THE USE OF THE WOODEN SHOE IN TREATING DORSAL CAPSULAR ROTATION OF THE THIRD PHALANX IN CASES OF CHRONIC LAMINITIS OF THE EQUINE.

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Introduction:

Numerous therapeutic shoeing methods have been proposed to aid the damaged hoof mechanics that are a result of laminitis. Chronic laminitis is defined by the presence of mechanical collapse of the lamellae and the displacement of the distal phalanx within the hoof capsule (1). The use of the wooden shoe is gaining popularity among veterinarians and farriers as a very workable solution to the multitude of complications each case can present (2). The advantages offered by the wooden shoe include:

1. Atraumatic application using wood screws supported with hoof glue or fiberglass casting material
2. Easily adjustable to the horse's comfort during and after application
3. Maximum recruitment of hoof load bearing surface area
4. Maximum mechanical advantages readily employed and easily adjustable
5. Maximum combination of rigidity, shock absorption, weight, and wearability
6. Readily available materials for construction and application
7. Ease of shoe design alterations-(formable) including post-shoeing
8. Ease of application (and reapplication) for horse and farrier

9. Immediate analysis of gait and pain relief (usually expected)
10. Accepts and maintains placement of viscoelastic sole supporting material
11. Easily adaptable load bearing surface to unload pained (toe) areas as it protects the sole area from ground forces
12. Maximum stabilization of the third phalanx while maintaining mobility of patient

The use of a full rolling motion metal shoe (a very similar design to the wooden shoe) with oakem sole packing was advocated in the late 1800's (3) as a treatment for chronic laminitis. The similar design of the wooden shoe better lends itself to the same parameters the author described earlier; however, with the aid of radiographs, many of the parameters can now be well defined and shoeing prescriptions adjusted according to the needs each case dictates.

The present knowledge of chronic laminitis recognizes the significance of the mechanical collapse of the lamellae and the variability with which the distal phalanx may be displaced. The successful treatment of this condition is dependant on the amount of damage to the lamellae and possibly our ability to mechanically minimize the stress on the damaged lamellae with therapeutic shoeing. Therapeutic shoeing should include stabilizing and protecting the internal hoof architecture of the hoof in a way to allow realignment and promote reattachment of the third phalanx as the hoof mass is encouraged to increase.

The importance of shoe mechanics in the treatment of chronic laminitis is becoming better understood and the veterinary and farrier professions are becoming better educated in providing advantageous mechanical aids to offset the deleterious effects of the mechanical collapse of the bony-lamellar attachment. The unique ability of the wooden shoe to be readily modified is very desirable in adding or subtracting mechanics to the shoe design as dictated by the individual case. The ability to easily add height to the shoe allows one to employ mechanics that very few shoe designs can easily duplicate. In general, the more rotation of the distal phalanx, the more palmar digital breakover needs to be placed to reduce the forces on the DDFT during locomotion. The less force the DDFT exerts on the distal phalanx as a result of the mechanics of therapeutic shoeing, the less mechanical shear forces will be exerted on the damaged lamellae. This will result in less pain to the damaged hoof, especially during locomotion. The limited height of most shoeing systems allows only a small amount of breakover modification without the solar surface being further invaded.

Dorsopalmar shoe mechanics are not unique to various shoeing systems; however, the unique design of the wooden shoe also employs mediolateral shoe mechanics that further reduce shear forces on the damaged lamellae. Most cases of dorsal capsular rotation show an increased pain response when the horse is turning. This seems to be the last portion of gait that pain subsides in the healing process. The wooden shoe addresses the problem of mediolateral shear forces on the lamellae and further aids the pained patient in attaining a more normal ability to locomote.

The solid, flat base of the wooden shoe allows for the maximum recruitment of surface area for weight-bearing. The ability to engage (load) the palmar foot (with the aid of a viscoelastic deformable impression material (a) and to unload pained areas (usually the toe region- by recessing the shoe's toe solar surface) is simplified using the wooden shoe. This allows further reduction of shear forces on the damaged dorsal lamellae by allowing weight-sharing by the soft palmar structures of the foot and reducing weight-bearing on the hoof wall-especially the toe (4).

