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Use of Dressings and Bandages in Equine Wound Management

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Horses often suffer wounds in relation to their habitat, their use, and their natural instinct. Massive tissue loss, excessive skin tension, contamination, and infection make it difficult to treat some of these wounds by primary closure and first-intention healing. Wounds that heal by second intention are often managed with a dressing that covers the wound, providing protection from further trauma and contamination, absorbing excess exudate, and stimulating repair.

First- and second-intention repair of wounds on the limbs of horses is often delayed because of swelling, which results from chronic inflammation, and excessive movement at the site of the wound. Soft and rigid bandages are frequently used to control swelling, provide coaptation, and immobilize an area to minimize disruption of the fragile newly formed tissue. Bandages are usually composed of three layers: a primary or contact layer, often referred to as a "dressing"; a secondary or intermediate layer; and a tertiary or outer layer.

Dressings

Categories

The perfect dressing provides and maintains a moist environment and an adequate gaseous exchange at the wound surface that favors the proliferative phase of repair, particularly epithelialization. The dressing should also protect the wound from infection by acting as a bacterial shield and should provide thermal insulation. An ideal dressing occludes dead space, permits atraumatic removal of excessive exudate from the wound surface, and is easy to manipulate and nonantigenic [1].

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Dressings can be classified as synthetic, semisynthetic, or biologic (Table 1). Synthetic dressings are composed of man-made fabric or plastic materials in the form of gauze, films, sprays, foams, and gels. Semisynthetic dressings are a combination of synthetic and biologic products. Biologic dressings are obtained from natural sources and include amnion, allografts, and xenografts as well as bioengineered tissues composed of various proteins (particularly collagen) or cultured wound-healing cells (primarily fibroblasts and keratinocytes). Biologic dressings often exert a beneficial effect on the wound in addition to providing protective covering.

According to their ability to adhere to a wound, dressings are also classified as adherent or nonadherent. According to their ability to permit passage of exudate and vapors, dressings are further classified as occlusive, semiocclusive, or nonocclusive (permeable). Occlusive dressings are impermeable to water vapor, fluid, and oxygen, thus providing an environment that favors proliferation of anaerobic bacteria. Because occlusive dressings encourage the formation of exuberant granulation tissue in equine wounds [2], it is recommended to restrict their use to the first 6 to 48 hours after

Table 1
Dressing categories

Dressings	Origin	Significant features
Fabric materials		
Release pad	Synthetic	Nonadherent
Telfa pad		Nonocclusive
Petrolatum-impregnated gauze		
Xerofoam	Synthetic	Nonadherent
Adaptic		Nonocclusive
Silver-impregnated gauze		
Silverlon	Synthetic	Low adherence
Acticoat		Antimicrobial properties
Hydrogels		
Solugel	Synthetic	Nonadherent
		Occlusive
Hydrocolloids		
Hydrofiber	Synthetic	Self-adherent
		Occlusive
Polyurethane		
Opsite	Synthetic	Nonadherent
		Semiocclusive
Calcium alginate		
Kaltostat	Semisynthetic	Adherent
		Nonocclusive
Processed collagen		
Vet BioSist	Biologic	Adherent
		Occlusive
Amnion	Biologic	Adherent
		Occlusive
Allograft	Biologic	Adherent
		Occlusive

injury. Conversely, semiocclusive dressings, which are permeable to oxygen and gases but not to fluids, provide a moist environment that favors wound epithelialization, which requires aerobic metabolism. Finally, nonocclusive dressings are permeable to fluid and oxygen in both directions.

Dressings may play an active role in wound healing. A dressing should be selected according to the condition of the wound and to the current phase of repair. The use of adherent dressings should be restricted to the initial inflammatory and debridement phases because they facilitate removal of debris and excess exudate but may damage fragile tissues formed in subsequent phases. Wide mesh fabrics accomplish this function and can be applied as a wet-to-dry dressing in wounds with thick exudate and as a dry-to-wet dressing in wounds with an abundant volume of fluid [3]. A gauze dressing pad and secondary gauze wrap impregnated with 0.2% polyhexamethylene biguanide antiseptic as an antimicrobial are now available to veterinarians. These dressings have been found effective in substantially reducing the amount of *Pseudomonas aeruginosa* and *Staphylococcus epidermidis* that penetrates bandages from topical contamination [4].

