THE VETERINARY CLINICS Equine Practice

Vet Clin Equine 19 (2003) 463–477

Hoof wall defects: chronic hoof wall separations and hoof wall cracks

William Moyer, DVM

Department of Large Animal Medicine and Surgery, College of Veterinary Medicine, Texas A&M University, College Station, TX 77843–4475, USA

Hoof wall injuries and defects in the form of separations, loss, and cracks are frequent occurrences and are often a reflection of environmental conditions, inherent structural problems, and specific athletic endeavors. The range of structural damage varies from being insignificant to being unable to bear weight on a given limb. There is little retrievable published evidence of the actual incidence of such problems, but it is this author's impression that the incidence has increased over the past few decades. It is the author's hypothesis that this increase in hoof wall failure is the result of probable genetic factors (eg, thin soles, low heels, long toes) (Fig. 1) and environmental risk factors (trimming and shoeing practices, stable management, weather and ground conditions, and reduced access to exercise), which, when combined with other factors, lead to weakened hoof wall material [1–7]. The role nutrition plays in the overall picture of the hoof wall is unclear. The likelihood of eventual and chronic hoof wall failure is high if a given foot or feet remain in a weakened state.

The dilemma facing horse owners, farriers, and equine practitioners is how best to manage a problem or problems in the absence of being unable to alter genetic or environmental factors. In many instances, the solution consists of a temporary artificial repair rather than a long-term solution, although in other cases, success is attained with the use of carefully considered foot care and shoeing principles. Successful management is dependent not only on defining the damage but on identifying the cause or causes. It is also apparent that hoof wall problems require farrier expertise; thus, the development and subsequent maintenance of a solid working relationship with a farrier or farriers is essential.

This article describes and discusses hoof wall separations, hoof wall loss, and hoof wall cracks. This group of problems is ubiquitous with regard to

E-mail address: w-moyer@tamu.edu

0749-0739/03/$ - see front matter © 2003 Elsevier Inc. All rights reserved.
doi:10.1016/S0749-0739(03)00003-8

Fig. 1. A long toe and low heel foot conformation is often accompanied by thin weak hoof walls and flat thin soles. Such feet are prone to chronic foot problems.

breed, athletic pursuit, and work load; they are universally and historically encountered in the horse world. A great deal of descriptive literature is available in both farriery and veterinary publications; however, there is little information regarding analytic and comparative studies with regard to treatment and management. It therefore important to recognize the following as being based on personal prejudice and experience.

Hoof wall separations and loss

Hoof wall separations with or without hoof wall loss are common occurrences. The degree of separation varies from insignificant to massive. The causes are many and include environmentally induced separations (''white line disease''), submural infections, mechanically and traumatically induced

separations with associated submural hemorrhage, extensive "canker" proliferation, and laminitis. This discussion does not include the management of laminitis. Treatment and management of separations vary somewhat with the cause, absence, or presence of underlying infection as well as with the location, extent, skill of the clinician and farrier, and wishes of the owner/trainer (sometimes the most important consideration).

Environmental induced wall separations

The descriptive term *white line disease* first emerged in the mid 1980s and, to date, has not acquired a universally accepted definition or pathogenesis. A working definition proposed by O'Grady [8] to consider is that it is a term describing a keratinolytic process ultimately characterized by structural damage and separation at the stratum medium and stratum lamellatum. Historically, the term was proposed in an attempt to describe a separation of the hoof wall that is similar in appearance to chronic laminitis yet is different in cause, structural levels of involvement, and, usually, outcome. The term *white line disease* is a misnomer, because the white line is anatomically defined as the junction of the hoof wall and sole and is thus a zone rather than a structure. White line disease involves separation of the hoof wall and often involves damage/separation proximal to the white line zone. Other descriptive terms historically exist, such as *seedy toe*, *hoof rot*, *hollow wall*, and *excessively flared walls* [9,10]. The lack of an accepted definition is a problem in that it creates varying opinions as to cause or causes and thus to treatments that have been proposed.