One of the major advantages of the wooden shoe is the atraumatic application and the ability to immediately access the patient's response to the shoe placement and its mechanical design features. The wood screws can be readily applied from the hoof wall into the shoe as the horse is standing on the sole impression material and the shoe. The screws are easily inserted and the shoe can easily be repositioned (after initial application) for maximum pain reduction, without any trauma to the patient.

Radiology:

Radiographic studies are vital in the prognosis, diagnosis, and treatment of chronic laminitis. Lateral and dorsopalmar (DP) views are necessary to determine the parameters of the damage of the lamellae. Dorsal capsular rotation of the distal phalanx is readily noted on lateral radiographs and the DP view reveals any medial or lateral displacement of the third phalanx. Thickness of the dorsal hoof wall, the amount of dorsal capsular rotation, the solar surface of the distal phalanx relative to the ground surface, and the amount of live sole beneath the dorsal margin of the distal phalanx all need to be considered to formulate a trimming prescription and shoe design.

The radiographic features of each case dictate the hoof trim in one's attempt to realign the distal phalanx with the ground surface (see Fig.1). Generally, substantial heel is removed to achieve a normal alignment of the third phalanx in severe cases of dorsal capsular rotation. The therapeutic trim may increase the tension on the DDFT causing more stress on the damaged lamellae, therefore, adding undesirable pain to the foot. The horse may show signs of discomfort and hold the heel off the ground suggesting addition of a significantly wedged shoe for maximum comfort.

The amount of healthy sole distal to the dorsal margin of the third phalanx is usually eroded in cases of rotation of the third phalanx. A sole thickness of 10 to 15 mm is considered to be adequate to allow proper vasculature function (5) to the dorsal hoof. Realignment- via the hoof trim- encourages the hoof to increase the solar mass (via increased blood flow). The increase in solar/hoof mass helps to stabilize and protect the phalanx.

The thickness of the dorsal hoof wall and the amount of separation of the parietal surface of the distal phalanx are visualized on lateral radiographs. Evidence of fluid pockets, abscesses, and necrosis of the distal phalanx can be observed on lateral radiographs. One author (MLS) realigns the dorsal hoof wall by rasping the diverging wall, such that the trimmed wall realigns with the parietal surface of the distal phalanx (if the trim can be done atraumatically). This atraumatic wall resection allows the removal of the dead dorsal hoof wall and some of the underlying damaged lamellae and allows a shorter, less traumatic route of exudate exit- in case of abscessation (see Fig.2). The use of the lateral wall support combined with palmar solar support offsets the diminished wall structural integrity. The displaced toe wall provides a template for distortion of the toe re-growth and adds to laminar shear forces in the unshod hoof.

The use of radiographs prior to re-shoeing is essential to determine if there is enough new hoof mass to justify the shoeing. Radiographs before and after shoeings allow vital information to formulate new farrier prescriptions as sole mass increases and other parameters change with the oftentimes abnormal foot growth. Proper realignment is not always possible due to the lack of adequate sole mass to allow sufficient heel removal on the initial treatment.

As sole mass increases, as indicated on subsequent radiographs, the third phalanx may be further realigned by additional heel removal. This is usually achieved 4 to 6 weeks after the initial shoeing. If sufficient sole mass is not available, more time can be allowed until sole mass is greater than 12mm.

