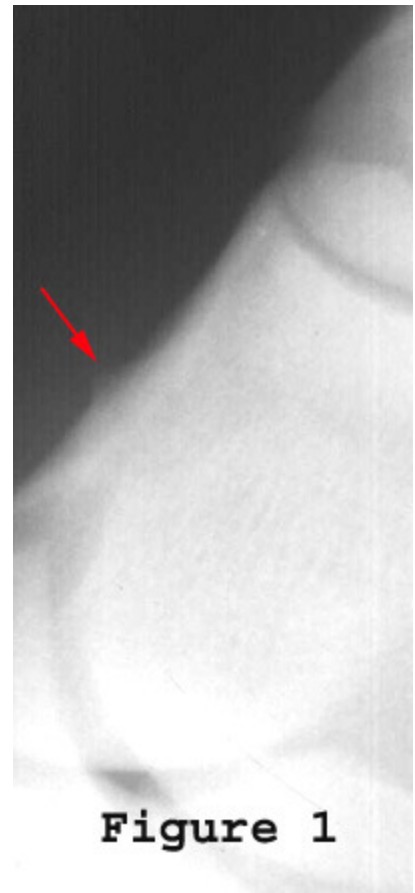
RADIOGRAPHIC ABNORMALITIES OF THE PHALANGES
This section will discuss some common radiographic abnormalities of the phalanges.

DEGENERATIVE JOINT DISEASE

Degenerative joint disease (DJD) is one of the most common causes of lameness in the horse. Degenerative joint disease may be primary (the result of "wear and tear") or secondary (due to an identifiable etiology such as joint instability, presence of a fracture fragment etc). The radiographic appearance of degenerative joint disease is the same no matter what the cause.

Radiographic changes of early and/or mild DJD include the following
Increase in intracapsular soft tissue (effusion and/or synovial thickening)
Osteophyte production (proliferation of bone at the junction of articular cartilage and bone)
Enthesiophyte production (proliferation of bone at the insertions of joint capsules, tendons and ligaments)
With late and/or severe DJD the following radiographic changes may also be present
Narrowing of the joint space
Cystic areas of subchondral demineralization
Ankylosis

Degenerative joint disease of the interphalangeal joints
The layman's term for degenerative joint disease of the interphalangeal joints is "ringbone" - low ringbone occurs in the distal interphalangeal joint and high ringbone in the proximal interphalangeal joint.


In the lateral radiograph it is difficult to see any abnormality of the distal interphalangeal joint. However, close inspection of the dorsal aspect of the joint (inset) shows small, sharp osteophytes on the extensor process of the distal phalanx and at the margin of the articular surface of the middle phalanx (arrows). Notice that the osteophyte on the extensor process is more lucent than the adjacent bone - this is typical of osteophytes as they are forming. The radiographic changes seem fairly minor. However,the distal interphalangeal joint does not tolerate DJD well and relatively little arthritic change may be present for the degree of lameness.
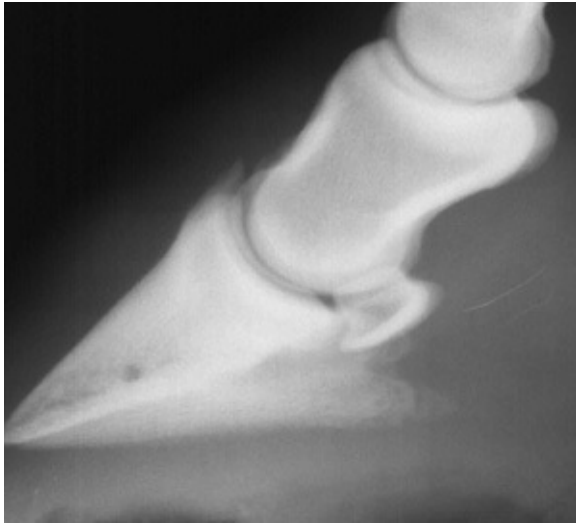
In this radiograph there is more obvious osteophyte formation on the extensor process of the distal phalanx. Significant periosteal proliferation is also present on the dorsodistal aspect of the middle phalanx. These changes are evidence of more advanced degenerative joint disease.

The radiographic changes of DJD at the proximal interphalangeal joint may be as subtle as those shown in the distal interphalangeal joint above or may be much more obvious.

The radiographs below are from a 13-year old Appaloosa with lameness of the right fore limb. The radiographic changes are evidence of severe degenerative joint disease of the proximal interphalangeal joint.
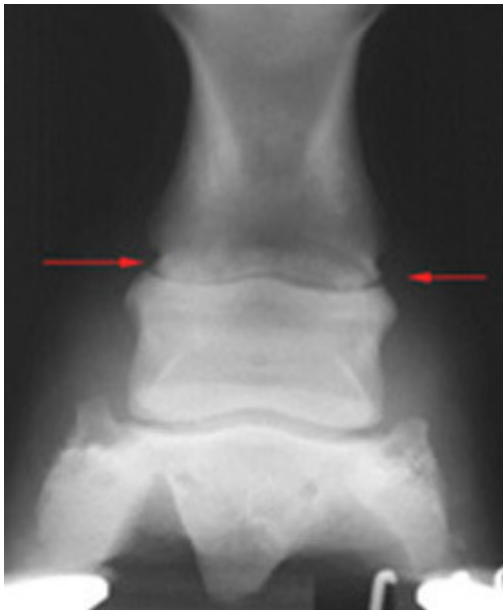
DORSOPALMAR VIEW
Narrowing of the proximal interphalangeal joint space (red arrows) is present. The narrowing is severe and symmetric. With careful evaluation subchondral lucencies can be seen in the distal surface of the proximal phalanx.

LATERAL VIEW
Significant periosteal response is present on the dorsal margins of the proximal interphalangeal joint (white arrows). Notice that the periosteal response extends well away from the joint margins. This is often termed "extra-articular" ringbone. This term is somewhat misleading as it implies that there is no involvement of the joint in the process.

Narrowing of the proximal interphalangeal joint space is also visible in this view but is more difficult to appreciate than in the dorsopalmar radiograph.

DMPLO VIEW

The oblique views are useful to show extension of the periosteal response to the dorsolateral and dorsomedial margins of the proximal interphalangeal joint (white arrow). The periosteal response often encompasses the entire dorsal surface of the joint, thus the term "ringbone."

Narrowing of the proximal interphalangeal joint space is also apparent (arrowheads).

FRACTURES

Fractures of the phalangeal bones are relatively common, usually occurring during athletic activity. Fractures of the distal phalanx occasionally occur from the horse kicking a stationary object (i.e. the wall).