Cause

The cause or causes have been theorized but, as yet, have not been proven, that is, duplicated under controlled scientific study. The damage created, either focal or generalized hoof wall separation, could conceivably be the result of direct trauma with subsequent damage to underlying soft tissue attachments, invasion of keratinophilic and destructive bacteria or fungal agents [9], abnormal and excessive exposure to moisture, or simple mechanical tearing of the wall away from its attachments; perhaps a more likely situation is that of a combination of these factors. The incidence of this problem seems to be highest in geographic areas with the greatest exposure to high moisture and ambient temperatures, and this problem is less common in mountainous and arid regions. It is likely that the keratinolytic feature of this phenomenon is the result of invasion of organisms (bacterial, fungal, or both) via preexisting defects (fissures) at the bearing surface of the foot with eventual proximal involvement.

Clinical signs

In many instances, the separation is unnoticed by the owner and is usually detected at the time a given horse is trimmed or shod. In more severely affected horses, lameness may be apparent. The appearance of the

bearing surface of the foot is that of a damaged and porous "white line" or hoof wall separation, fissures, and frayed hoof wall material (Fig. 2). The zone of damage/separation may occur at any point on the foot (with the toe and quarter region being the most common location). The depth of separation varies but may extend to the coronet region. If the separation is sufficient in length and area, it may produce a hollow sound if percussed. It may involve one or all four feet and may or may not be accompanied by lameness. The depth of separation may be approximated with a flexible probe and further defined with radiographs. The underlying damaged horn is usually of a powdery consistency if not recently exposed to moisture. Manipulation of the involved area with hoof testers may or may not elicit a painful response but is useful in determining the degree of structural loss.

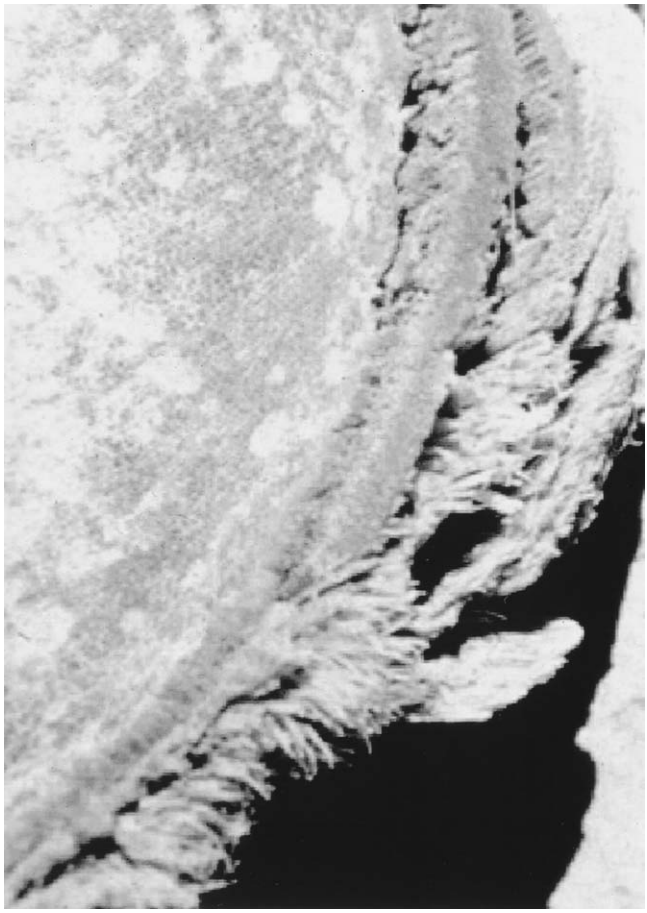

Fig. 2. The bearing surface of an involved foot demonstrates wall separation, multiple fissures, and fraying of wall horn as the result of white line disease. (Courtesy of Dr. Kent Carter and Don Sustaire, College Station, TX.)

