

Current Practices and Considerations in Therapeutic Farriery for Equine Tendon and Ligament Injuries



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KEYWORDS

- Farriery • Tendon • Ligament • Deep digital flexor tendon
- Superficial digital flexor tendon • Suspensory ligament
- Distal interphalangeal joint collateral ligament

KEY POINTS

- Decreasing the path distance of a tendon or ligament decreases the tension or strain on the structure.
- Farriery can be used to alter the position of the insertion site(s) of tendons and ligaments.
- Heel elevation induces distal interphalangeal joint flexion and metacarpophalangeal/metatarsophalangeal extension (“fetlock drop”).

INTRODUCTION

The underlying goal of farriery is to maintain the horse’s foot in a manner that maximizes its biomechanical efficiency.^{1–3} The process of shoeing a horse involves the preparation of the hoof capsule and the application of the horseshoe or appliance. Hoof preparation, more commonly referred to as trimming, influences several factors necessary for maintaining or enhancing the mechanical efficiency of the foot. Most of the elements involved with trimming a horse’s foot have “loose” definitions and rely on the farrier’s knowledge and experience to optimize them.

Hoof Preparation

Appropriate hoof preparation and shoe fit are integral to soundness and performance.^{4–6} Elements of hoof preparation include hoof length, hoof angle, mediolateral hoof orientation, sole thickness, and the frog.⁷ Trimming to an ideal hoof length (toe length) is often a point of contention between veterinarians and farriers. This controversy is likely due to a disparity between the radiographic appearance of what seems

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Abbreviations

CL	collateral ligament
DDFT	deep digital flexor tendon
DP	dorsopalmar/plantar
MCPJ	metacarpophalangeal joint
ML	mediolateral
PIPJ	proximal interphalangeal joint
SL	suspensory ligament

to be insensitive sole and the actual extent of noncornified solar epithelium. Elongated terminal papillae of the dermal lamella⁸ in the toe region are often inadvertently reached during trimming when attempting to achieve an “ideal” radiographic toe length, especially in a foot with a negative solar angle of the distal phalanx.

Hoof balance has no definitive definition but has been described as the hoof shape that enhances performance and minimally interferes with long-term soundness.⁹ The generally accepted optimal dorsopalmar/plantar (DP) hoof balance is considered a straight hoof-pastern axis when the limb is viewed from the side. This should correlate with a linear plane of the dorsal aspect of the coffin bone and middle phalanx on a lateromedial radiographic projection. Dorsopalmar/plantar hoof balance is influenced by the amount of hoof wall removed at the toe relative to the heel. Mediolateral (ML) hoof balance varies widely in its definitions among veterinarians and farriers, ranging from equal lengths of the medial and lateral aspects of the hoof wall to uniform depths of the medial and lateral collateral frog sulci. With a DP radiograph, ML balance may be accessed by evaluating the plane of the distal phalanx’s solar surface or comparison of the medial and lateral spacing of the distal or proximal interphalangeal joints (PIPJs). Radiographic assessment of ML hoof balance is conceptually more reliable, but the positioning of the limb and weight shifting may influence joint spacing.

Horseshoe Application

Multiple variables exist in the application of a horseshoe. *Shoe fit* refers to how closely the shape of the horseshoe’s outer rim, or edge, matches the shape of the outer surface of the bottom of the trimmed foot from the leading edge of the toe to the widest point across the bottom of the foot. Shoe fit influences pressure distribution on the hoof wall/sole. When a shoe properly fits, the nail holes on an appropriately selected manufactured horseshoe should be in their ideal position over the white line. *Expansion* in horseshoeing refers to the part of the horseshoe that extends outward beyond the outer hoof wall from the widest point of the bottom of the foot to the last point of heel contact, allowing room for the hoof to expand and contract. Insufficient expansion may result in the hoof wall “overgrowing” the shoe during the shoeing cycle. Excessive expansion may increase the risk of shoe loss due to the amount of shoe exposed. *Heel length* refers to the amount of the horseshoe that is palmar/plantar to the last point of the bearing surface of the heel. Solar bruising or “corns” may result if the shoe is too short and the entire bearing surface of the heel is not covered. Excessive heel length may increase the risk of shoe loss due to reasons similar to excessive expansion. Steel and aluminum are the most common materials used for horseshoes. The weight of the horseshoe primarily impacts the swing phase of the stride at high speeds.⁹ In certain disciplines, aluminum shoes are used to reduce “knee action” and lower hoof heights.¹⁰ Various methods exist for attaching a horseshoe to the hoof capsule. Horseshoe nails are the traditional and most widely utilized method. Ideally, nails should be driven into the white line and should not be placed behind the widest part of the hoof to avoid restricting the elasticity of the hoof capsule.