Fractures of the distal phalanx are classified based on their location. The diagrams below show the common types of fractures.
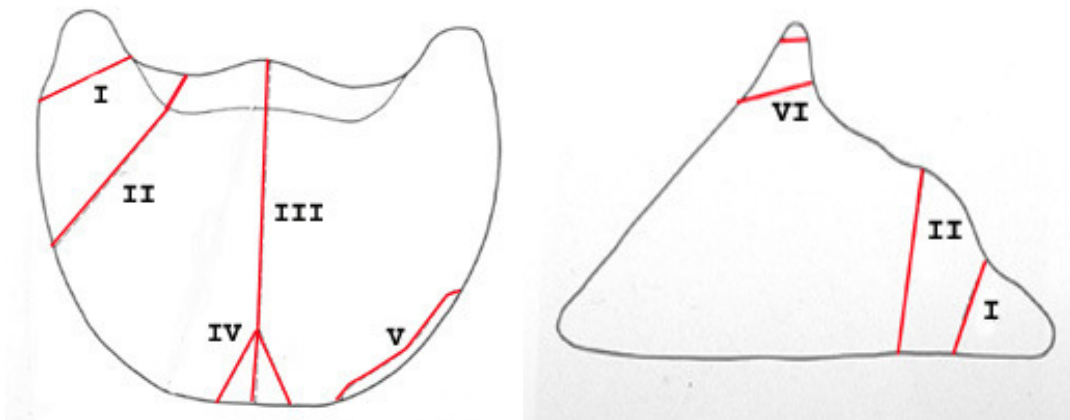
I = Nonarticular oblique palmar/plantar process (wing) fracture
II = Articular oblique palmar/plantar process (wing) fracture
III = Sagittal articular fracture
IV = Comminuted fracture - articular or nonarticular
V = Solar margin fracture
VI = Extensor process fracture (variable size)
This classification scheme is from *Adams' Lameness in Horses* but other authors use a different classification system. For example *Thrall's Veterinary Diagnostic Radiology* uses the following system
I = Nonarticular oblique palmar process (wing) fracture
II = Articular oblique palmar process (wing) fracture

III = Sagittal articular fracture
IV = Extensor process fractures (variable size)
V = Comminuted fracture of body or fracture owing to foreign body penetration or osteomyelitis
VI = Solar margin fracture

Because of this variability it may be better to describe the fracture configuration than to use a numbering system.

Fractures of the palmar process are the most common types - articular fractures are more common than nonarticular fractures. These fractures may be visible in the dorsopalmar view but oblique views are almost always needed to determine if articular involvement is present. Articular involvement has a significant effect on the prognosis and outcome of distal phalangeal fractures so is a key fact to be determined by the radiologic examination.

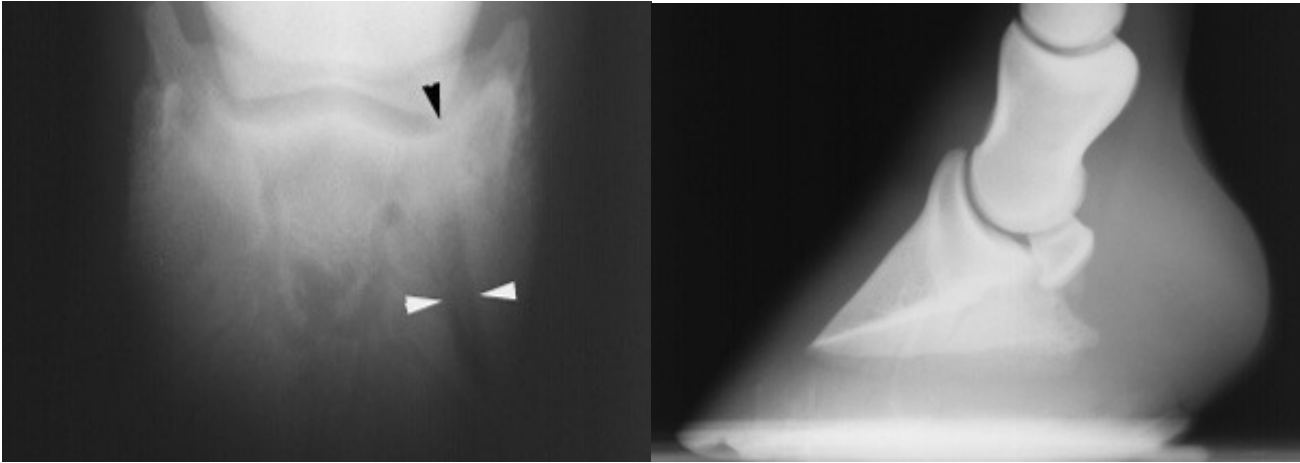Nonarticular Palmar Process Fracture
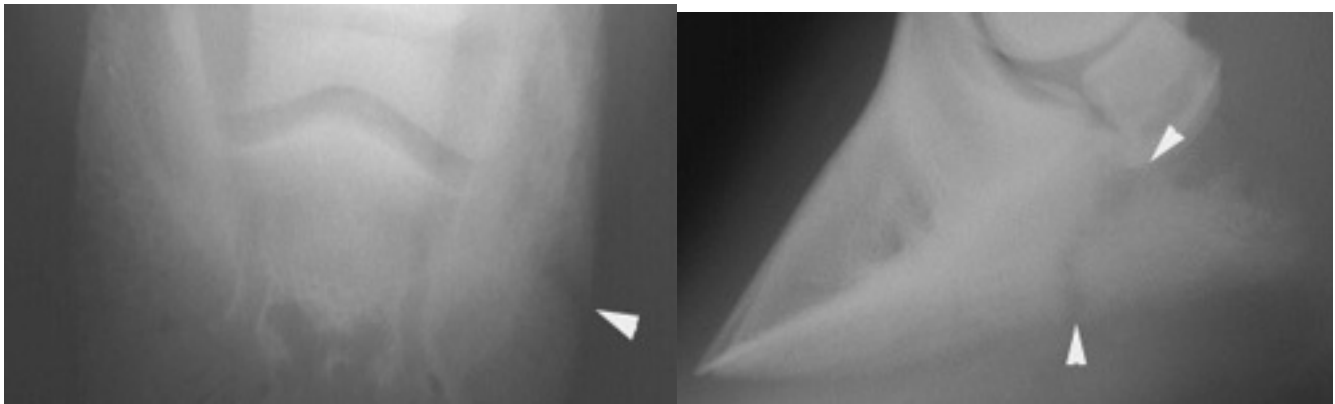
In the radiographs above a fracture line (arrowheads) is visible in one of the palmar processes of the distal phalanx (lateral based on the labeling of the dorsopalmar view that has been omitted from the image). This case is somewhat unusual in that the fracture line is seen very well in the lateral view.
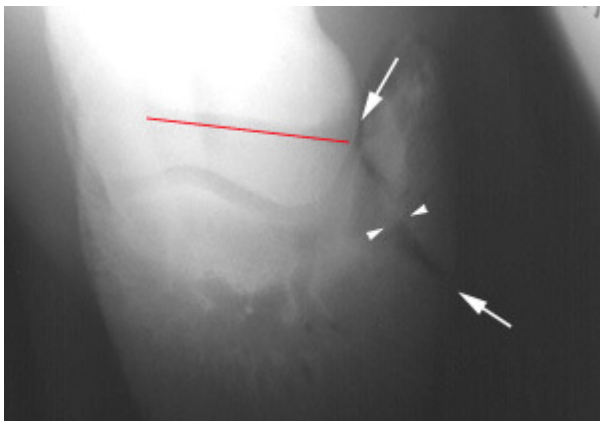
However, with only these views it is difficult to determine if the fracture involves the articular surface.

The DLPMO view is used to provide better visualization of the lateral palmar process. The fracture line is much wider and easier to see (white arrows and arrowheads). The fracture line extends to the surface of the palmar process immediately adjacent to the articular surface (denoted by the red line). This is a nonarticular fracture but just barely!

