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Proximal interphalangeal arthrodesis in seven horses: A retrospective study in Brazil (2011–2019)

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ABSTRACT: *This study discussed several cases of proximal interphalangeal arthrodesis in horses at a veterinary hospital in Brazil. The medical records of seven horses that underwent proximal interphalangeal arthrodesis between 2011 and 2019 were analyzed for indication, technique, and complications. Short- and long-term outcomes were obtained from both the medical records and telephone interviews with the owners. A dynamic compression plate (DCP) was used in one of the seven horses that underwent surgical arthrodesis, and locking compression plates (LCP) were used in the others. Hospital discharge was recorded in 71.4% (5/7) of the horses, with an average hospital stay of 79 ± 45 days. Casting was maintained for 59 ± 26 days. Contact with owners was possible in four cases, two of which regained their prior level of function. The proximal interphalangeal arthrodesis may improve a horse's well-being, especially when it is considered an early intervention, minimizing the chances of immediate postoperative complications. Additional cases of surgical arthrodesis should be evaluated in long term to better characterize the outcomes of this procedure in Brazil.*
Key words: *orthopedics, lameness, pastern, phalanx.*

Artrodese interfalangeana proximal em sete equinos: um estudo retrospectivo no Brasil (2011–2019)

RESUMO: *Este estudo teve como objetivo apresentar e discutir casos de artrodese interfalangeana proximal em equinos atendidos em um Hospital Veterinário no Brasil. Os prontuários de sete equinos submetidos à artrodese interfalangeana proximal foram analisados quanto à indicação, técnica e complicações, entre 2011 e 2019. As informações sobre os desfechos de curto e longo prazo foram obtidas pela avaliação dos prontuário e entrevista telefônica com os proprietários. Em um dos sete cavalos submetidos à artrodese cirúrgica foi utilizado implantes DCP, e nos demais, LCP. A alta hospitalar foi registrada em 71,4% (5/7), com média de permanência hospitalar de 79±45 dias. A imobilização externa durou 59±26 dias. O contato com os proprietários foi possível em quatro casos, dos quais, em dois, os animais voltaram às suas funções. A artrodese interfalangeana proximal pode melhorar a qualidade de vida dos equinos, principalmente quando se considera a intervenção precoce, minimizando as chances de complicações pós-operatórias imediatas. Casos adicionais devem ser avaliados ao longo prazo para melhor caracterizar os resultados desse procedimento no Brasil.*
Palavras chaves: *ortopedia, claudicação, quartela, falange.*

INTRODUCTION

Conditions involving the proximal interphalangeal joint (PIJ) in horses that require surgical arthrodesis are common (MCILWRAITH & GOODMAN, 1989; HERTHEL et al., 2016; LISCHER & AUER, 2019). These conditions primarily include luxations, fractures, subchondral cystic lesions, degenerative joint disease secondary to septic arthritis, osteochondrosis, and osteoarthritis (OA) (GROOM et al., 2000; KNOX & WATKINS, 2006; SAKAI et al., 2018). Although, medical therapy can provide temporary relief, in many cases lameness can only be resolved through surgical arthrodesis and facilitated or spontaneous ankylosis (WATKINS, 2020a).

Of the different methods for performing arthrodesis, the use of implants (plates and screws) is currently the most recommended (WATKINS, 2020a). LISCHER and AUER (2019) previously described the use of a specific 4.5 mm locking compression plate (LCP) along with two or four 5.5 mm transarticular cortical screws as the gold standard for such procedure.

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Clinical outcomes of PIJ arthrodesis in horses have been well documented in several retrospective studies. Results are similar for various diagnoses and breeds, and horses with OA often achieve a better prognosis concerning their return to function (KNOX & WATKINS, 2006; HERTHEL et al., 2016; SAKAI et al., 2018). When reviewing the medical records of 34 horses that underwent PIJ arthrodesis using two 5.5 mm cortical screws with a lag screw technique, MACLELLAN et al. (2001) identified no differences in the outcomes of horses with OA, luxation, or fracture. However, ankylosis seems to be improved by the use of LCP (SAKAI et al., 2018), which has been corroborated through *ex vivo* biomechanical studies (ZOPPA et al., 2011; SEO et al., 2014; LATORRE et al., 2020).

Most of the retrospective studies previously published reported data from horses in North America and Europe. No studies have characterized the performance and results of PIJ surgical arthrodesis in horses in Brazil. Thus, this study discussed cases of proximal interphalangeal arthrodesis in horses treated at a veterinary hospital in Brazil.

MATERIALS AND METHODS

Case selection

We retrospectively reviewed the medical records of horses admitted to the Equine Medical Clinic Service at the Veterinary Hospital, School of Veterinary Medicine and Animal Science, University of São Paulo, from 1995 to 2019. However, since no PIJ arthrodesis had been documented there before 2010, the period included for review was January 1, 2011 to December 31, 2019.

To be included, we only considered horses that underwent PIJ arthrodesis using plates (DCP, LC-DCP, or LCP) with or without associated transarticular cortical screws, or those individually applied, regardless of limb number or diagnosis.

Review of medical records

The medical record information collected included clinical manifestations, modality, activity level, the affected limb, diagnosis, lameness duration, indication for arthrodesis, pre- and postoperative radiographic findings, medical treatments, surgical technique, implants, surgical time, postoperative care, and complications.