The appearance of a given foot may mimic that created by laminitis or seedy toe, particularly if the separation is confined to the toe region. Radiographic examination is recommended to determine the total area of involvement as well as the possible inclusion of other damage.

Treatment

Numerous treatment and management regimens have been proposed. Most available reports suggest removal of the separated wall, allowing exposure to the underlying damaged inner layers of horn, as well as removing the horny shelf that tends to retain moisture and foreign material [9,11]. The author believes it is necessary to remove all the separated wall to the extent of reaching normal attached wall (Fig. 3). Treatment management beyond this point varies, in the author's opinion, with the amount of wall removed, the location of the removed wall, the shape of the foot, the environment, and the overall management skills of the owner or caretaker. In most situations, it is best to have the horse shod after resection to protect the remaining unaffected hoof wall, unsupported sole, and exposed lamellar tissues; this may be a significant challenge, however, if little normally attached wall exists after removal. The design of the shoe should be dictated by the remaining shape of a given foot, and it is prudent to provide a bar shoe of some type to stabilize the foot. Clips or similar creative additions to the shoe may help to secure such a shoe (Fig. 4). Foot bandages or glue-on shoes may be useful if sufficient wall has been removed, making it difficult to

Fig. 3. Separated or loosely attached hoof wall is removed using a motorized burr to the level of normally attached wall. (Courtesy of Dr. Kent Carter and Don Sustaire, College Station, TX.)

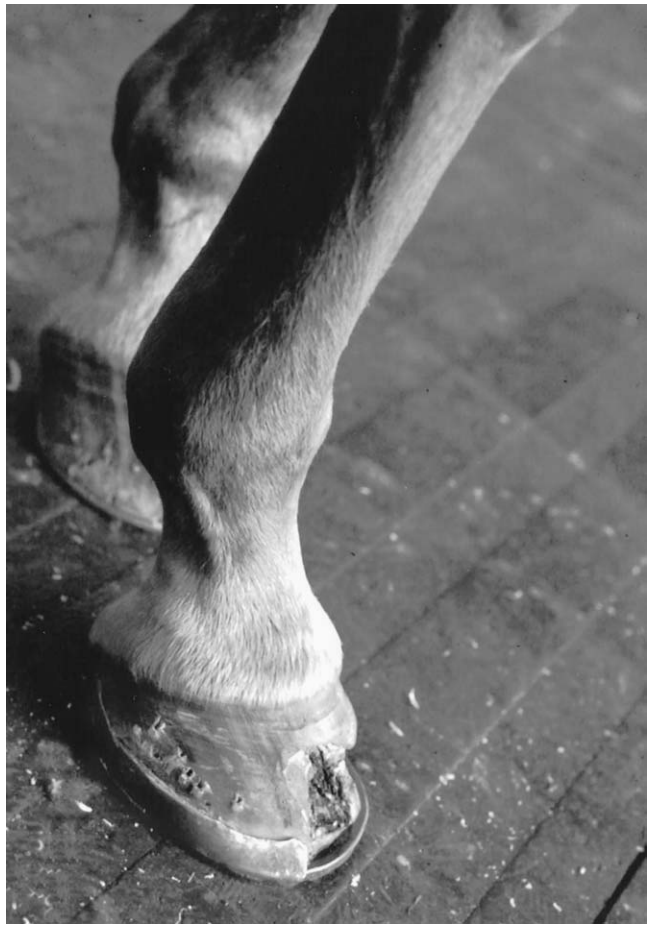

Fig. 4. Significant loss of hoof wall may necessitate the use of creatively designed shoes to ensure stability as well as ability to hold the shoe in place. The use of shaped and welded sheet metal to form a "continuous clip" is demonstrated.