Articular Palmar Process Fracture

In this example of an articular palmar process fracture the fracture line is visible in the dorsopalmar view (white arrowheads). The fracture line extends toward the articular surface (black arrowhead) so articular involvement is highly suspected.

Notice that the fracture line is not visible in the lateral view. This is typical of an articular fracture - the fracture line is more dorsally located than a nonarticular fracture and is obscured by the superimposed bone of the distal phalanx.
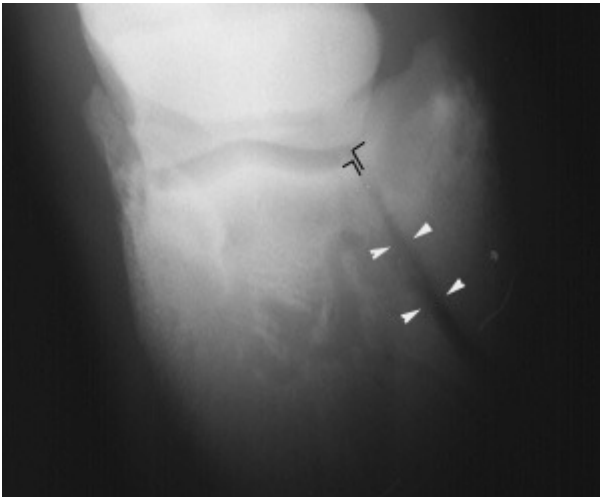
As with the nonarticular fracture the oblique radiograph is needed to show the exact location of the fracture. The fracure line (arrowheads) is seen to extend to the articular surface. Discontinuity of the articular surface (a "step lesion") is seen - the black lines indicate the margins of the bone at the articular surface.

The fracture is in the medial aspect of the distal phalanx.
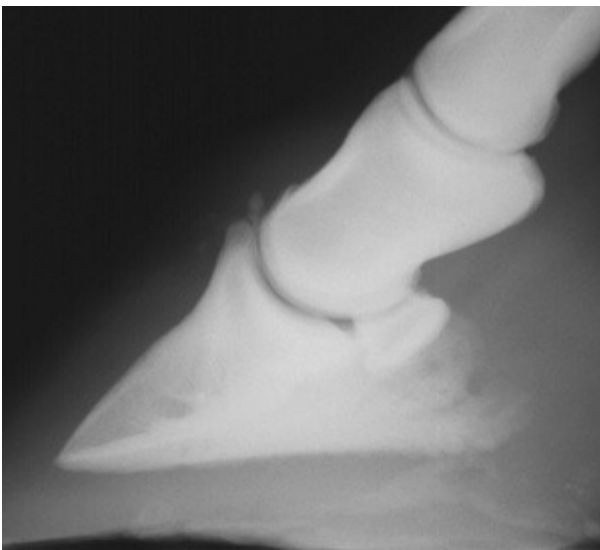
Extensor Process Fracture

Fractures of the extensor process may be seen as incidental findings or may be a cause of lameness. Radiographic evidence of an extensor process fracture does not prove that it is the cause of lameness. The results of the radiographic study must be combined with the findings of the lameness examination and intra-articular anesthesia to determine the significance of the finding.

A small fracture fragment is seen arising from the extensor process. The fracture fragment is relatively round and smooth and there is no radiographic evidence of degenerative joint disease. These findings suggest that the fracture is chronic and may, therefore, be an incidental finding.
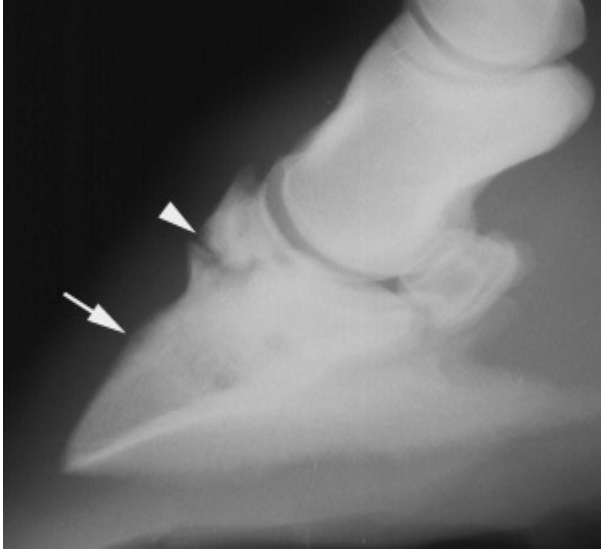
This radiograph is from a horse with a chronic extensor process fracture. The original fracure line is faintly visible (arrowhead). The unusual, bulging shape of the extensor process is the result of remodeling. Despite the size of the fracture fragment and the extensive remodeling there is little evidence of degenerative joint disease (in fact, this fracture was an incidental finding - lameness was the result of navicular disease!)

Smooth periosteal response is present on the dorsal surface of the distal phalanx (arrow). This is usually an indicator of prior inflammation of the distal phalanx and may be related to the fracture.

Fracture of the Middle Phalanx
Fracture of the middle phalanx is most commonly seen in horses that perform activities that require sliding and turns on the hindquarters (the weight of the horse is on the hindlimbs only as the horse pivots). Polo ponies, Western performance horses (cutting and reining horses) and jumpers are the most likely to suffer a fracture of this bone during athletic activity. They may also occur during leisure activity (lunging, light riding, unrestrained paddock exercise). These fractures are typically comminuted and involve the articular surfaces of the proximal and distal interphalangeal joint.
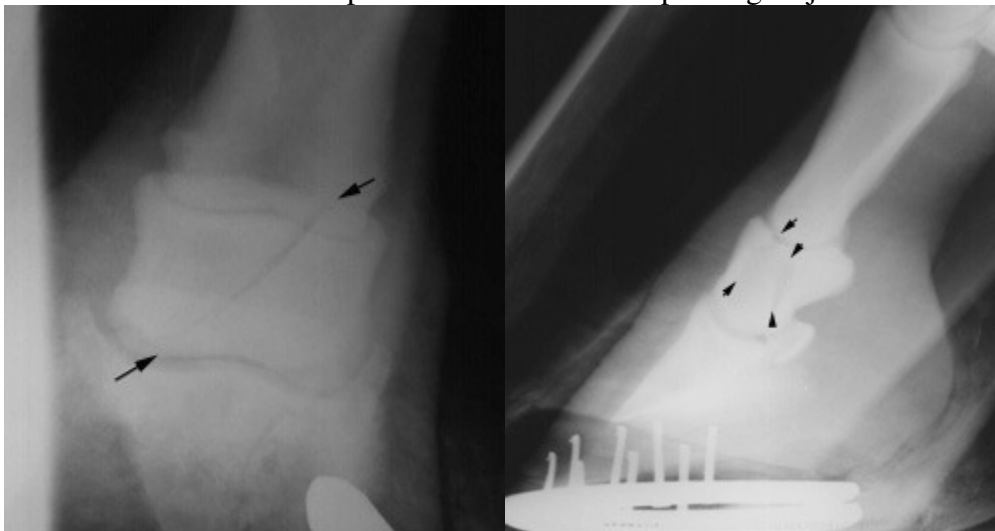
The radiographs above are not of good quality but this is because a cast has been placed on the distal limb to stabilize the fracture for transport to the university. This is an appropriate level of care and can significantly improve the chance for successful repair of the fracture.