Adhesives are widely used to attach a horseshoe to the hoof capsule. The term “direct-gluing” refers to the adhesive being placed between the ground surface of the foot and the foot surface of the shoe. This method is mainly used with aluminum or polyurethane horseshoes. “Indirect-gluing” refers to the use of an adhesive to attach a horseshoe to the hoof wall via a cuff or sleeve incorporated into the shoe.

Therapeutic Farriery

Understanding the relationship between footing and different horseshoes is crucial for therapeutic farriery for tendon and ligament injuries due to biomechanical influences. The angle of the hoof-sole at the walk on sand resembles the presence of a heel wedge on firm ground and shows patterns of tendon strain similar to those obtained from walking on a flat surface with a heel wedge.¹¹ Kinesiotherapeutic farriery uses horseshoes with a modified ground contact surface area in combination with deformable footing to change the mid-stance orientation of the hoof in kinematic events, creating proposed therapeutic benefits while limiting potential adverse mechanical side effects.^{11–15} Region(s) of a horseshoe with a larger ground surface area will remain closer to the surface of deformable footing during weight-bearing, whereas region(s) with a smaller ground surface area will penetrate deeper into deformable footing. Regardless of the method used to change the orientation of the hoof, it is important to consider that elevation of an area it will result in higher loads on that part of the hoof. This is likely to have a negative impact on the structure of the hoof and the growth of the horn in the elevated region.¹⁶

Therapeutic farriery has been defined as the treatment of diseases of the equine distal limb through trimming or the application of various appliances.¹⁷ A “normal” foot is designed to balance strain on soft tissue structures. The concept of therapeutic farriery is not necessarily to “balance” the hoof but rather to strategically alter the orientation of the hoof to remove mechanical stress from a particular structure determined to be the source of lameness, thus aiding in healing.^{13,18} Ultimately, therapeutic farriery for soft tissue injuries aims to provide the injured anatomy with an optimal biomechanical environment for healing. There are 3 moments in the stance phase when the horse is more susceptible to injuries: the impact phase, submaximal limb loading, and when the heels leave the ground (“breakover”).¹⁹

Before addressing how to utilize farriery to optimize the environment for the healing of tendon and ligament injuries, it is essential to understand the functional anatomy, pathophysiology of injury, and healing process of tendons and ligaments.

FUNCTIONAL ANATOMY OF COMMONLY INJURED TENDONS AND LIGAMENTS IN THE HORSE AND BIOMECHANICAL CONSIDERATIONS FOR THERAPEUTIC FARRIERY

Deep Digital Flexor Tendon

The deep digital flexor tendon (DDFT) has a prominent role in distal interphalangeal joint (DIPJ) stabilization.²⁰ The interaction between the DDFT and the distal sesamoid bone changes substantially during the stance phase of the stride.²⁰ During full weight-bearing, the DDFT is only in close contact with the distal border of the navicular bone. During propulsion, the increasing angulation of the DDFT on the navicular bone creates progressively higher pressure on the flexor surface. At the end of the stance phase, the active contraction of the deep digital flexor muscle and the DDFT/accessory ligament of the deep digital flexor tendon (ALDDFT) elasticity substantially induce the elevation of the fetlock and propulsion. In the first part of the swing phase, the tension of the deep digital flexor apparatus passively contributes to the initiation of flexion of the interphalangeal, metacarpal, and carpal joints.²⁰

The DDFT has a high modulus of elasticity and a substantial strength to rupture.²¹ Primary injury to the DDFT may result from acute traumatic fiber disruption at the end of the stance phase, repetitive overload stress, or a combination of both.²⁰ The probability of primary DDFT injury may increase as degenerative changes accumulate in the tendon with age or as overload stress results in a progressive increase of proteoglycans in the tendon matrix. Primary injury to the distal portion of the DDFT can originate at any level, including the insertion to the distal phalanx, the palmar surface of the navicular bone, or the transverse ledge of the middle scutum.²⁰ Alteration in the tendon's angulation at its insertion may result in abnormal local stress distribution, which could lead to failure.²² Pathology in the distal portion of the DDFT may also result from distal dissemination of tendinopathy at the digital flexor tendon sheath level. Fibrillation of the dorsal surface of the DDFT is usually considered secondary degeneration as it frequently occurs concurrently with degenerative changes of the palmar fibrocartilage of the navicular bone.²⁰

Superficial Digital Flexor Tendon

In the forelimb, the actions of the superficial digital flexor tendon (SDFT) result from the active contraction of its muscle group and the passive tension of its accessory ligament.²⁰ Extension of the metacarpophalangeal joint (MCPJ) during weight-bearing induces tension on the accessory ligament of the superficial digital flexor tendon (ALSDFT), impeding overstretching of the superficial flexor muscle during MCPJ overextension.²³ Tension in the SDFT unit restricts extension of the MCPJ and carpus. The PIPJ is stabilized by the SDFT (and DDFT) during full weight-bearing.²⁰