During the proliferative and remodeling phases of repair, nonadherent dressings are favored. They may have an absorptive layer that facilitates draining of exudate and a petrolatum layer that permits easy dressing changes without disrupting new epithelium.

Particular materials

Nonadherent dressings (Release pad; Johnson & Johnson, Arlington TX) or petrolatum-impregnated gauze (Xerofoam; Tyco International, Argyle, NY) is frequently used to cover wounds on horses. These nonocclusive dressings are most useful when applied during the proliferative phase of repair. They are available in different sizes and easy to remove once exudate has saturated their absorption capacity. A study demonstrated that the use of nonadherent gauze pads on limb wounds of horses led to significantly reduced healing times, production of wound exudate, and development of exuberant granulation tissue compared with that obtained with synthetic semiocclusive or fully occlusive dressings [2].

Silver chloride–coated dressings (Silverlon; Argentum Medical LLC, Lakemont, GA) are reputed to have a broad antibacterial spectrum [5] and are the dressing of choice in the treatment of burn wounds in human patients [6]. The dressings, available in pads and packing strips for deep wounds, are used from the inflammatory phase into the proliferative phase of repair. The authors have used Silverlon dressings in clinical equine practice, where they seem effective in controlling infection.

Hydrogels are three-dimensional, water-swollen, cross-linked structures that seem to promote healing by providing a biocompatible environment while increasing the moisture content of necrotic tissue and favoring collagenase production, thus facilitating debridement. They can also act as carriers for antimicrobial agents, growth factors, and other biologically active molecules [7]. Clinical trials in people suggest that hydrogels are superior to more conventional forms of dressings in some wounds [8]. Solugel is a commercially available mixture of 25% propylene glycol, 0.6% saline, and a gelling agent (Solugel; Johnson & Johnson). In an equine model, Solugel did not seem to have any beneficial effect on the healing of small full-thickness limb wounds [9]. Because hydrogels promote repair by enhancing debridement, it is possible that the model may have limited the opportunity to demonstrate the reported advantages of Solugel on more traumatically induced wounds. Indeed, clinical assessment has suggested some beneficial effect in naturally occurring wounds.

Hydrocolloid dressings, composed of a hydrophobic polymer bound to hydroactive particles (carboxymethylcellulose) that react with surface exudate or water vapor from the wound to form a semisolid gel, are occlusive and usually self-adherent [1]. These dressings provide a low oxygen content and moist environment for migration and proliferation of cells, particularly keratinocytes and are thus credited with facilitating epithelialization, at least in human beings. Unfortunately, a study performed in the horse showed no benefits in using hydrocolloid dressings in the management of limb wounds [2].

Calcium alginate dressings are made of a natural fiber derived from seaweed. They possess hemostatic properties and promote fibroplasias [10]. Wounds suitable to be covered with a calcium alginate dressing must produce enough fluid to transform the calcium alginate into a gel-like substance so as to avoid desiccation and excessive scarring [11].

Polyurethane dressings are highly conformable, nonadherent, and semiocclusive. The foam can be used to absorb exudate from the wound, thereby decreasing tissue maceration; simultaneously, they maintain a moist environment while, with the sheet form (Opsite; Smith & Nephew, Indianapolis, IN), exudating pools beneath the dressing. These dressings can be used in the early inflammatory phase as well as in the proliferative phase of repair because they do not adhere to the regenerating tissue and leave it undisturbed at bandage changes. In heavily exuding wounds, these dressings should be replaced frequently to increase comfort, whereas the frequency of dressing change decreases as healing progresses and less fluid is produced by the wound [12].

Silicone dressings are used as an effective alternative to intra-lesional corticosteroids, surgical excision, laser surgery, and cryosurgery for the management of excessive scarring in man. It appears that this type of synthetic, non-adherent, and fully occlusive dressing surpasses other modalities in decreasing the amount of scar tissue while exerting no negative side effects. In a recent study performed in wounds of the distal limbs of horses, the silicone dressing surpassed a conventional permeable, non-adherent dressing in preventing the formation of exuberant granulation tissue and improving tissue quality [13].