In the dorsopalmar view a fracture line is seen (arrows) extending from the proximal interphalangeal joint, obliquely through the middle phalanx to the distal interphalangeal joint. In the lateral view 2 fracture lines are seen (the arrowheads are at the proximal and distal aspects of each fracture line).

Because of the complexity of these fractures, radiographs tend to underestimate the number of fracture lines (and therefore, fracture fragments) that are present. Oblique views are also obtained in an effort to better define the fracture configuration. If available, computed tomography can be extremely useful in the evaluation of these fractures and allow for accurate surgical planning.

Fracture of the Proximal Phalanx

In this section we will show examples of proximal phalangeal fractures that involve the body of the bone - those fractures that involve only the proximal articular margin of the bone will be discussed with the fetlock joint. Fracture configurations of the body of the proximal phalanx are quite variable and range from incomplete sagittal fractures to comminuted fractures.

Incomplete fractures of the proximal phalanx begin at the proximal articular surface in the sagittal groove. They extend a variable distance into the proximal phalanx along a sagittal plane but do not exit the bone (this would be a complete fracture). They are common in Standardbred racehorses.

These fractures are usually only visible in the dorsopalmar (or dorsoplantar) radiograph. In the acute phase the fracture line may be difficult to impossible to visualize. Within 7-10 days bone resorption will occur along the margins of the fracture making the fracture line wider. Sclerosis of the surrounding bone may create increased opacity around the fracture. These changes allow the fracture line to be easily seen (red arrow).

Careful evaluation of the lateral view may show faint periosteal reaction along the dorsoproximal margin of the bone. This is not seen in the acute stage since periosteal new bone takes 2-3 weeks to be visible radiographically.

Although the diagnosis is obvious in this case, an acute incomplete fracture can be virtually impossible to detect. If an incomplete fracture is suspected from the clinical history, a conservative approach is indicated. This may consist of resting the horse and repeating the radiographs in 7-10 days. It is important to take several dorsopalmar projections at different angles to the joint and using different techniques when evaluating for a possible incomplete fracture. Slight overexposure of the dorsopalmar view will make a fracture line easier to see. On the other hand, slight underexposure of the lateral view will make subtle periosteal reponse easier to see. If the owner does not want to wait to retake films then nuclear scintigraphy can be performed to evaluate for the presence of bone activity. If a fracture is present a focal, intense area of isotope uptake will be present in the dorsal first phalanx (that is in fact how the above fracture was initially diagnosed).

Incomplete fractures of the proximal phalanx may progress and become complete fractures. Complete fractures may remain in the sagittal plane and exit the bone at the center of the distal articular surface or may exit along the lateral or medial aspect of the bone. Although this is only faintly visible in this view, oblique views demonstrated that the fracture in this case exited along the lateral aspect of the bone (arrowhead) proximal to the articular surface.

The red arrows indicate the fracture line within the bone. Although there is only one fracture two lines are visible. This is because the plane of the fracture is different in the dorsal and palmar cortices of the bone. The fracture line appears to cross over into the distal metacarpal bone (black arrow). The fracture is only in the proximal phalanx - this appearance is the result of superimposition of the articular surface of the proximal phalanx (dotted line indicates the palmar aspect of the articular surface) with the distal third metacarpus.

The prognosis of a fracture, particularly in an athlete, is significantly affected by articular involvement. In this case the fracture enters only the proximal interphalangeal joint. The prognosis is better than if it entered both the proximal and distal interphalangeal joints.

Lag screw fixation of this fracture configuration is the preferred treatment. This helps to stabilize the fracture and prevent further damage to the articular surface. If the alignment and compression is good very little secondary arthritic change should develop in the joint.

The distal screw enters the proximal phalanx along its lateral margin.The 2 proximal screwheads appear to be placed within the bone but are actually on the dorsolateral bone surface. They were placed in this fashion to follow the slight "spiral" path of the fracture. The fracture line is still faintly visible but is much narrower indicating that good compression has been achieved.
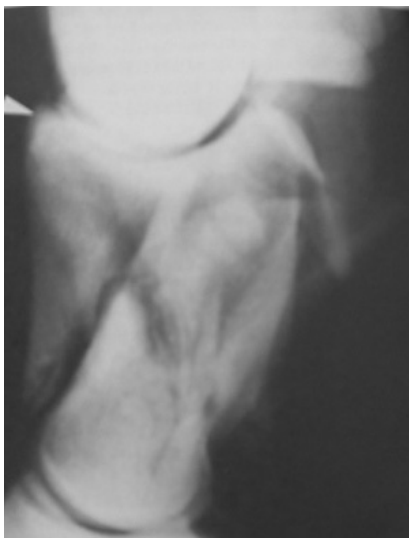
In the "worst case" scenario, an incomplete fracture may progress to a highly comminuted fracture as in this example. If this occurs there is no surgical option. If a horse is economically valuable and has potential as a breeding animal an attempt may be made to treat the fracture with a cast or external fixator. The healing time is prolonged and the horse will often be significantly painful until the fracture heals. Even if fracture healing occurs the horse will generally be lame as a result of the severe arthritic changes that develop.

Horses with this type of fracture are often humanely destroyed. This is often the wisest choice both humanely and economically.

LAMINITIS

Laminitis is defined as inflammation of the laminae of the foot. Factors that may trigger the onset of laminitis include endotoxemia, overeating, local trauma and corticosteroid administration. Research suggests these and many other factors can trigger a peripheral vascular response within the feet. Vascular changes including decreased capillary perfusion and significant arteriovenous shunting lead to ischemic necrosis of the laminae.

Clinically the affected horse is lame and painful with the pain localized to the feet. There is increased heat in the feet and the palpable digital pulses are increased. Laminitis is most common in the forefeet but may occur in all 4 feet. It may also be seen in a single foot if the horse is non-weight bearing on the contralateral limb. Most horses with laminitis will stand with the forefeet stretched forward so that the majority of the weight is borne on the heels. They are generally quite reluctant to move and may spend a lot of time recumbent.

The radiographic changes of laminitis are the result of edema of the sensitive laminae and of loosening of the interconnections between the sensitive and insensitive laminae of the hoof.

Laymen often use the term "founder" as synonomous with laminitis. This is the "f" word of equine practice!

Radiographic Evaluation for Laminitis

Lateromedial views of the feet are the only views needed to evaluate for laminitis. The dorsal 65-degree proximal-palmarodistal oblique view may be used to evaluate the vasculature of the distal phalanx and to determine if bone resorption is present. However, this is not needed in most examinations.

