Weight bearing – Hoof, wall or both?

Hoof stream

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How and where the foot is loaded has been a point of much discussion over the past few decades: one contention is that the external epidermal hoof wall is the primary loading structure, while at the opposite end of the spectrum that the solar surface structures are the primary loading structures. In the former situation, the hoof wall is trimmed in such a manner that the hoof wall extends below the solar surface in order to be loaded through the application of a shoe or merely be the extension of the hoof wall. This peripheral loading of the hoof wall will allow the wall to suspend the distal phalanx and other foot tissues through connecting tissue elements between the distal phalanx bone and internal hoof wall tissues. On the other end of the spectrum loading the solar surface will place the load a greater area of the foot including the sole and frog epidermis along with bars. The filling and potential supporting of solar foot through the dirt plug will probably have a role depending ground surface. The internal foot tissues within the distal phalanx, digital cushion, lateral cartilages, etc. through solar loading will be different than the hoof wall loading. The foot tissues will adapt and respond to the loading forces differently in these two instances and they will respond either in a positive or negative manner. Morphological evidence will be presented showing the changes that the internal foot tissues undergo when the hoof wall is the primary loading structure as well as the solar surface.

Loading of the foot

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The tissues within the foot will respond differently: With the hoof wall being the loading structure virtually all or most of the loading forces will be within the hoof wall, while in the latter solar loading situation, the wall will be at most only minimally loaded, somewhere between 5-20% of the weight is an approximate "guestimation" with the remainder of the weight loading will be on the sole and potentially other solar tissues. Obviously, the extent of wall loading in the barefooted condition will be dependent upon how much the wall is beveled along the wall-white line junction.

Regarding the biomechanical effects on the foot's tissues with the hoof wall as the primary loading structure, this support mechanism will suspend the distal phalanx and other foot tissues through the hoof wall as the connecting tissue elements form the bond between the distal phalanx bone and internal hoof wall tissues. In the barefooted horse usually, the hoof wall is trimmed in such a manner that the hoof wall extends below the solar surface for some distance which will be loaded.

In the latter situation with the barefooted condition, the solar surface of the foot will be under compression with reduced tangential forces being present upon the hoof wall during some time of the trimming cycle. In this barefoot situation, the wall loading will vary somewhat depending upon the extent of beveling the wall and the time interval between trimmings: as the wall will gradually assume greater loading percentage surface as the wall grows.

The questions are "Are there changes to the tissues within the foot under these two conditions, and if so, what are they?"

Peripheral loading of the hoof wall

In the finite element model, when foot loads are applied to a cross-section of the hoof wall, the model shows that bone as calcium loss will be in the distal third of the coffin bone, while it will be deposited more proximally in the coffin bone. This bone loss, or thinning, of the cortices of the coffin bone can be verified through histology and measurements of the cortical bone thicknesses which show significantly less bone in the distal and lateral portions of the coffin bone. Such peripheral loading of the foot will also change the supporting architecture of the internal foot of the inner wall and the bone of the distal phalanx.

The peripheral loading forces pass via the wall to the coffin bone; these forces result in the reorientation of the connective tissues along the distal phalanx to attach to the inner hoof wall. This reorientation changes from a parallel position to the dorsal cortex of the distal phalanx (i.e., periosteum) to one in which collagen fibers become more perpendicular to bridge the dermis between the bone cortex and the inner hoof wall. (NOTE: the actual orientation will vary depending upon where they are positioned on the foot.)

These collagen fiber attachments are referred to as the Suspensory Ligament of the Distal Phalanx (SADP). These SADP attachments between the coffin bone and the inner hoof wall will be under different stresses around the circumference of the hoof wall due to differences in loading: (1) During movements when loading of the foot, the hoof wall will be loaded and forced proximally, while the bony column of the digit will descend into the foot. This action creates opposing movements -shear forces-between the hoof wall and the coffin bone. (2) Greater movements are present distally as the hoof wall moves due to the physical forces at the ground surfaces and due to the viscoelastic properties of the hoof wall enabling movements in all three plans to reduce or alleviate internal wall stresses. (3) There will also be movements between the coffin bone surface and the hoof wall as the perimeter of the hoof wall becomes loaded.

With movements between the coffin bone and the hoof wall, bone is lost around each collagen bundle attachment (SADP), creating a pore, or "cookie cutter hole", within dorsal cortex of the coffin bone. With greater movements the hole into the cortex will be larger than with minimal movements. This created hole in the dorsal cortex is in addition to the thinning of the cortical bone due to the peripheral loading of the foot as evidenced via the finite element modeling.

Solar loading of the foot

With more solar loading greater compressive forces will be located on the foot as opposed to the hoof wall. However, the loading forces will vary quantitatively, depending upon how the foot is trimmed: (1) With a wall trimmed level with the hoof wall, some weight will be on the wall with presumably more on the solar surface due in part the dirt plug, etc. However, with time as the wall grows distally, the wall will have more and more of the load being shifted from the sole to the wall. The wall may crack, or break, under these increased forces. (2) With greater beveling of the hoof wall more and more load will be located on the sole.

This solar shifting of the load will also be dependent upon the frequency of trimmings, etc. Thus, barefooted horses should be trimmed more frequently than intermittently. Under these situations though the more bone in the coffin bone will be deposited in accord with the finite modeling. Also, the connective tissues surrounding the distal phalanx with preferentially remain as the periosteum, or connected to the coffin bone, rather than become part of the SADP.

These solar loading changes will result in (1) denser cortical and solar bone of the distal phalanx and (2) fewer pores, or holes, in the dorsal cortex, which also contribute to a denser coffin bone. These two observations will result in a denser coffin bone and thus be in a better position to support the bony column. Other foot tissues will also benefit with solar loading including the digital cushion, lateral cartilages, ligaments, etc.

In terms of an overall healthy foot the foot should be significantly engaged with the solar surface of the foot. However, in all practicality the wall will also be loaded during some part of the trimming cycle as if the wall is trimmed flat to the sole, the wall will gradually grow and extend beyond the sole a small amount. With growth more and more of the wall will be loaded.