nail a shoe on. It is best to confine the involved horse or horses in a reasonably dry area. Topical medication, such as 2% iodine or methiolate, can be used to minimize further contamination as well as to provide the owner/caretaker with a reason to examine and clean the involved area frequently (initially and until underlying exposed lamellar tissues are firmly keratinized, this is best done on a daily basis). Various other topical applications have been used, but, at present, there is no convincing evidence indicating that a particular product is superior. The author believes that removal of the wall to prevent the continued capture and retention of moisture and environmental debris as well as the potential for further mechanical tearing in combination with a shoe designed to meet the needs of

the affected foot or feet is the most important aspect of therapy. It is not unusual to have to make repeated attempts at resection as the foot continues to grow if the growing horn is not attaching. In some instances, it is best to take the horse out of organized work to prevent any undue mechanical forces (excessive motion at the site of removal) during the repair process. The damaged area can be filled in with various hoof wall repair materials, but it is important that the underlying lamellar tissues be fully keratinized. The author is unaware of any nutritional or topical products that increase either the speed or quality of hoof wall growth.

Submural infections

Hoof wall separations occurring as the result of underlying infection may be the result of puncture wounds, hoof wall lacerations, hoof wall cracks, or the presence of foreign bodies. In most instances, involved horses are lame and show evidence of focal pain with hoof testers or local percussion. Exploration of the separation is facilitated by gently using a hoof knife and a flexible probe. Radiographic examination may be necessary to determine if underlying bone is involved. In most cases, treatment consists of removing the unattached hoof wall, thoroughly cleaning and exposing underlying lamellar tissues and bone; curettage of infected or necrotic areas if present; and local application of an appropriate disinfectant, such as 2% iodine solution, and a protective type bandage (duct tape and gauze pads cut and shaped to fit are an excellent choice). A more lasting ''patch'' type bandage can be achieved by applying a thin layer of ''super glue'' to the surrounding horn just before duct tape application. The removed hoof wall can be artificially replaced (described below) if necessary at a later date when the underlying lamellar tissues are fully keratinized and no evidence of infection remains. Those submural infections resulting from hoof wall cracks generally require further resection if significant undermining of associated wall is present. Hoof wall stabilization techniques are described below. The use of systemic antimicrobials is questionable if the infected area is open and accessible to local treatment.

Shoes maybe be necessary or helpful if extensive wall loss exists. In such cases, the principles of shoeing are determined by the multiple factors discussed previously.

Mechanically or traumatically induced hoof wall separations or loss

Focal hoof wall separations (often referred to as wall ''flares'') are not unusual . Wall flares may be the result of unequal weight bearing on a given foot, representing a foot imbalance situation, a conformational problem, or, often, simple neglect. A common situation, for example, is that of a flared outside toe-quarter region on a horse that possesses ''toe-out'' conformation. Toe wall separations may be seen with excessively long toes with an

appearance not unlike chronic laminitis or white line disease. Toe wall separations in moderate to severely club-footed horses are not uncommon. Traumatic hoof wall avulsions can occur at any region of the hoof wall. The most common are partial avulsions, which originate at the coronary band and involve the heel and quarter region. In some instances, the damage to the germinal tissues responsible for horn production is beyond repair, and a permanent wall defect evolves.

Horses with such separations may or may not be lame, but the potential for further tearing/separation, wall cracks, submural infections, or wall loss is realistic. Most shallow separations can be managed with careful and routine trimming and removal of flared wall material. Horses with moderate to severe upright club feet often require additional treatment, such as inferior check desmotomy surgery to correct the "broken forward axis" problem at the level of the distal interphalangeal joint. Because of the potential for further damage, it is prudent to remove separated hoof wall. The extent of separation, and thus removal, determines the type and design of shoe to be applied. Horses that are turned out should be trimmed (if allowed to remain barefoot) on a routine basis as determined by their average wall growth.