It is important to be able to locate the dorsal surface of the hoof wall and the location of the coronary band when evaluating radiographs in laminitic horses. This allows measurements to be made that help define the severity of the disease process and the prognosis for the horse. Placing a metallic marker (nail, horseshoe nail, etc) along the dorsal surface of the hoof wall with its proximal aspect at the coronary band allows easy identification of these structures.
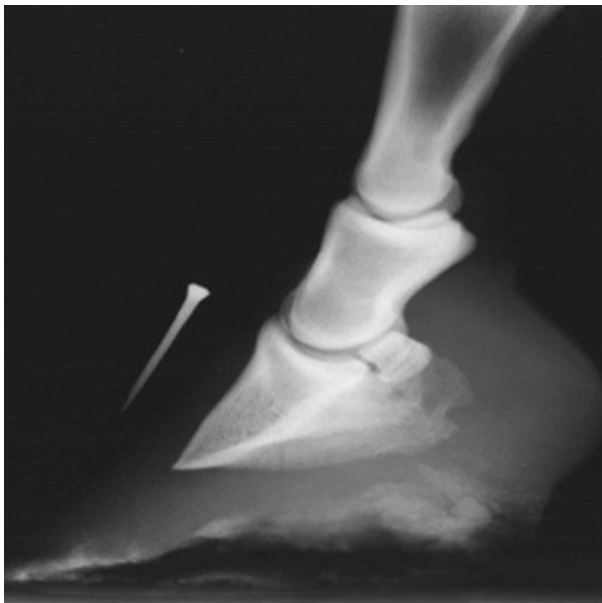
In this case a horseshoe nail has been used to mark the hoof. The head of the nail is at the coronary band. Notice that although the radiographic technique used has overexposed the dorsal soft tissues of the hoof the dorsal margin can be identified by the marker.
Notice that in this normal horse the marker is parallel to the dorsal surface of the hoof wall. The hoof is excessively long in this horse but the skeletal structures are normal .

Laminar Edema
Some individuals with laminitis will have only laminar edema. This causes an increased thickness of the laminae that is seen as increased distance between the dorsal hoof wall and dorsal surface of the distal phalanx.

Radiographically, this appears as increased thickness of the dorsal soft tissues. The distance between the marker and the dorsal surface of the distal phalanx is measured perpendicular to the hoof wall, in three areas.
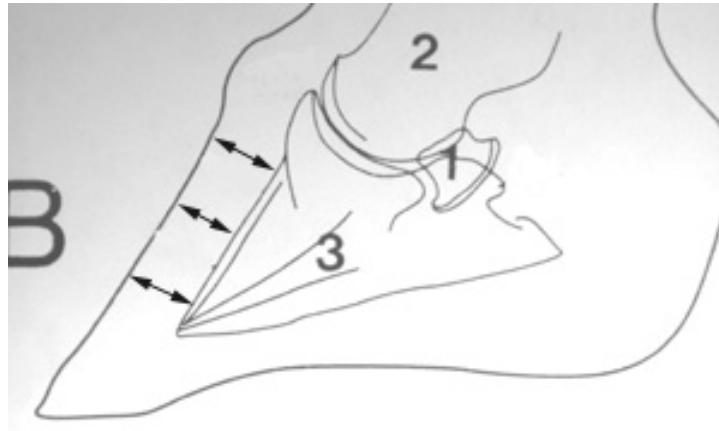

Proximal - 2mm distal to the junction of the extensor process and dorsal cortex of P3
Distal - 6 mm proximal to the tip of P3
Middle - halfway between proximal and distal
In normal horses the 3 measurements are the same. In a study evaluating Thoroughbred racehorses the dorsal soft tissue thickness was approximately 15 mm. A value of 18 mm or less is considered normal for light horses. The value may be slightly higher in Warmbloods and higher in Draft breeds.

The thickness of the dorsal soft tissues is affected by the size of the horse and also by radiographic magnification. In order to compensate for these factors a method of measurement has been used that compares the thickness of the dorsal soft tissues to the palmar cortical length of the distal phalanx. Use of a ratio removes the effect of horse size and magnification since both factors in the ratio are equally affected by these variables.
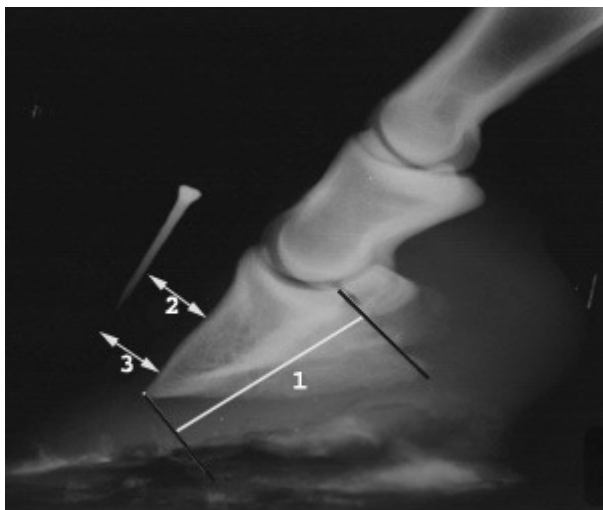

The soft tissue thickness in the middle (2) and distal (3) areas is compared to the length of the palmar cortex of the distal phalanx (1). The palmar cortex extends from the dorsal tip of the the distal phalanx to the articular margin(indicated by white line). In this example the dorsal soft tissues measured 11 mm and the palmar cortex measured 59 mm on the original radiographs. The ratio is therefore 19%.

In a study of Thoroughbred racehorses the normal soft tissue : palmar cortical length ratio was 23% in the middle area and 23.5% distally. It is suggested that a ratio of 28% or greater is consistent with laminar thickening.