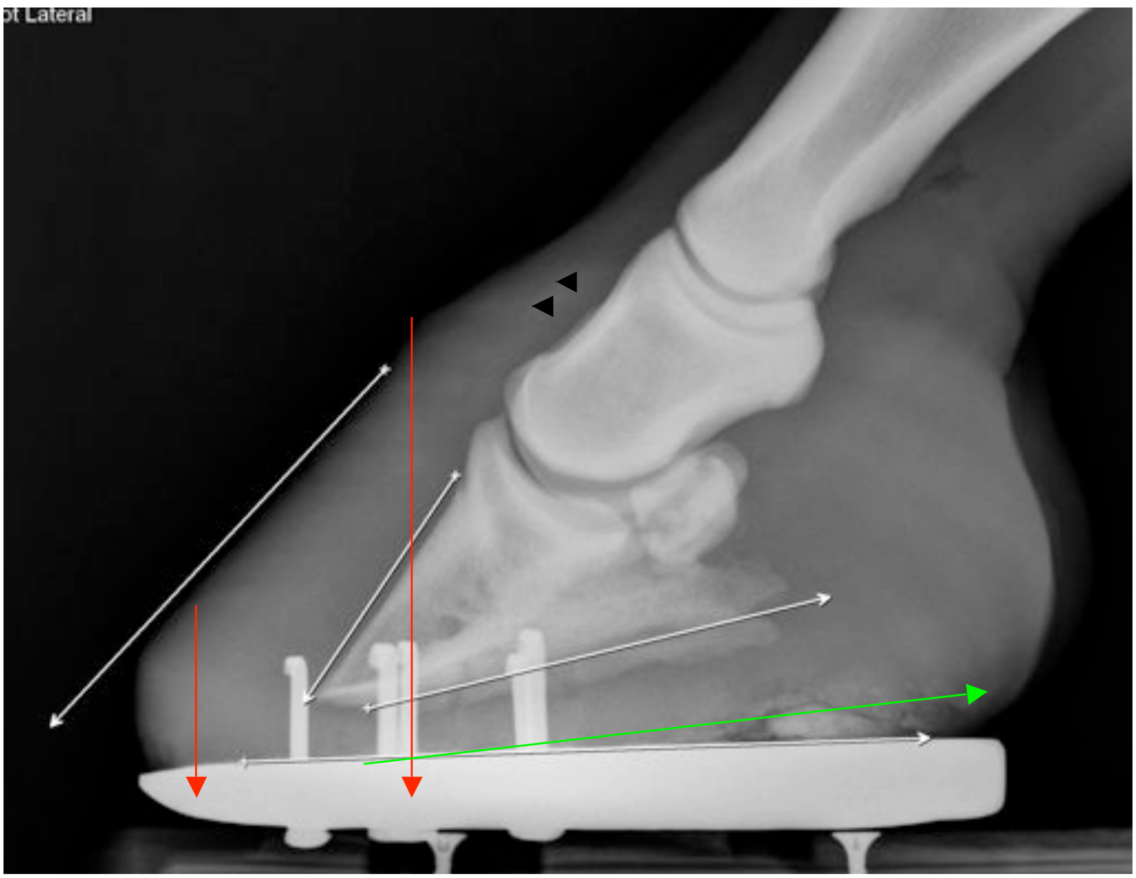

Fig.1. Dorsal capsular rotation is noted as the dorsal hoof wall diverges from the dorsal parietal surface of the distal phalanx. The green line at the top of the shoe and the solar surface of the heel region indicate the amount of heel to be removed to realign the bone with the ground surface. The quantity of live sole will often limit the realignment on the initial trim. The red lines represent the actual and theoretical breakover.