Horses with acute partial or complete hoof wall avulsions should be handled as emergencies. In most instances, the process of examination and initial treatment is facilitated with sedation and local anesthesia (usually a unilateral base-sesamoid nerve block suffices) to allow careful exploration and thorough initial wound cleaning. Most cases are best managed by removing the unattached horn to the level of normally attached horn. If, however, one is dealing with a recent and clean avulsion (one lacking significant swelling or devitalization of tissues) involving the coronary band tissues, an attempt to suture the flap back in place can be made to include the hoof wall. It is best to inform the owner/handler that failure (dehiscence) to heal primarily is quite possible but that the attempt, even if it fails, should not create further damage. If one does remove a major portion of the weight-bearing horn, the foot should be protected with foot bandages or cast application. The author prefers foot bandages initially and often tapes a full stiff foot pad or shaped-to-fit rubber matting section to the bottom of the bandage. This application sometimes provides comfort. Further therapeutic efforts (eg, selection of shoes) are determined by the degree and health of future hoof wall growth, but, invariably, are best managed with a bar shoe of some type. Although it may seem ridiculous to mention, it is important that the owner/caretaker understand that, initially (for the first few weeks), it is important, and even imperative, that the horse remains in a stall. Motion at the site of these injuries is a consistent reason for lack of success. Turning affected horses out until the underlying damaged lamellar tissues are fully keratinized is an invitation for permanent damage and an unsuccessful outcome. The use of antibiotics, anti-inflammatory medications, and topical medications is best handled on a case-by-case basis.

Hoof wall repair techniques

Those horses in which hoof wall loss exists for whatever reason may benefit from performing wall repair/replacement to return structural strength/stability to the total hoof, perhaps resulting in a shorter time frame before returning to athletic endeavors. This generally requires using materials that adhere to underlying and surrounding hoof material, are nontoxic and nonirritating, mimic the mechanical properties of hoof wall, and allow the placement of shoeing nails. Multiple products exist. The author's primary experience evolves around the use of polymethylmethacrylate, but other products can be used effectively. It is important to point out that any such repair material or technique can result in untoward results if improperly used and applied. It is therefore prudent to understand the principles of application, and they may be summarized as follows [7,12]:

- Regardless of the chosen materials or technique, do not cover infected or nonkeratinized horn. The only exception to this rule is in those instances in which drainage is created in such a way that the repair material is not in contact with infected or nonkeratinized tissues (Fig. 5).
- It is important to trim the involved foot or feet before applying the repair material.
- Always begin with a clean hoof.
- All nonconnected or weak hoof wall material should be removed. This can be facilitated using a variable-speed motorized tool.
- Be aware that repairs grow out with the hoof wall and, if applied properly, can be trimmed and shod in a normal pattern. Some repairs may require the use of implanted materials to strengthen the repair, however, and a subsequent farrier should be made aware of this so as to prevent shoeing tool or repair damage when the horse is trimmed or shod.
- It is useful to protect the coronary band region with an appropriate covering, such as tape, to preventive contact with materials that can be difficult to remove.
- Test the chosen materials before application to be sure that desired results (proper setup) occur with that batch of product.
- Use appropriate safety techniques: wear protective eye wear when removing and sanding hoof material, protective gloves when applying the chosen adhesives, and an appropriate shoeing apron.
- Carefully choose a proper operative environment: attempt to work at room temperature (cold temperatures interfere with proper product curing); provide a dry and nonslip surface for the horse and operator; request or provide quiet and competent horse handlers (good luck, these days); attempt to work in a clean, dust-free, and well-ventilated area; pay particular attention to detail with regard to the instructions accompanying the material chosen for use (in my experience, this is the most common reason for failure); and do not hesitate, if circumstances allow, to tranquilize or sedate the horse to improve working conditions.

Fig. 5. Exposed septic nonkeratinized lamellar tissues can be made accessible for therapy in concert with hoof wall repair. A focal "window" was created in the polymethylmethacrylate material to enhance local therapy without substantially weakening the wall repair.

- The techniques can be expensive and time-consuming because they all depend on meticulous preparation.