Palmar Deviation of The Distal Phalanx

Laminar edema causes the interdigitations between the sensitive and insensitive laminae to loosen, especially those along the dorsal surface of the distal phalanx. As the horse bears weight, P3 moves downward in the hoof capsule causing separation of the lamina. In addition, the deep digital flexor tendon pulls the tip of the distal phalanx in a palmar direction. The effect of these two actions is palmar deviation of the tip of P3. Because of this palmar movement of the tip of P3, the bone appears to "rotate" within the hoof capsule. The common term for this palmar deviation is "rotation of P3."
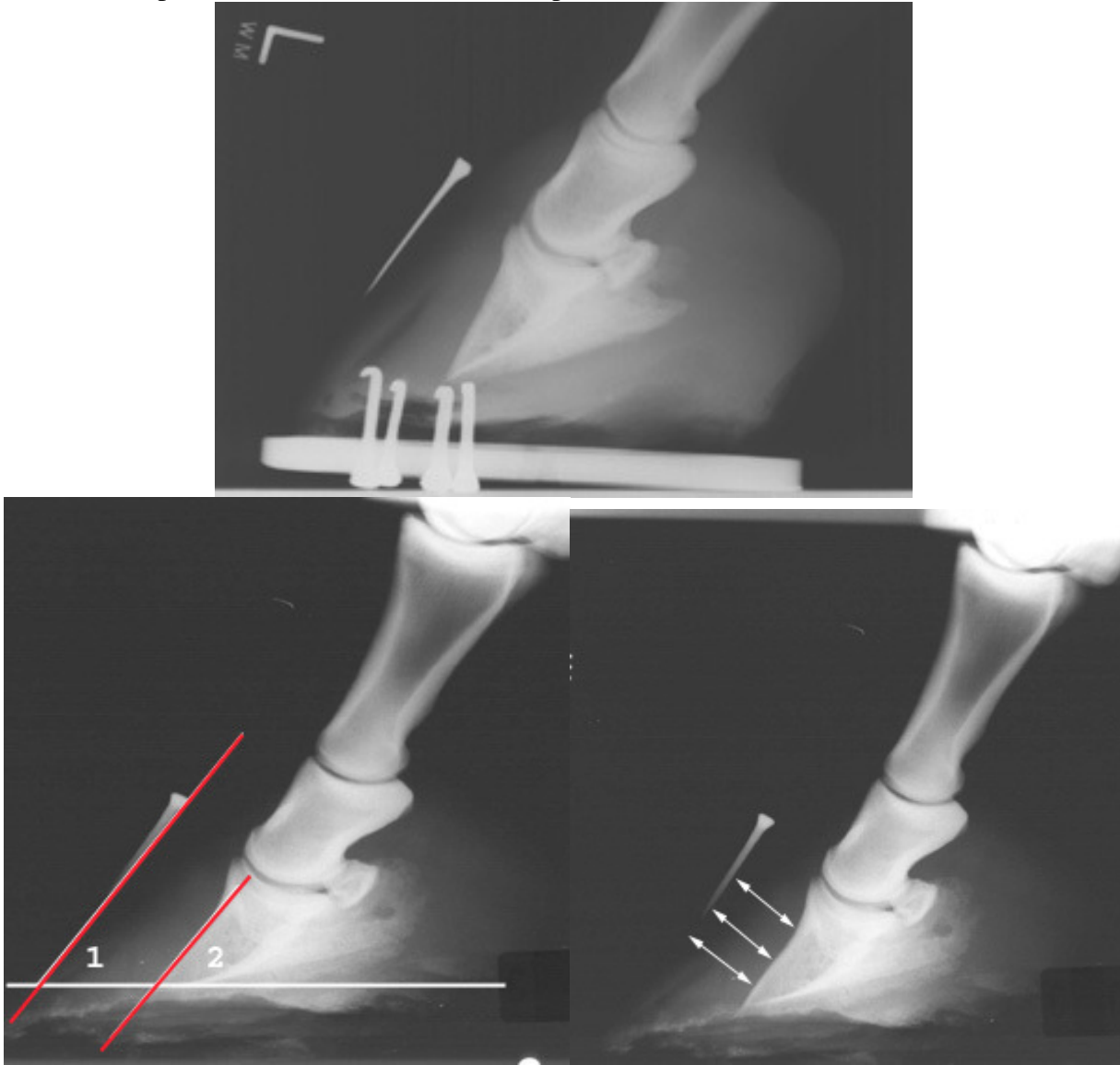
Two methods may be used to determine the degree of palmar rotation of the distal phalanx.

Method 1 - Lines are drawn along the dorsal aspect of the hoof wall and distal phalanx (red lines). Notice how the metallic marker on the hoof wall helps in this process. A line is then drawn parallel to the ground surface of the hoof to intersect these two lines. The angles (1) and (2) are compared and in a normal horse should be approximately equal. If rotation is present angle (2) will be greater than angle (1). In the example used here angle (1) measured 58 degrees and angle (2) measured 60 degrees.

Method 2 - The distance between the dorsal surface of the hoof and the dorsal surface of the distal phalanx is measured in the three areas described above (proximal, middle and distal). The three

measurements should be approximately equal. If rotation is present the distal and/or middle measurements will be greater than the proximal one. In the example used here the measurements are proximal = 25 mm, middle = 25 mm and distal = 28 mm.

Method 1 is the preferred method of evaluation since it determines the degree of rotation and the degree of rotation has been shown to be inversely related to the ability of the horse to return to athletic function.
Favorable prognosis - less than or equal to 5.5 degrees of rotation
Guarded prognosis - 6.8 to 11.5 degrees of rotation
Unfavorable prognosis - greater than or equal to 11.5 degrees of rotation
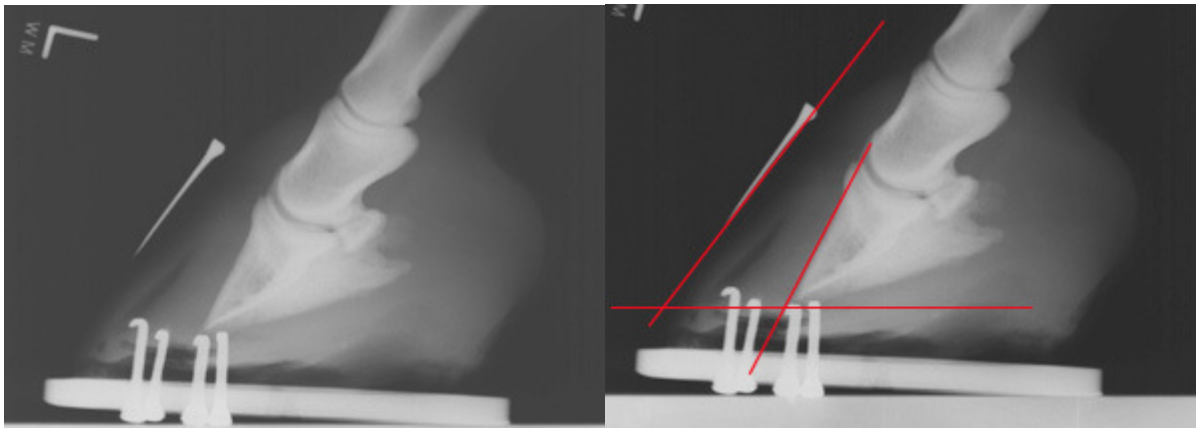
This is an example from a clinical case. Although rotation of the distal phalanx is clearly evident, placement of lines along the dorsal surface of the hoof and the distal phalanx allows the measurement of the degree of rotation. In this case there is approximately 10 degrees of rotation. The lucent area in the dorsal laminar tissue is gas. This is an indication of laminar separation.

"Sinking"
A variation of laminitis in which the entire distal phalanx sinks within the hoof capsule is commonly referred to as sinking (the horse is then referred to as a "sinker"). In these horses all of the laminae of the hoof (not just the dorsal laminae) loosen, and the weight of the horse drives P3 distally within the hoof capsule.

Clinically these horses tend to stand with the forefeet under the body (not out in front as in classic laminitis). They are extremely painful and reluctant to move. As the distal phalanx separates from the hoof and moves distally, an obvious palpable depression may develop at the coronary band.

Radiographically, sinkers have evidence of thickened dorsal soft tissues and an increase in the ratio of dorsal soft tissue thickness to palmar cortical length (some researchers consider an increase in this ratio to be an indicator of sinking). Additionally, the extensor process of P3 moves distally with respect to the coronary band. The coronary band is not usually visible as a distinct structure in a radiograph - this is why it is important to mark its position. Because the entire distal phalanx is moving distally, the dorsal surface of the hoof capsule and of P3 remain parallel.

The exact vertical distance between the coronary band and extensor process is quite variable between horses so it is difficult to determine if a horse is a sinker from one film series. Sequential film series may be compared for a change in the vertical distance between the coronary band and extensor process. An increase in this distance is considered evidence of sinking.