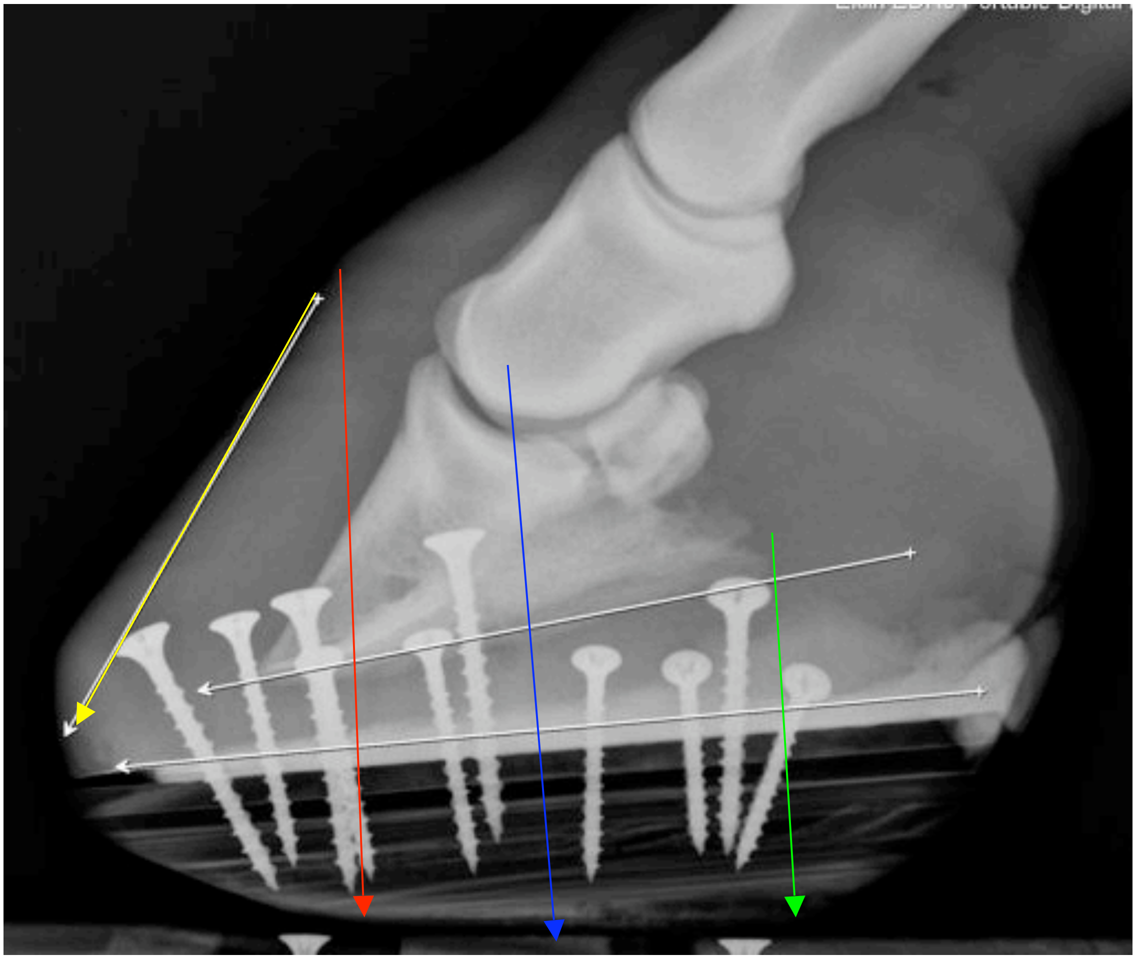

Fig.2. This is the foot from Fig.1 after the wooden shoe was applied. Breakover (as represented by the red line) was moved palmarly by further grinding the toe area after a 45 degree angle was initially cut into the shoe. The yellow line represents the dorsal hoof wall that can be further rasped to realign the dorsal hoof wall. The green line is the palmar portion of the shoe that initially makes ground contact. The point corresponds with the palmar-most aspect of the third phalanx. The impression material can be noted beneath the sole on the top of the shoe's solid base. The shoe is placed to extend palmarly to fully support the soft structures of the digit. The shoe is supportative of the bony column centered with the point of articulation (blue line). This also represents the widest part of the hoof.

Fig.3. This hoof model belonged to a horse that suffered laminitis as noted by the bony-lamellar deformity at the distal end of the third phalanx. Note the trough recessed in the shoe at the apex of the frog to the toe wall. This allows for the unloading of the toe region to minimize the weight bearing on this region. This area can be packed with a medicated packing, or opened to the front for abscess treatment/lavage. Impression material can be cut from the front of the foot to make sure no weight bearing is allowed in very sore cases.

Fig. 4. The combination belt sander/grinder is a very useful tool employed by many farriers. The belt sander makes fast work of applying breakover in a more palmar aspect simply by taking the toe bevel towards the back of the shoe in a 15 degree slope. The sander can bevel the 45 degree angles to the wall areas of the shoe and add heel angles if a band saw isn't available. Many farriers are carrying "blanks" of various sizes and adjusting the beveled sides and breakover as each case dictates. This picture shows a trough being ground into the top of the shoe to allow for a "dropped sole" to be unloaded. The sander allows a blending of the three planes of the wooden shoe in such a manner they appear as a smooth transition in hoof gait when the shoe is on hard surfaces. The mediolateral breakover designed into the shoe further reduces lamellae stresses, especially on turns.

Hoof Trim and Shoe Design and Placement:

The guidance of good radiographs is invaluable in providing the vital information to formulating a shoeing prescription to realign the displaced phalanx. Theoretical lines of heel removal to achieve a more normal relationship of the third phalanx and the ground can be plotted; however, caution should be exercised in all trimming as to not invade sensitive tissue. The entire surface area of the sole needs to be trimmed/ cleaned to achieve as flattened an area as practical for shoeing. As much necrotic debris, as possible, should be removed from the toe region and painful areas noted.