The SDFT has a moderate modulus of elasticity and relatively high strength to rupture.²⁴ An increase in SDFT/ALSDFT tension is induced by MCPJ extension during weight-bearing.²⁰ SDFT tension increases significantly after desmotomy of the ALSDF.²⁵ This increased tension is attributed to the resulting change in the MCPJ angle, which increases the moment arm of the SDFT about this joint. The strain curve of the SDFT of the hindlimb is similar to that of the forelimb.²⁶

Suspensory Ligament

The primary function of the suspensory ligament (SL) is to prevent excessive extension of the MCPJ when the limb is weight-bearing. As the fetlock extends, the SL branches undergo tension that limits distolateral movement and compression of the proximal sesamoid bones.²⁰ The body of the SL has a relatively high modulus of elasticity and considerable strength to rupture.²⁴ Fetlock extension during mid-stance induces high strains on the SL, sesamoid bones, and distal sesamoidean ligaments.²⁰

Distal Interphalangeal Joint Collateral Ligaments

The collateral ligaments (CLs) of the DIPJ originate from depressions on the distal medial and lateral aspects of the middle phalanx and insert in depressions on the dorsomedial and dorsolateral aspects of the distal phalanx, close to the joint margins and the dorsal aspect of the medial and lateral cartilages of the foot. These CLs stabilize the DIPJ during its movements in the sagittal, dorsal, and transverse planes.²⁰

Injury to the CLs of the DIPJ may occur during the stance phase of the inner limb as the horse moves on a circle where lateral motion and medial rotation of the DIPJ occur.²⁰ Presumably, uneven footing and foot imbalance are predisposing factors to DIPJ CL injury.

THERAPEUTIC FARRIERY FOR TENDON AND LIGAMENT INJURIES

Currently, there are no treatment strategies available to fully restore an injured tendon or ligament's functional, structural, and biomechanical properties to those of its native tissue. The overarching objective of therapeutic farriery for soft tissue injuries of the distal limb of the horse is to provide an environment conducive to healing by limiting excessive strain on the injured tendon or ligament. With an understanding of the anatomy of the equine limb and the pathophysiology of tendon/ligament injuries, the rationale used in therapeutic farriery for soft tissue injuries of the distal limb is quite logical. The tension or strain in a viscoelastic structure increases as the distance between its 2 endpoints increases. The origin points of tendons and ligaments are relatively fixed on the limb's anatomy. In therapeutic farriery, foot manipulation is used to change the position of the insertion sites. This reduces the distance traveled by the tendon or ligament, leading to decreased tension. Under static conditions, modifications of the foot orientation in the sagittal plane induce distal joint displacements and rearrange the tensions within the flexor tendons and suspensory apparatus.^{20,27-30} In vivo radiographic studies on standing horses^{31,32} and in vitro studies³³ have demonstrated that elevation of the heels induces an increase in extension of the MCPJ and an increase of flexion of the PIPJ and DIPJ.

Deep Digital Flexor Tendinopathy

Altering the angle of the distal interphalangeal joint affects the tension of the deep digital flexor tendon due to the location of its insertion on the flexor surface of the distal phalanx. Heel elevation induces DIPJ flexion, while toe elevation causes DIPJ extension.^{20,30-33} Evidence exists that on nondeformable footing, the DDFT tension significantly decreases with 6° to 7° of heel elevation and significantly increases with 6° to 7° of toe elevation.^{15,30,34-37} Flat bar shoes and flat open-heel horseshoes with region(s) of asymmetric surface area appear to have little to no effect on decreasing the tension of the DDFT on nondeformable footing.^{15,35-38} Modifications to the horseshoe believed to hasten "breakover" (rolled-toe, rocker-toe, square-toe, and natural balance shoe) do not appear to significantly reduce the DDFT tension compared with a plain steel shoe on nondeformable footing.^{27,38-41} On deformable footing, horseshoes with greater surface area in the heel region of the shoe, such as bar shoes, cause a steeper solar angle,³⁸ which should decrease the maximal strain of the DDFT. The intent of therapeutic farriery for DDFT injury would, therefore, involve increasing the solar angle of the distal phalanx. Increasing the solar angle causes increased coffin joint flexion (or decreasing extension) and alters the position of the distal sesamoid bone, reducing the tension on the DDFT. This goal is commonly pursued by using graduated horseshoes and wedge pads for horses on nondeformable footing and utilizing a larger surface area in the heel region of horseshoes (**Fig. 1**) for horses on deformable footing.