Preliminary work has been performed to establish the distance between these structures in normal horses but reference numbers for all horses are not yet available. Also, the method used to determine this distance is relatively complicated.
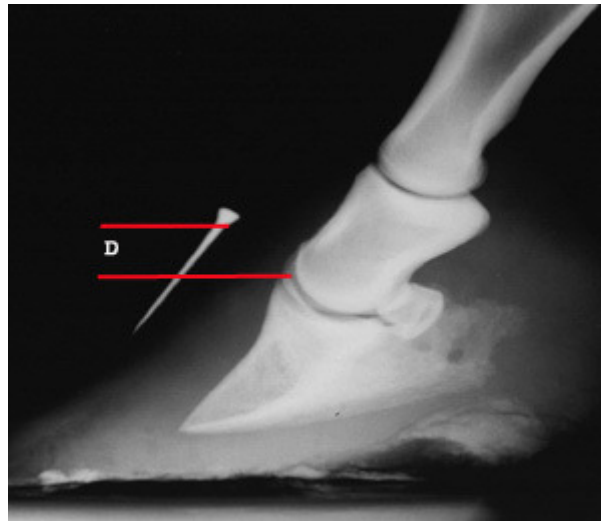

The vertical distance between the coronary band and extensor process is designated D. The true distance (corrected for magnification) can be calculated by using the formula

Actual Length of D =

Length of D measured on the radiograph X Actual length of the marker

Length of marker measured on radiograph

Chronic Laminitis

If a horse has had chronic (> 3-4 weeks) laminar inflammation, radiographically detectable remodeling of the distal phalanx will occur.
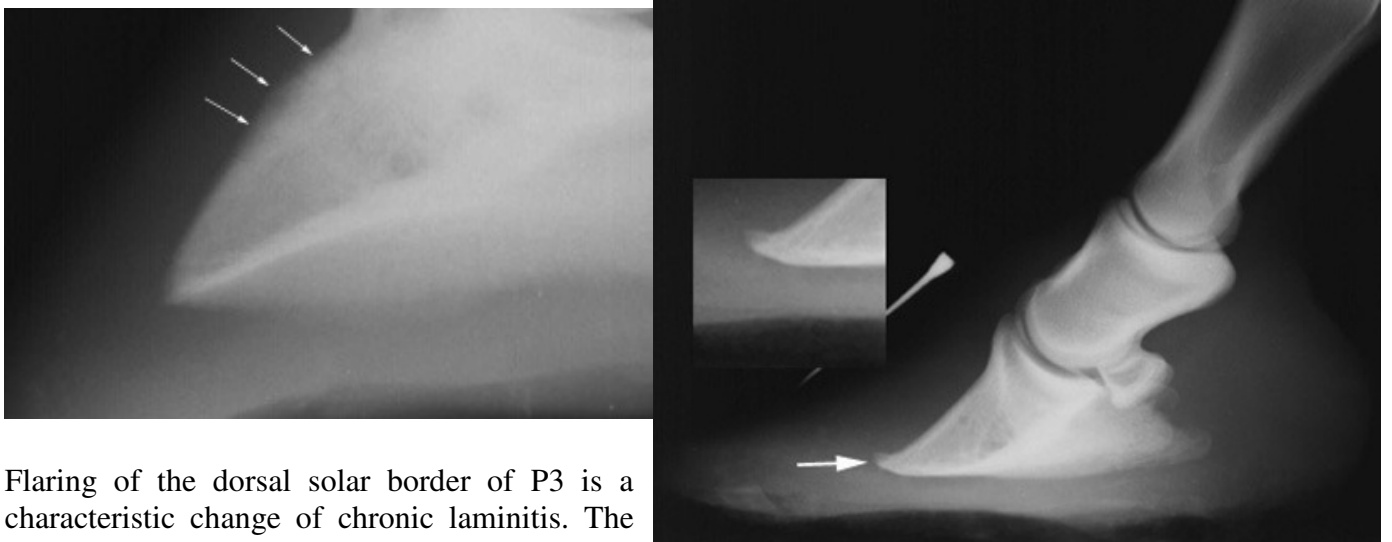
Flaring of the dorsal solar border of P3 is a characteristic change of chronic laminitis. The tip of P3 may have a distinct "ski-tip" appearance (see inset left) or may appear fuzzy and indistinct. Thickening of the dorsal cortex of P3 may occur (arrows right). If the change is active the margins of the cortex may appear slightly fuzzy; if inactive the margins will be smooth. These radiographic changes do not usually regress if the laminitis resolves - therefore, they may be seen in animals that have no current clinical evidence of laminitis.

If severe and long-standing laminitis is present. resorption of much of the distal phalanx may occur. This radiograph is from a pony with severe, chronic laminitis (there are two types of ponies - those that have laminitis and those that will have laminitis!!). The hoof is misshapen and the distal half of the distal phalanx is no longer visible. The proximal sesamoid bones are very lucent - this change is consistent with disuse osteopenia. The pony is, for obvious reasons, bearing little weight on this limb.

MISCELLANEOUS

Osteomyelitis

Osteomyelitis may occur in any of the phalanges, usually as the result of a penetrating wound or surgery.

Osteomyelitis of the distal phalanx occurs relatively frequently following penetration of the sole by a sharp object (nail, sharp metal, etc). The radiographic appearance of osteomyelitis of the distal phalanx is somewhat different from that of other bones. Because the distal phalanx has a modified periosteum there is little evidence of periosteal proliferation. The dominant feature of osteomyelitis of the distal phalanx is bone lysis. Bone lysis may not be radiographically visible for 10-14 days following injury and in the early phase the lysis can be quite subtle. This is why it is important to re-radiograph the distal phalanx if the horse fails to respond to appropriate treatment following penetrating injury to the foot.
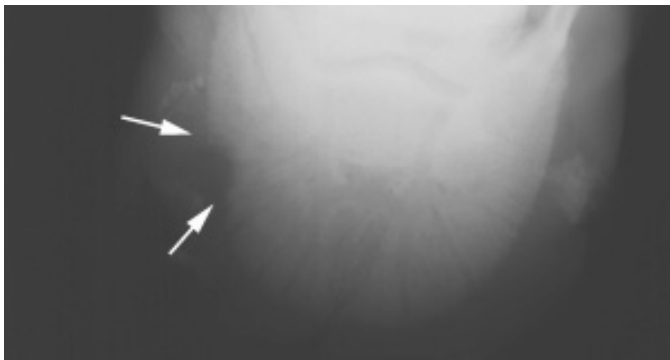

Dorsopalmar and dorsopalmar oblique views of the distal phalanx are needed to evaluate for osteomyelitis. In this radiograph, an area of bone resorption is evident along the solar margin of the distal phalanx (arrows). The areas of opacity in the tissue around the distal phalanx are material within the hoof.

Bone Cyst
Occasionally, bone cysts (syn. - subchondral bone cysts) occur in the phalanges as a result of osteochondrosis - a developmental orthopedic disease. The cysts may occur adjacent to any joint but are most typically seen in the distal articular surface of the proximal phalanx, proximal articular suface of the middle phalanx and at the articular surface of the distal phalanx.

Remember that osteochondrosis is the result of a failure of enchondral ossification. A cyst is formed by the retention of cartilage within the bone immediately adjacent to the articular surface. This thickened area of cartilage undergoes necrosis and is visible as a circular lucency in the subchondral bone.