Procedure for hoof wall repair

Be careful to be sure that the underlying lamellar horn is fully keratinized, stiff to digital pressure, and free of infection. Undercutting the exposed wall is useful to act as an additional anchor for the prosthetic materials (generally, the depth of the "undercut" does not have to exceed 0.125 inch). Sand the surrounding hoof wall material to which the adhesive material will be applied; this step is performed to increase the ability of the adhesive to adhere by increasing surface area contact and only requires superficial removal. Apply tape to the coronet region to prevent the adhesive from contacting skin and hair. In most instances, it is necessary to tape a wooden (or something similar) block of material to the bottom of the foot to allow the horse to bear weight during the setup time. Thoroughly rinse the area to be repaired with acetone, and scrub the area with a steel brush. Acetone is necessary to remove any surface materials that would prevent adhesion to the underlying horn (especially true of feet treated with hoof dressings). Be sure the foot is dry before application. The drying (evaporation) process can be enhanced with a heat gun or hair dryer. I prefer to repair such wall voids in two steps. The first step is to apply

sufficient repair material to fill in and overlap the area involved. A tongue depressor works nicely for application as well as for smoothing the material. If the choice is to use polymethylmethacrylate, cover the repair with polyethylene, because an oxygen-free environment facilitates the cure and the polyethylene protects the repair from foreign material becoming attached. When the material has cured (rigid and not warm to the touch), sand the area to smooth the repair. The second step is to cut a piece of fabric (eg, lightweight fiberglass, Kevlar, Spectra) to fit the area to be repaired. Impregnate the fabric (generously apply to both sides of the fabric) with the repair material, and apply to the repaired area. Cover the area with polyethylene, making an effort to remove air pockets as well as smooth over the repair. Hold the repair in place with tape, and allow the material to cure. The final step is light sanding to remove any rough areas [7].

The choice of shoes varies somewhat based on the factors discussed previously. In most instances, I prefer a bar shoe of some type to provide more mechanical stability than an open shoe. The choice of nail-on or glue-on shoes is dependent on the situation. Have the shoes reset on the normal schedule for that horse. Instruct the owner/trainer/caretaker to make an effort to avoid excessive exposure to environmental moisture if possible.

Modifications of this technique include the same repair technique while also providing for drainage or flushing of exposed infected tissues [7]. Personally, I prefer to allow infections to heal before application, but there are times when such a technique is requested. In those instances, the basic technique of application remains the same; however, the infected area is protected from the repair material by applying either Play-Doh or modeling clay directly over the affected tissues and placing a drain tube (intravenous tubing works well and is readily available) from the most proximal to the most distal aspect of the repair. Remove the tubing after the cure and access the Play-Doh or modeling clay with a small curette to remove the protective material. The final product is a tunnel that traverses the infected area and is accessible for flushing. Use duct tape to cover the entrance and exit holes when not flushing. A similar technique to allow access to a focal infected or nonkeratinized area is demonstrated in Fig. 5.

Hoof wall cracks

Hoof wall cracks represent a focal wall failure, and as such, they can occur anywhere on the hoof wall to include bar cracks [1–7,10,11,13]. Most are oriented in the direction of hoof tubule orientation. Occurring less commonly are those cracks oriented perpendicular to horn tubular structures and parallel to the coronet. In most instances, linear defects parallel to the coronet are a reflection of preexisting injury/damage or infection of the coronary corium tissues. Hoof wall cracks are generally described by their location (toe, quarter, heel, or bar), length (partial or full length), depth (superficial or deep), and the presence or absence of

hemorrhage or infection [7]. In most instances, the underlying wall damage is considerably more extensive than that noted from the exterior.

The same effort should be made to determine, if possible, the cause of the defect. In the author's experience, central toe cracks often show evidence of significant wall separation (chronic laminitis, white line disease [Fig. 6], and club foot malformation), heel and quarter cracks are frequently associated with underrun heels and long toes, and linear cracks parallel to the coronet invariably represent preexisting damage to the coronary corium tissues (trauma or infection) interrupting normal wall growth. In some instances, the damage to the coronary corium is permanent; thus, the crack/defect remains in place regardless of the technique of repair chosen.