Collagen dressings are commercially available in the form of sheets, mats, powders, gels, sponges, and laminates [14]. The benefits of these dressings relate to enhanced inflammation and hemostasis [15] and the provision of a collagen scaffold thought to accelerate fibroplasia and epithelialization. Topically applied bovine collagen gel and a collagen membrane were found to yield equivocal results when experimentally evaluated in equine wounds [16,17].

A lyophilized, porcine-derived, small intestinal or vesical submucosa product is available for use as a primary layer in wound management (Vet Bio-Sist; Cook Veterinary Products, Bloomington, IN). It contains collagen (types I, III, IV, V, VI, and VII), fibronectin, hyaluronan, chondroitin sulfate A, heparan, and heparin sulfate as well as various growth-enhancing cytokines. The product acts as a scaffold and is gradually replaced by host tissue with characteristics of normal adjacent tissue. It has been used clinically [18] and experimentally [19] in horses, with no apparent advantages over a traditional synthetic nonadherent pad [19].

Amniotic membrane has been used for the treatment of large skin wounds and burns in human patients since the early 1900s. It is also useful as a temporary dressing in the preparation of wounds for skin grafts and as a bandage for skin graft donor sites. Amnion is essentially a layer of epithelial cells overlying a matrix containing a large amount of collagen and scattered fibroblasts [20]. Amnion adheres and conforms to the surface of the wound and reduces pain. Its occlusive nature prevents the loss of fluids, electrolytes, and proteins from the wound surface and helps to control bacterial contamination [21]. Studies in horses suggest that wounds of the distal limb treated with amnion heal significantly faster, with greater epithelialization and decreased formation of exuberant granulation tissue [22,23], although controversy exists [2].

Amnion should be separated from the chorionic portion of the placenta near the convergence of umbilical vessels shortly after parturition. It should then be lavaged and debrided of any gross contaminants before being placed in a sterile container containing 2% povidone-iodine and saline solution and refrigerated. Within 24 hours, the amnion can be cut into smaller segments, which are washed in 2% povidone-iodine and saline, then sterile physiologic saline, and finally 0.25% acetic acid. After the final wash, the dressing is frozen at −20°C in a 0.25% acetic acid solution indeterminately or refrigerated for a maximum of 4 to 6 weeks [22].

Cutaneous autografts are the most physiologically normal dressings available; however, their quantity is limited. Conversely, an allograft refers to a skin graft transferred between members of the same species and represents the temporary wound dressing of choice for burn wounds in human patients. Allografts are more effective than other biologic or synthetic dressings in promoting rapid wound healing and arresting infection. Indeed, although the cells within the allograft do not survive long term, the graft provides a biologic wound environment that prevents desiccation, induces angiogenesis, and enhances fibroplasia and epithelialization [24,25].

Allografts used to treat skin defects can be split thickness or full thickness. Split-thickness allografts are obtained from the ventral aspect of the abdomen of cadavers, whereas full-thickness allografts can be obtained from the cranial pectoral region of a standing and sedated horse. In the case of the latter, subcutaneous tissue should be removed before grafting to optimize vascularization of the allograft. Aseptic technique should be used in preparing and collecting the skin [26]. Graft fenestration yields many advantages, including the ability to expand the graft, and permits medications to be in contact with the wound as well as facilitating drainage and the avoidance of dead space separating the graft from the wound bed [27].

Allograft revascularization relies on the presence of healthy granulation tissue in the wound bed. The initial binding of the graft to the granulation bed is accomplished with fibrin [28] in a manner analogous to that occurring in autografts. Proliferating vessels from the recipient bed penetrate this fibrin layer within the first 48 hours after grafting to anastomose with graft vessels within 4 to 12 days [29]. Unlike xenografts, allografts seem to cause a minimal antigenic reaction even when applied repeatedly [25,30].

Adherence of the allograft to the wound determines the success of the procedure because it allows revascularization and precludes suppuration beneath the dressing. Moreover, adherence can reduce pain and limit infection, increasing acceptance of the graft and, consequently, optimizing the rate of healing [31]. Fibrin glue is used to improve adhesion between the graft and the granulation bed, especially in areas in which movement is difficult to avoid [32].