Initially, the articular cartilage over the cyst may be intact. If a defect develops in the articular cartilage the necrotic material within the cyst drains into the joint and causes synovial inflammation. This begins the cycle of degenerative joint disease.
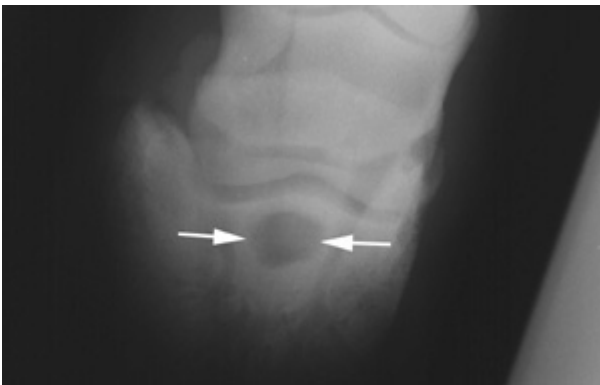

This dorsopalmar view shows a very large cyst in the center of the distal phalanx (arrows). There is no obvious connection between the cyst and the distal interphalangeal joint in this radiograph. A dorsopalmar horizontal beam view would also demonstrate the lesion and possible connection to the joint (this is not always visible radiographically however).

Keratoma
Keratomas are benign tumors that arise from the keratin containing cells of the lamina of the hoof. They are relatively rare. The tumors grow as soft tissue masses within the hoof capsule. Because there is little room for expansion of the mass, with increasing size resorption of the distal phalanx occurs as a result of pressure necrosis. Clinically, the horses are chronically lame. In some cases the soft tissue mass may be palpable above the coronary band.

Radiographically, an area of bone resorption will be seen in the distal phalanx. The area of bone resorption tends to be relatively large by the time the horse is significantly lame and radiographs are obtained. The bone resorption may occur anywhere within the distal phalanx.
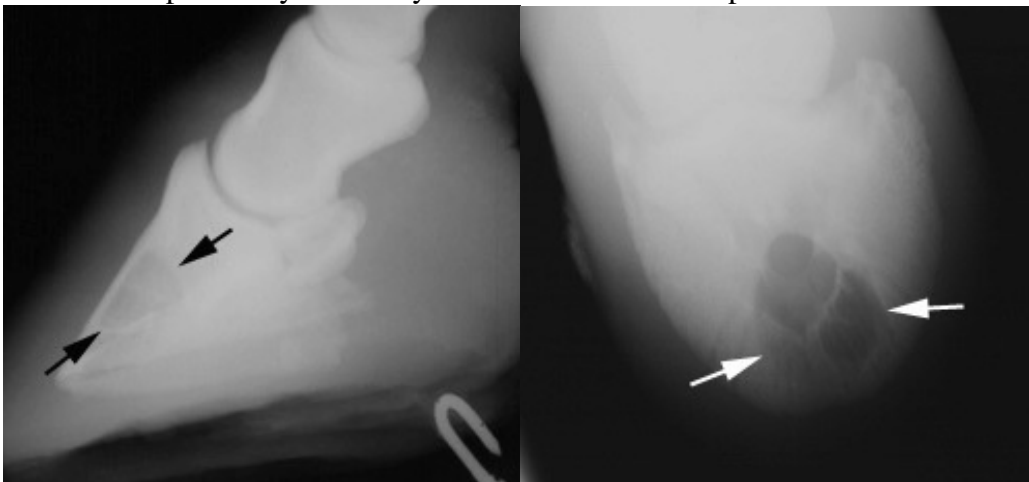
These radiographs are typical of a keratoma. The area of bone resorption is visible in the lateral view (black arrows) but is considerably more obvious in the dorsopalmar view (white arrows) . Although there is bone loss as in osteomyelitis the large size of the lesion and the distinct margination make a diagnosis of osteomyelitis unlikely. Another key differentiating factor in this case may be the history - gradual onset of lameness with no history of penetrating wound (keratoma) vs. acute onset of relatively severe lameness following a penetrating wound to the foot (osteomyelitis).

Very rarely, other types of soft tissue tumors arising from the laminar tissue will create this radiographic appearance. Tumor types that have been reported in the literature include hemangioma, squamous cell carcinoma and intraosseous mast cell tumor.

Ossification of the Accessory Cartilages (Sidebone)
Ossification of the accessory cartilages of the distal phalanx occurs to some extent in most horses. It is only when the ossification is extensive that a clinical problem may develop. Many horses with radiographic evidence of cartilage ossification have no lameness related to it.

Excessive ossification is thought to be related to trauma to the cartilages as a result of concussion to the quarters of the hoof. The concussive force to this area may be worse in horses with poor conformation, as a result of poor shoeing or as a result of work performed on hard surfaces. When draft horses worked on cobblestone streets sidebone was more often a cause of lameness.
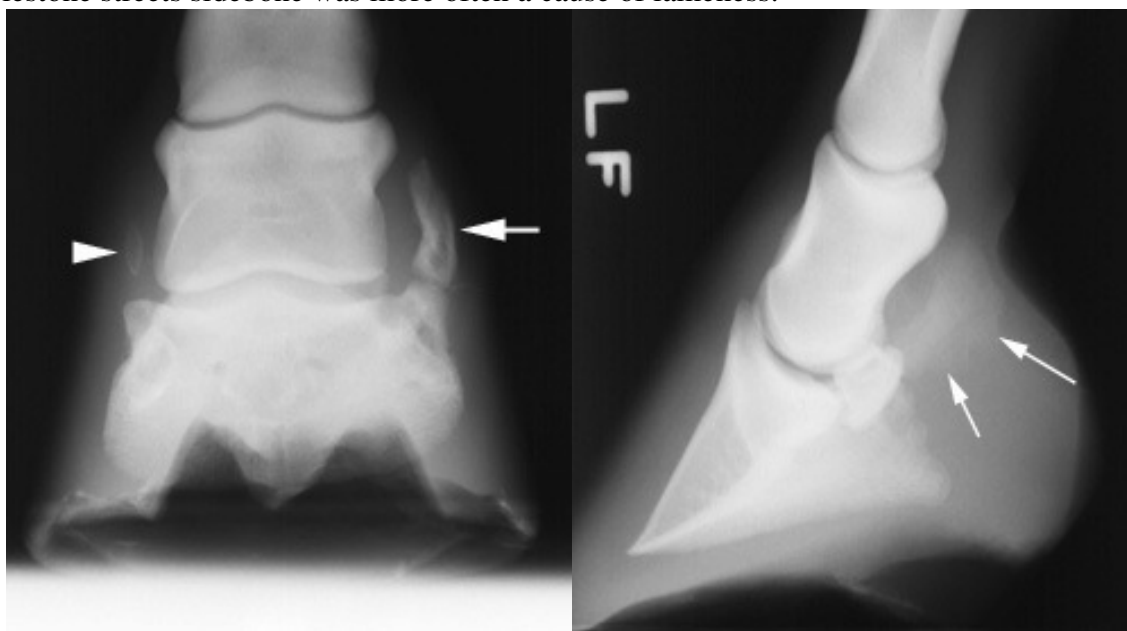
In the dorsopalmar view the accessory cartilages are visible as mineralized structures extending proximally. The lateral cartilage (arrow) is large and well mineralized. The lucent line between the ossified cartilage and the remainder of the distal phalanx is an area of non-ossified cartilage between the bone and the ossified cartilage, not a fracture line. The medial accessory cartilage has less obvious mineralization (arrowhead).

In the lateral view the faint mineral opacity palmar to the middle phalanx (arrows) is the superimposed ossified lateral accessory cartilage

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