A myriad of materials and techniques exist [3–5,7,10–15], and, to date, this author is unaware of a particular technique that is routinely superior. The techniques used include careful placement of shoeing nails across the crack; hoof staples (see Fig. 6) and clamps; screws and wire and other suture materials; plates (Fig. 7); patches using rubber, acrylics, plastics, glue, and composites; relief of weight bearing at the crack sight; various corrective shoes; and corrective shoeing and time. The goal of any such repair is to gain stability at the crack site to allow for future uninterrupted solid hoof wall growth. Regardless of the technique chosen, it is important that each crack be explored and that all extraneous nonattached hoof wall material be removed. This action is facilitated with use of a motorized burr. Infected or

Fig. 6. A central toe crack with hoof wall loss and separation resulting from white line disease. Stabilization of the crack was achieved using hoof staples. (Courtesy of Kurt Ilgen, Sheridan, WY.)

Fig. 7. Heel crack stabilized with predrilled holes, brass plates, and stainless steel suture before the application of polymethylmethacrylate repair. The foot conformation demonstrates a long toe and low heel shape.

painful cracks may require the use of local anesthetics, but it is best to avoid their use so as to avoid penetration into sensitive tissues. Those cracks that are infected or demonstrate exposed nonkeratinized tissues should be explored and opened to enhance drainage and successful application of disinfectants, such as 2% iodine solution. Delay further repair until lamellar tissues are keratinized and free of hemorrhage or exudate. If immediate stabilization in the face of infection is required, use a technique described previously, allowing for placement of a drainage and flushing system [7,13], or simply provide stabilization that does not cover the defect, such as hoof staples or sutures without overlying repair materials.

The use of implants (eg, sutures, plates, fabrics) in combination with prosthetic hoof wall repair materials generally provides adequate stabilization. Some techniques require drilling for either screw or suture placement; thus, sufficient thickness of wall material is essential to avoid penetration into sensitive tissues or further weakening of the wall (see Fig. 7). In those cases lacking sufficient wall to anchor (proximal heel wall cracks in racehorses are an excellent example), it is probably best to avoid any wall penetration and simply to glue stiff plastic patches or prosthetic hoof wall repair materials without implants requiring drilling.

A suggested approach to hoof wall crack repairs for clinicians lacking training or experience is to use feet removed from cadavers or to become familiar with the techniques by watching and assisting experienced people.

The techniques that are described in the literature can be deceptively simple on paper but are quite clearly capable of creating further damage. In the author's experience, the most likely circumstances creating problems or failure are:

- Penetration of the hoof wall with either a drill bit or implant (screws and wires)
- Use of wire without reinforcing the drill hole (eg, metal plate, small washers), because wire will cut through hoof wall (see Fig. 7)
- Drill holes that are sufficiently shallow to weaken the wall further and thus allow the repair to be easily pulled out of the repair site
- Lack of meticulous preparation of the associated wall so as to allow successful adhesion of the prosthetic hoof wall repair material
- Placing repair materials over nonkeratinized or infected tissues prematurely or not providing a drain/flush system (see Fig. 5)
- Less than ideal curing of the materials at the time of application (eg, cold temperatures, out-of-date or defective materials, improper mixing of the components)
- Lack of proper shoeing after repair

The following is a technique the author has used as a temporary means of quarter and heel crack stabilization when time or circumstances did not allow for a more elaborate and considered approach. In most instances, these were horses identified with hoof cracks on the day of a competition who were not showing evidence of overt lameness and when resetting a shoe was not likely. The technique uses either elastic tape or duct tape cut to fit (without making contact with the palmar or plantar coronary band region) the heels. The region surrounding the crack is sanded, a roll of tape is cut to fit, and a quick-setting glue is lightly smeared on the sanded surface just before application of the tape. Five or six complete circles of tape are applied with pressure around the entire hoof. The author has used this technique numerous times on Thoroughbred and Standardbred racehorses without ill effect. The technique is not, however, recommended beyond a "one-time basis," because it weakens within days and thus does not provide stability.