Harvested allografts can be used immediately or can be stored frozen, refrigerated, or glycerolized for later use [33]. Fresh skin has a better ability to survive after grafting than does skin that has been previously refrigerated, frozen, or dried [34]. Although cryopreservation is simpler and of superior longevity compared with refrigeration, the latter yields better results on grafting. Storage solutions should provide a physiologic concentration of electrolytes, nutrients, and buffers so as to ensure graft preservation, although air must also be present within the container to provide oxygen for cellular metabolism [35]. The graft can be refrigerated for 4 to 6 weeks.

Preparation of the wound bed and application of the allograft resemble what is described for conventional autografting. Allografts can be applied repeatedly in successive "crops" after the preceding graft has been absorbed, leaving a clean granulation base [36].

Tissue engineering has generated commercially available cultured epithelial allografts (Apligraft; Organogenesis, Canton, MA) that seem to provide a potent healing stimulus to the wound bed, possibly via the release of cytokines or other mediators that stimulate the formation of extracellular matrix [37,38]. According to this premise, it is suggested that cutaneous allografts may enhance wound healing by providing a skin substitute and by adding stimulatory cytokines to the wound environment [39].

The use of porcine cutaneous xenografts in the management of large wounds in human patients arose from the need for a substitute biologic dressing because of the short supply of cadaveric skin. Like allografts, xenografts decrease bacterial colonization of the wound through adherence and promotion of angiogenesis at the recipient bed. Clinical comparisons have nonetheless shown that porcine xenografts are inferior to allografts because they adhere less tightly, allowing higher bacterial counts in the wound, and cause a more intense immunologic response, often leading to rejection [30,40]. Equine wounds treated with porcine xenografts, however, did not form exuberant granulation tissue and healed faster than control wounds [41], suggesting some benefit in this form of therapy if allografts are not available.

Bandages

Bandages are usually made of natural or synthetic materials applied consecutively over the primary contact layer. Commonly, equine bandages are composed of a secondary layer and a tertiary layer that maintain the dressing in place. The main purpose of the secondary (intermediate) layer is to absorb deleterious agents (eg, serum, blood, exudate, bacteria, necrotic debris) from a wound. This layer should be thick enough to collect absorbed moisture, pad the wound against trauma, and splint it to prevent excessive motion. Materials used in the secondary layer are elastic gauze and cotton pads, which must be carefully applied to conform to the shape of the leg.

The tertiary layer is usually composed of materials stiffer than those used for the secondary layer. The purpose of this outer layer is to hold the previous layers in place, prevent contamination and trauma, provide coaptation to minimize swelling of the limb with a consequent increase in tension at the wound edges, and decrease the range of motion. This final layer should be porous yet waterproof. Elastic self-adhesive bandages (Vetrap; 3M Animal Care Products, St. Paul, MN) are frequently used as the tertiary layer. The tertiary layer must be applied with constant pressure that is gradually increased as the bandage is wrapped in a distal-to-proximal direction. The most proximal and distal aspects of the cotton pad (secondary layer) are initially left uncovered to avoid pressure points that may affect circulation within intact skin. As a final step, the proximal and distal ends are covered with an adhesive band that adheres to the outer layer and the skin. This is done to prevent penetration of foreign bodies (eg, shavings, dirt) between the skin and the bandage, which may cause skin sores and wound contamination.

Special bandaging techniques

Some anatomic particularities must be considered when applying bandages and dressings on horses. Wounds involving the superficial deep flexor tendon (SDFT), deep digital flexor tendon (DDFT), hoof and pastern area, carpus, hock, head, and trunk require special techniques to hold the bandages in place and to avoid long-term complications associated with bandaging.

Hoof and pastern

Wounds of the coronary band and the pastern are subjected to a significant amount of motion that favors proliferation of granulation tissue and consequent delays in repair. A cast applied with the horse sedated or under general anesthesia is the authors' preferred method to manage wounds of this area. A nonadherent synthetic dressing is applied over the wound and is secured with elastic gauze. A roll of brown gauze is used to wrap the hoof and the pastern. A double layer of stockinette is applied from the bottom of the hoof to 4 to 5 cm past the planned proximal end of the cast. At the proximal aspect of the pastern, a 2- to 3-cm wide band of orthopedic felt is applied to the circumference of the leg over the stockinette and maintained in place with adhesive tape. In the standing and sedated horse, three to four rolls of 7.5-cm fiberglass cast tape are applied starting from 1 cm below the proximal edge of the orthopedic felt and rolling down to the bottom of the foot, without covering the sole. After 3 to 4 minutes (enough time for the cast to harden), the hoof is picked up and two to three rolls of 10-cm fiberglass cast are applied to the bottom of the hoof to cover the sole and the hoof wall. Immediately after casting, an acrylic protector (Technovit; Jorgensen Laboratories, Loveland, CO) is applied to the bottom of the cast to minimize wear on weight bearing. The cast is left in place for 10 to 14 days; at that time, the wound is re-examined. If necessary, a new cast can be applied at that time.