The palmar hoof is normally recruited to weight share via adding impression material to the frog and heel regions. This area will usually accept the task of weight-bearing without adding pain to the foot. One way to unload the painful toe region is by creating a recess in the top of the wooden shoe just dorsal to the apex of the frog (see Fig.3). This can be done with a grinder, router, or by laminating 2 layers of plywood (ie. a .25 inch piece glued to a .75 inch piece) and cutting the top layer in a way as to allow the toe area to be suspended. Disengaging the toe region can also be done by not using impression material dorsal to the apex of the frog. The area can be packed with other medicated materials which do not encourage weight-bearing of this region.

Plywood is the authors' preferred material choice for shoe construction because of its combination of strength, shock absorbency properties (6), formability, and availability. A 1.125 inch plywood (sold as subflooring) is a useful thickness that can be modified to include the mechanics most cases dictate as well as enough height to allow a wedge effect to be cut or sanded into the shoe. A 45 degree angle is cut using an adjustable band saw around the perimeter of the shoe using a commercially available square-toe shoe (b) as the pattern for basic shoe design. The heel region is cut at approximately a 30 degree angle. The shoe can easily be modified to adjust breakover by using a belt sander or a hoof rasp to the ground surface (see Fig.4).

A good rule of thumb to use in deciding breakover placement, is to drop a line vertical from the dorsal portion of the coronary band to the sole. This will usually provide maximum release of shear force pressure on the dorsal lamellae during locomotion. Wedges are indicated when substantial heel is removed and the horse experiences discomfort from the increased tension on the DDFT or the horse has excessive tension on the DDFT. If shoe mass is sufficient, a wedge design can be incorporated into the shoe in conjunction with the breakover modification using a belt sander. If necessary, a wedge pad can easily be added to the shoe's digital surface with 2 one inch screws. Wedge effects exceeding 9 degrees are not uncommon in shoe design to achieve maximum comfort in a laminitic case.

Shoe placement follows the recommended farrier practice of supporting/balancing the distal phalanx on the shoe. The widest part of the hoof represents the center of articulation and should correspond with the widest part of the shoe. The shoe needs to extend past the widest part of the frog, fully supporting the heels. Shoes can be larger and extend more palmer than normal because the shoe will not be used at speed and also will be "safed and boxed" using casting material or hoof glue.

The use of screws to position and secure the wooden shoe is very alarming to a lot of veterinarians and farriers. The use of at least two screws (one inch or 1.625 inch wood screws- these are good all purpose sizes) at the toe/quarter region allows for the securing of the shoe/impression material as the system is evaluated for proper placement. The shoeing system should achieve maximum comfort possible- (immediately)-otherwise, the shoe should be repositioned. This is easily, atraumatically possible with the use of the screws and a power drill. Glue or nails do not allow for the easy, atraumatic shoe adjustment. Screws need not penetrate the hoof wall at normal nail depths and are applied from the wall into the shoe as the horse stands on the shoe. (As competency increases, the shoe is applied with the foot in the farrier position and set down to load the foot prior to the impression material curing into its permanent form). Pilot holes can be used (drilled from the solar surface) until one becomes confident with screw placement.

Most cases of chronic laminitis have ample quarter walls to allow for easy screw placement without invading sensitive tissue. Only two to three screws need to penetrate each quarter region to provide ample wall attachment. The use of additional screws applied (as strut support) to just outside the heel walls, such that the screw head rests against the heel walls, aids the stability of the shoe. The four to six screws in the heel region allow increased surface area for glue or fiberglass casting material to add to the securing of the shoe to the hoof. Some cases only have hoof wall adequate for one screw in each wall quarter which is sufficient for shoe placement until glue or the casting material is added for long-term attachment. When shoeing extremely painful patients, guide screws can be placed just outside the toe regions to insure proper hoof/shoe placement as the hoof will tend to migrate forward under load. These cases don't allow one foot to be suspended for more than a few seconds at a time. The foot can be loaded onto the prepared shoe/impression material and slid into place as these cases are unable to load one foot for more brief periods of time due to the pain. Some cases are shod while lying down or in a sling made of a girth and a hand wench.