Horizontal cracks seldom require repair unless they are extensive and expose sensitive tissues. Repair, if necessary, is similar to that described previously. Those cracks resulting from preexisting and permanent damage to the coronary corium are unlikely to resolve; that is, a permanent wall defect may be present, in which case repairs to create stability may be a lifetime effort for a given horse.

As stated previously, this author is not aware of a single technique that is superior and thus prefers to use a variety of techniques to suit the situation. The simplest approach is to have the foot trimmed and balanced and shod with a full bar shoe, with the horse taken out of activity in the hope that the defect will grow out. Those cracks requiring stabilization need careful

exploration, an appreciation for the depth of the horn and underlying anatomic structures, and a meticulous approach.

Summary

Hoof wall defects in horses are common occurrences, and, fortunately, many of those detected present little or no danger to the individual horse. Those defects that are either presently a problem or have a great likelihood of being a problem do often require specialized consideration. Horse shoeing and farriery are ancient practices; over the years, a multitude of methods, theories, and management schemes have been proposed. It is unfortunate to note that few studies are available to provide an accurate incidence rate, a better understanding of the various causes, and, lastly, a comparative appreciation of the possible modes of treatment and management. This discussion reflects the thinking and experience of the author and, as such, should be read and viewed with an open and critical mind set.

References

[1] Moyer W, Anderson JP. Lameness caused by improper shoeing. JAVMA 1975;166:47–8.
[2] Moyer W, Anderson JP. Sheared heels: diagnosis and treatment. JAVMA 1975;166:53–5.
[3] Moyer W. Corrective shoeing. Vet Clin North Am 1980;2:7.
[4] Moyer W. Hoof wall cracks. In: Colahan J, Mayhew IG, Merritt AM, et al, editors. Equine medicine and surgery. 5th edition. St. Louis: Mosby; 1999. p. 1496–8.
[5] Moyer W. Therapeutic principles of diseases of the foot. Proc Am Assoc Equine Pract 1981;453–8.
[6] Moyer W. Underrun heels (low heel, long toe). In: Colahan J, Mayhew IG, Merritt AM, et al, editors. Equine medicine and surgery. 5th edition. St. Louis: Mosby; 1999. p. 1509–10.
[7] Moyer W, Sigafoos RD. A guide to equine hoof wall repair. Trenton (NJ): Veterinary Learning Systems; 1993.
[8] O'Grady SE. White line diseases—an update. Equine Vet Educ 2002;3:66–72.
[9] Kuwano A, Yoshihara T, Takatoria K, et al. Onychomycosis in white line disease in horses: pathology, mycology and clinical features. Equine Vet J 1998;(Suppl 26);27–35.
[10] Lungwitz A, Adams JW. Disturbances of continuity of the hoof. In: A textbook of horseshoeing. Philadelphia: JB Lippincott; 1913. p. 164–9.
[11] Stashak TS, Hill C, Klimish, et al. Cracks. In: Adam's lameness in horses. 5th edition. Philadelphia: Lippincott Williams & Wilkins; 2002. p. 1113–5.
[12] Moyer W, Sigafoos R. Preliminary experience and uses of composite hoof wall repair. Proc Am Assoc Equine Pract 1991;153–6.
[13] O'Grady SE. Quarter crack repair: an overview. Equine Vet Educ 2001;3:280–2.
[14] Evans LH, Jenny JJ, Raker CW. The repair of hoof cracks with acrylic. JAVMA 1966;148:355–7.
[15] Moyer W. Repairing hoof cracks in horses: a review and report of a new technique. Compend Contin Educ Pract Vet 1983;2(Suppl):S495.