Superficial Digital Flexor Tendinopathy

Because of its insertion on the adjacent aspects of the proximal and middle phalanges, the tension of the superficial digital flexor tendon is influenced by the angle of the metacarpophalangeal/metatarsophalangeal and PIPJs. Heel elevation has been shown to increase the extension of the MCPJ/metatarsophalangeal joint (MTPJ),³⁰⁻³² and elevation of the toe provokes the pastern to become more vertical and the MCPJ/MTPJ to be less extended.²⁰ Evidence exists that on firm footing, 6° to 7° of toe elevation decreases strain on the SDFT¹⁵ but induces a higher rate of strain increase in the SDFT in the early stance phase.³⁴ Data also exist that on firm footing, 6° of heel

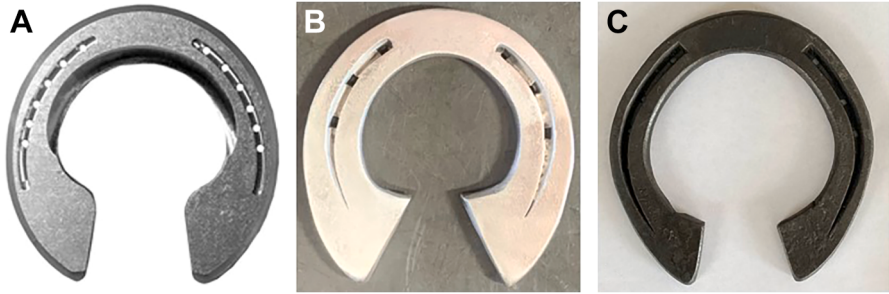


Fig. 1. Examples of (A) manufactured, (B) handmade, and (C) modified keg horseshoe with increased ground surface area in the heel region. (Images courtesy of [A] Grand Circuit Products. [B] Eric Gilleland.)

elevation increases the strain on the SDFT,⁴² while other data exist that SDFT strain is unchanged with heel elevation.^{15,37,38} To summarize, elevation of the toe may increase the strain rate but decrease the maximal tension of the SDFT, and heel elevation may increase the tension of the SDFT. Science implies that therapeutic farriery for SDFT injuries would avoid the use of horseshoes or modifications that result in heel elevation.

Suspensory Ligament Desmopathy

With its insertion on the proximal sesamoid bones, altering the angle of the metacarpophalangeal/metatarsophalangeal joint influences the tension of the SL. Heel elevation increases MCPJ extension ("fetlock drop"), and toe elevation reduces MCPJ extension.^{31–33} Evidence exists that toe elevation decreases the strain of the SL and that heel elevation may increase the tension on the SL.^{15,36,37} The objective of therapeutic farriery for SL injury is to decrease fetlock extension. Elevation of the toe using graduated shoes or wedge pads is not common practice. However, incorporating a larger surface area in the toe region of the shoe (Fig. 2), causing the toe to remain elevated on deformable footing, is more commonly utilized.

Distal Interphalangeal Joint Collateral Ligament Desmopathy

Inserting on the dorsomedial and dorsolateral aspect of the proximal portion of the distal phalanx, alteration of the orientation of the distal phalanx influences the tension



Fig. 2. Examples of (A) manufactured, (B) handmade, and (C) modified keg horseshoe with increased ground surface area in the toe region. (Images courtesy of [A] Grand Circuit Products. [B] Iván D. Gómez.)



Fig. 3. Examples of (A) manufactured, (B) handmade, and (C) modified keg horseshoe with increased ground surface area of one branch of the shoe. (Images courtesy of [A] Grand Circuit Products. [B] [Steve Sermersheim](#).)

of the DIPJ CLs. Mediolateral foot balance on nondeformable footing may be altered by trimming or, less commonly, the application of wedges.¹⁶ On deformable footing, a shoe with a larger surface area on one branch (**Fig. 3**) causes that side of the foot to stay closer to the surface of the footing. Meanwhile, the side with the branch with less surface area penetrates deeper into the footing, resulting in an altered orientation of P3. Logically, this change in orientation of the distal phalanx would result in a decrease in the tension of the DIPJ CL on the side of the broader branch and an increase in the tension of the DIPJ CL on the side of the narrower branch. On nondeformable footing, this type of asymmetric shoe causes no significant change in the orientation of P3, but pressure forces increase considerably beneath the widened regions of this shoe.⁴³

CLINICS CARE POINTS

- Alteration of joint angles by farriery can influence the tension of tendon and ligaments of the distal limb.
- Elevation of a region of the hoof capsule causes an increase in pressure experienced by that region.
- The type/firmness of the footing should be considered when implementing therapeutic farriery.

DISCLOSURE

None.

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