Each case should be treated according to general mechanical and weight redistribution parameters, but the individual modifications are dictated by variations in pained areas, hoof mass available, and available vascular supply. Shoe design modifications are made to maximize the comfort and support of the patient. The attention to the horse's body language and understanding the language is essential to maximizing the effectiveness of all therapeutic shoeing systems. <u>Pain should always be decreased with all shoeing systems</u>. The atraumatic application usually allows this system to be applied without the use of tranquilizers, digital blocks, or a twitch. The system allows the horse the ability to communicate the needs the condition dictates to maximize the comfort of the patient.

Abscesses are a complication to shoeing the laminitic horse. The ability to maximize pain relief is unachievable with an active abscess and compromises one's ability to observe and possibly achieve maximum benefits of the mechanical and weight-sharing support of the therapeutic shoe. Nevertheless, many cases are therapeutically shod and the foot is treated with osmotic gradient soakings with the shoe intact. Allowances are made to open and drain abscesses, while the shoe incorporates design features such that the abscessed area is unloaded to insure maximum pain relief. Once the abscess is resolved, the shoe may be reset to further reduce pain.

Shoe attachment with one screw at each quarter allows the easy "fine-tuning" of shoe placement to achieve acceptable positioning of the shoe for maximum comfort to the horse. The shoe is attached with the screws after the therapeutic trim is complete and sole impression material is (generally) palmarly placed in the sole. One author (MLS) routinely applies the sole impression material and shoe in the farrier position, tightens the pre-placed screws, and immediately loads the system (puts the foot on the ground and fully loads it for a few seconds). This allows the impression material to form to the solar architecture in a way as to engage/disengage the viscoelastic material as weight is added/ subtracted. Additional screws are added to the quarters as needed and screws may be added to the heel region as strut supports. These screws need not penetrate the hoof wall, but merely be applied in close proximity to the heel walls. Most cases suffice with two to four screws in the quarters of each hoof and four to eight screws serving as strut supports.

The screws are subject to stress fracture/rusting and need additional support, especially as the patient becomes more mobile as the condition improves. Wall glue can be applied to the heel region inclusive of the shoe, screws, and hoof wall. Glue should never be allowed onto the solar surface as the hardened, unforgiving glue can cause "sole pressure" and can compromise laminar blood flow- especially in the toe region. (Screw heads filled with impression material enhances removal of the shoes.)

Two inch fiberglass casting material is the preferred support of one author (MLS) as it can be easily applied to wet hooves, is easily removed, and helps to support the hoof as a unit as it totally surrounds the foot (see Fig.5). The use of the hoof casting material in combination with the wedged shoe (providing palmar solar support), and palmarly placed breakover, offers substantial unloading (possibly > 90%) of the dorsal hoof wall (4). One must keep the material below the coronary band. Windows can be cut in the toe region of the casting material if an abscess needs medicating. In cases without sufficient lateral hoof wall, the casting material can be applied and screws inserted through the cast material, acting as the hoof wall extension.

Screws can be applied to a hoof wall that does not extend to the level of the shoe. The screw will suspend the wall in a fixed position and not allow wall movement due to the screw threads incorporated within the hoof wall. This helps to further stabilize the hoof and combined with the casting material/glue may aid in maximizing the minimal hoof movement (with the help of sole impression material) and help to re-activate the damaged hemodynamics. It is important stabilization of the entire hoof unit be achieved, yet over-tightening the screws must be avoided. The horse will usually react when screws are tightened too tight.

It is important not to apply the impression material to pained areas (one can cut out areas of the impression material after it has formed by removing the 2 screws and reapply the system). It is also important to not load the solar region constantly (active loading). This can be mistakenly achieved by applying too much impression material that is "setting up" too fast- prior to the horse's weight conforming the material to allow unloading at rest (passive loading).

In the learning phase of this technique, the sole impression material can be applied to the trimmed sole and wrapped before the hoof is loaded on a flat, clean surface or a template. The shoe can be added after the impression material has "set up". One can easily make modifications to the impression material to unload sore areas prior to the shoe being applied.

Results:

The results of all therapeutic shoeing systems are variable due to the extent of lamellar and vascular damage each hoof suffers. Accessing the success of a laminitic shoeing technique is wrought with enormous scientific difficulties; however, this technique has been developed and utilized over a 20 year period, clinically, by one author (MLS) with a much higher success rate than any other technique attempted. More than 300 cases of chronic laminitis have been treated in this period with sets/resets of therapeutic wooden shoes numbering in the thousands.