Tendon and ligament injury

Injuries to the SDFT and the DDFT require special bandaging techniques to decrease tension on the wound edges and permit adequate healing. Lesions affecting more than 50% of the SDFT, DDFT, or both should be immobilized with the fetlock fixed in partial flexion. A fiberglass cast is applied from the bottom of the hoof to the proximal aspect of the metacarpus or metatarsus. A wedge of wood or a folded roll of fiberglass tape placed on the bottom of the hoof elevates the heel and improves weight bearing. For injuries affecting the hind limbs, a Kimzey splint (Kimzey, Woodland, CA) keeps the fetlock in partial flexion and avoids complications associated with the prolonged use of a cast, while enabling open wound management.

Carpus

Bandaging the carpus requires special care to avoid placing excessive pressure over the medial and lateral tuberosities of the radius or over the accessory carpal bone, because these prominent and superficial structures are predisposed to the development of pressure sores. An adhesive primary dressing is preferred. A cotton pad may be used as a secondary layer, from which a plug of cotton is removed over the prominence to minimize pressure. An adhesive bandage applied in a figure-eight fashion, starting from proximal to distal and avoiding the prominence, is recommended as a tertiary layer. Alternatively, a "donut" of stockinette can be used over the secondary layer to encircle the prominence and thereby redistribute pressure from the tertiary layer to the periphery of the bony prominence, which is much less prone to pressure necrosis.

Hock

One of the most challenging areas to bandage is the hock. The conformation and the combination of forces that allow flexion and extension (ie, reciprocal apparatus) impose some important considerations when applying a bandage to this area. Horses are more reluctant to accept a contraption in this region and frequently disrupt the bandages because of exaggerated flexion. The primary and secondary layers should be applied, avoiding excessive pressure over the point of the hock (calcaneal tuberosity), using the same techniques as described for the carpus. The tertiary layer, a figure-eight bandage, is applied starting with complete loops on the distal aspect of the tibia and continuing down with figure-eight loops below and above the point of the hock (Fig. 1). The authors use a thick cotton bandage as a secondary layer on the distal aspect of the leg from the coronary band to the most proximal aspect of the metatarsus. This helps to prevent slippage of the hock bandage and, by decreasing the range of motion of the fetlock, restricts movement. Applying a rigid bandage or splint to the distal limb with the fetlock in partial flexion significantly decreases the range of motion of the hock, thereby increasing survival time of the bandage and allowing optimal wound healing.

Head wounds

It is sometimes necessary to cover wounds of the head. A custom-made stockinette with perforations for the ears and eyes is suitable for this purpose. To cover wounds that require some pressure (ie, enucleation, sinus flap), a figure-eight self-adhesive bandage is wrapped above and below the eyes and around the circumference of the nasal bones and the mandible (Fig. 2). Horses are usually tolerant of this type of bandage.

Trunk wounds

Stent or "tie over" bandages are suitable to cover wounds of the trunk. This is achieved by placing loops of heavy nonabsorbable suture material (no. 1 or 2) through the skin 3 cm apart and parallel to the wound edges. The bandage