Failure rates are dictated by the amount of lamellar damage, amount of ongoing necrosis of the third phalanx with resulting sequestrate/abscessation, and owners' finances/ tolerance of the ongoing painful condition. Many cases dictate humane euthanasia, yet some owners will not succumb to ending the life of their beloved pet and insist on attempting measures to decrease as much pain as possible.

The authors have found the wooden shoe to be a successful alternative to deep digital tenotomy, even in cases of solar prolapse. The tenotomy is indicated in cases of pathological contracture of the flexor tendon.

The results listed here are from a 12 month period (2006) on horses that had undergone a previous treatment program (with negative results) and had experienced laminitis for at least 60 days and were treated for a minimum of 60 days. These cases are divided as each author's case load varied due to one author a general practitioner (Steward) and the co-author (O'Grady) a podiatry specialist.

Type of Displacement	**Number of Cases**	**Favorable Response**	**%**
Dorsal Capsular Rotation	18 (Steward)	16	88

Negative responses were attributed to ongoing necrosis of the distal phalanx and pathological contracture of the DDFT.

Discussion:

Therapeutic shoeing techniques to enhance the chances of recovery and diminish pain are being advocated to the farrier and veterinary professions. Many systems have their merit and are sometimes effective in different hands, especially highly trained, experienced professionals. The wooden shoe has many advantages to the horse, farrier, veterinarian, and owner that should result in more cases being successfully treated (rather than being euthanized) due to ease of treatment and economic factors. This system generally encourages the increased mobility of the patient, within reason, and may possibly help to reverse the venoconstriction experienced by the laminar venous system of the laminitic hoof (7). The (theoretically) re-activated hemodynamic system may help (in most cases) to enhance blood flow, promoting hoof mass to increase at an accelerated rate. Realignment can often allow a release of the abnormal compressive forces exerted on the vasculature by the dorsal margin of the displaced distal phalanx. The arterioles and venuoles serving the dorsal lamellae are the portion of the hoof vasculature most prone to compressive collapse (in cases with dorsal capsular rotation) as they course upward from the sole. Realignment not only changes the exertion of force angles, but redistributes weight-bearing in a more desirable manner while reducing pain in the hoof.

The healing of the laminitic feet is dependant on the often severely damage vasculature (see Fig.6) and may, in the future, be found to determine more of an impact on future prognosis than the emphasis now placed on lamellar damage and the amount of rotation of the distal phalanx.

As the third phalanx rotates distally at the dorsal margin, the palmar lamellae-bony attachment experiences abnormally positioning of forces as the hoof is loaded/unloaded. The laminitic dorsal stance of the patient generally positions the front feet such that the palmar foot is engaged on landing. The patient is attempting to protect the damaged lamellae as he physically attempts to realign the distal phalanx to the ground with the altered stance and gait. Rotation of the third phalanx results in shear forces to the dorsal lamellae (especially while weight-bearing), but also may alter the forces on the heel lamellae possibly applying upward torque forces to the palmar lamellae (particularly while non-weight bearing). Realignment of the distal phalanx, in relationship to ground forces, and the proper application of therapeutic shoes should reduce the forces to the dorsal lamellae and probably allow a more normal loading of the heel lamellae while redistributing weight-bearing (8). Hoof support that reduces stress on the dorsal hoof wall is considered important to prevent or minimize progression of lamellar injuries, prevent compression of the circumflex artery and solar plexus, and reduce pain (9). The patient with dorsal capsular rotation will usually position his feet in a more normal stance- when the wooden shoes are properly applied, and gait improvement is usually immediate (2).

Fig.5. Two inch fiberglass casting material is wrapped around the hoof, shoe, and screws to secure the shoe. A window may be cut into the toe region if an abscess needs medicating. The casting material is easier to remove than hoof glue, yet secures and stabilizes the foot. One roll is usually ample for two hooves. A wrap is placed around the casting material to secure the end until the cast sets up. The visible screws do not penetrate the hoof wall, and are merely strut supports. Hoof wall glue can be used in conjunction with the fiberglass casting material if added support is needed.

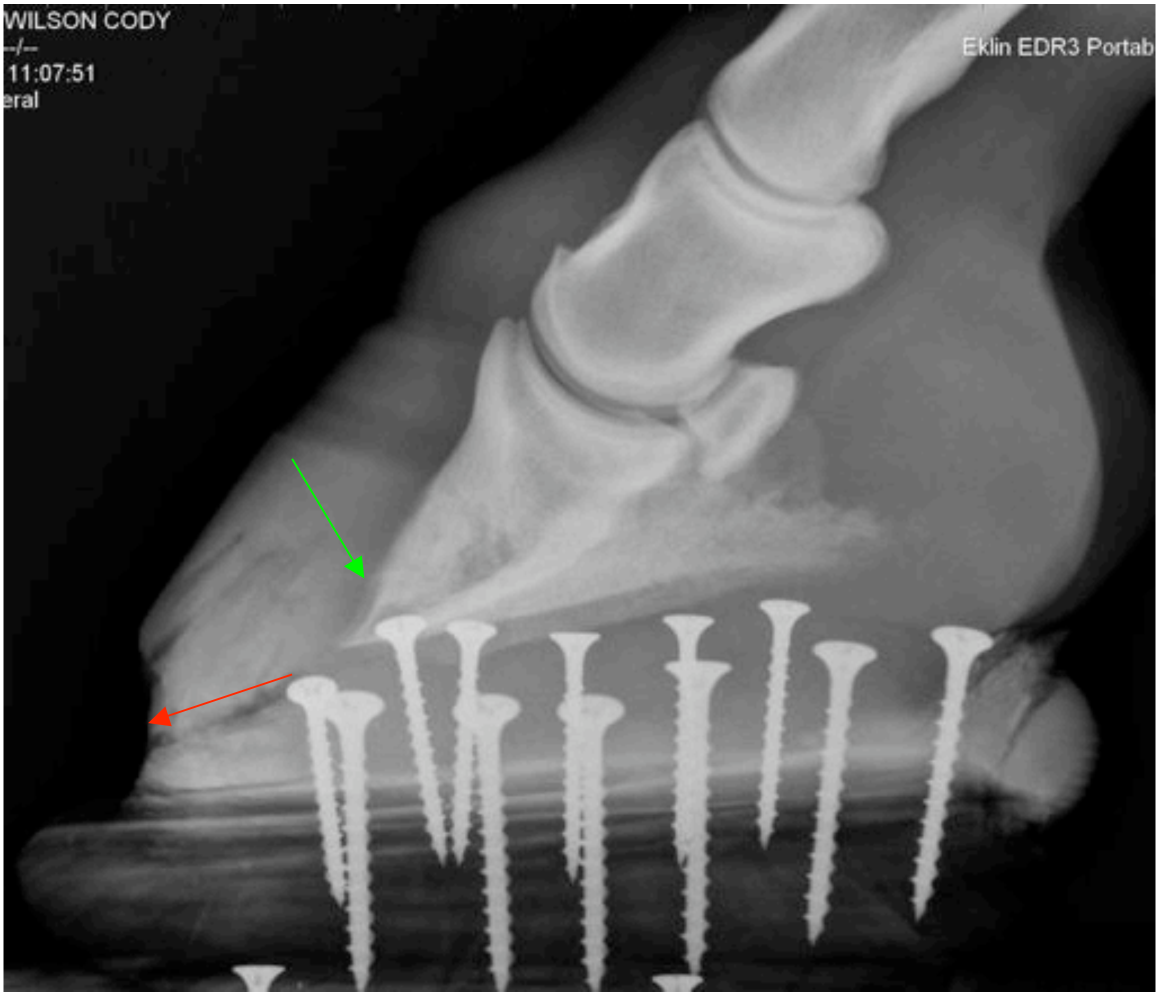

Fig. 6. This case suffered dorsal capsular rotation and distal displacement (sinker) and had been treated extensively and continued to deteriate. Tenotomy was proposed, but the owner's decided to try the wooden shoe. Sole growth and hoof mass was enhanced with the use of the wooden shoe, yet the distal phalanx continued to deteriate probably due to the permanently damaged vascular supply. Note the damaged lamellar region which was eventually removed. The red arrow denotes the shortest route of debris exit. The green arrow shows the extent of lysis of the third phalanx.

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