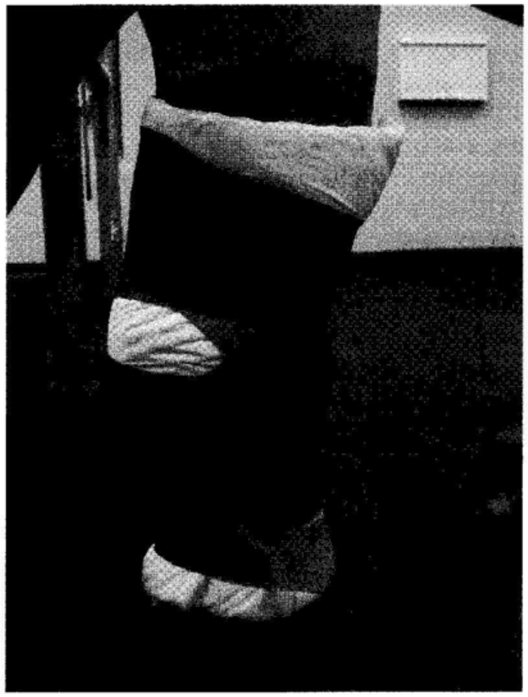

Fig. 1. Bandage of the hock.

that is applied to cover the wound is maintained in place by lacing umbilical tape through the previously created suture loops. The bandage can be changed as frequently as necessary. This type of bandage prevents retraction of the wound edges, keeps the wound free of contaminants, and provides a moist environment that is conducive to healing.

Casts and splints

Casts and splints are frequently used to immobilize wounds on the distal aspect of the limb. Wounds involving extensor or flexor tendons; wounds over the fetlock, carpal, and tarsal joints; and lacerations over the pastern, coronary band, and heel bulbs often heal more quickly and with less scarring when the leg is immobilized.

Fiberglass is preferred over plaster of Paris because of its greater strength and durability. Casts of various lengths are used according to the location of the injury. A hoof cast that covers only the hoof and the pastern is recommended for wounds involving the hoof wall, coronary band, heel bulbs, or pastern region. For wounds involving the fetlock or the extensor and flexor tendons, application of a half-limb cast that extends from the bottom of the hoof to the most proximal aspect of the metacarpus or

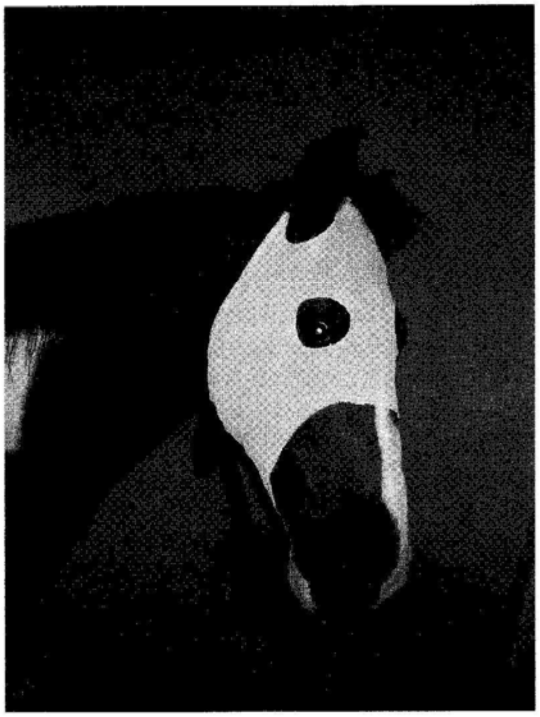

Fig. 2. Stockinette used to cover a wound on the head of a horse.

metatarsus is recommended. Tube casts from the most distal aspect of the metacarpus or tarsus to the most proximal aspect of the radius or tibia are suitable to manage wounds over the carpal and tarsal joints.

Bandage casts are useful to manage wounds that need long-term immobilization yet frequent monitoring. To construct a bandage cast,

Fig. 3. Bandage cast. A window was created to monitor a wound on the dorsal aspect of the fetlock.

primary, secondary, and tertiary layers are applied over the wound. Several rolls of fiberglass cast material are then applied over the bandage to increase its strength and ensure immobilization (Fig. 3). This final coat can then be split into halves for wound treatment and dressing changes. After rebandaging the wound, the two parts of the cast are reapplied and fixed with commercially available elastic tape.

Alternatively, distal limb immobilization to protect lacerations of the extensor and flexor tendons can be provided with custom-made polyvinyl chloride (PVC) splints or with a commercially available metal splint (Kimzey). These splints allow frequent monitoring of the wound and dressing changes while providing adequate immobilization of the involved tissues.

Cast sores are a common complication of fiberglass casts. An increase in lameness, fever, poor appetite, and low fecal output may signal the presence of cast sores, and the cause should be investigated immediately.

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