Surgical procedure

All procedures were performed using the horse in a lateral recumbent position with the affected limb upwards, under general inhalation anesthesia with isoflurane. When present, horseshoes were removed before the induction of anesthesia. The same surgeon performed all surgical procedures. All the horses underwent standard PIJ arthrodesis (LISCHER & AUER, 2019) with proper adaptations for each case. Palmar/plantar digital perineural anesthesia was administered at the abaxial surface of the proximal sesamoid bones using 0.75% ropivacaine. In all cases, the articular cartilage was removed using a curette and/or drill, followed by osteostixis using a 2.5 mm drill bit. Animal size and implant availability guided the selection of plate size and type for each case. All plates were shaped to maximize bone-to-plate contact. After the surgical procedure, the half-limb cast for applied, and trans operative radiographs were performed to confirm the implant positioning.

Drug therapy

Preoperatively, the horses were treated intravenously (IV) with one of the following: amikacin (15 mg/kg) plus ceftiofur (4 mg/kg), amikacin (15 mg/kg) plus cephalothin (20 mg/kg), or gentamicin (6.6 mg/kg) plus ampicillin (20 mg/kg). These regimens were continued for 5–7 days depending on the surgeon's recommendation. Regional perfusion with amikacin (1 g) was performed for at least 30 min immediately before the start of surgery.

Phenylbutazone (4.4 mg/kg, IV) was administered to all horses pre-and postoperatively for variable periods, depending on the horse. In horses 3 and 7, the postoperative anti-inflammatory therapy was changed to meloxicam (0.6 mg/kg, PO). Morphine (0.1 mg/kg, IM), ketamine (0.1–0.25 mg/kg, PO), and amitriptyline (0.5–1.0 mg/kg, PO) were used as postoperative analgesia for horses 3 to 7. Dose, frequency, and duration for each drug were adjusted according to pain assessment and case evolution. In horses with an affected hind limb (horses 1 and 3), the morphine was administered through an epidural catheter fixed in the space between the first and second caudal vertebrae (0.1 mg/kg, BID, or TID).

Postoperative care

All horses were kept with the cast distally to the carpal/tarsal joint. The cast was initially removed on postoperative day 15 to remove the suture, and then a new cast was applied. The cast was then replaced every 30 days, or when the horse showed discomfort with either external immobilization or spots, which feature conspicuous wound secretion. Cast changes were performed using horses under upright sedation or general anesthesia in a lateral recumbent position.

Telephone contact

One of the authors (AFS) interviewed the horse's owners by telephone to communicate with them concerning information on rehabilitation time, horse activity at that time, the appearance of the affected limb, and level of satisfaction.

RESULTS

Horses

At the time of our review, 29 horses had diagnoses related to the pastern. Of these, seven (24.1%) had undergone surgical arthrodesis of the PIJ, and included the following breeds: three Quarter Horses, one Brazilian sport horse, one Belgian warm blood, one Lusitano, and one crossbreed. Their ages ranged from 2–15 years old (9.3 ± 4.6 years), and weight from 277 to 550 kg (462.9 ± 93.8 kg) (Table 1). A horse with a comminuted fracture of the middle phalanx was excluded from the study for being treated with casting only.

The initial diagnoses were as follows: OA was identified in two horses, one of which (horse 4) also had distal interphalangeal OA in the same limb; fracture of the middle phalanx in two horses (with a uniaxial fracture of the plantar eminence and a comminuted one), and proximal interphalangeal luxation in three horses (Table 1).

The right hind limb was affected in two horses, the right forelimb in four, and the left forelimb in one. Of the included cases, only one limb was affected in each horse (Table 1). Diagnostic analgesia was performed only in horses with OA, and the diagnosis was made through physical, radiographic, and ultrasound examinations.

Horse 1, which fractured the lateral palmar eminence of the middle phalanx, underwent its first intervention for fixation of the fragment using the lag screw technique; however, the fracture was not made stable. Arthrodesis with plate and screws was subsequently performed 18 days later.

In horse 4, 70% ethyl alcohol was injected into the distal interphalangeal joint of the same limb in which the arthrodesis was performed. The OA was radiographically observed in this joint, surgical fixation was not considered. The digital palmar nerves in the most distal portion of the pastern were chemically neurolysis with Sarapin® (High Chemical Company, Levittown, USA) during hospitalization for persistent lameness.

Implants

Only horse 1 received a DCP, while all other horses received LCP. Only horse 3 received a 3-hole LCP specifically made for treating PIJ arthrodesis, and horse 2 received a 5.0 mm 7-hole LCP, with monocortical locking screws. In the remaining horses, 4-hole LCP was used, in which the third proximal hole received no screw as it was over or near the joint. In the cases where locking implants were used, the second proximal hole always received a cortical screw, while locking screws were used in all other holes (Figure 1).

The screws used for joint compression varied by horse. In horse 1, compression was achieved with one screw placed medially to the plate. In horse 2, it was placed into the combi-hole of the plate. Horses 3, 4, 5, and 7, received two screws, which were inserted medial and lateral to the plate. All screws were 4.5 mm. The most proximal screw of the plate

Table 1 - Breed, age, weight, modality, the affected limb and diagnosis of the seven horses that had undergone proximal interphalangeal arthrodesis, included in this retrospective study.

Horse	Breed	Age (years)	Weight (kg)	Modality	Limb	Diagnosis
1	Lusitano	4	426	Training	RH	Fracture (P2)
2	Crossbred	15	277	None	LF	PIJ luxation
3	Quarter Horse	12	457	Barrel racing	RH	PIJ instability
4	Warmblood	13	540	Horse riding	RF	PIJ and DIJ osteoarthritis
5	Quarter Horse	2	550	Racehorse	RF	PIJ luxation
6	Brazilian Sport Horse	10	520	Horse riding	LF	Comminuted fracture (P2)
7	Quarter Horse	9	470	Barrel racing	RF	PIJ osteoarthritis

PIJ: proximal interphalangeal joint; DIJ: distal interphalangeal joint, P2: middle phalanx.
RH: Right hind limb; LF: Left forelimb; RF: Right forelimb.

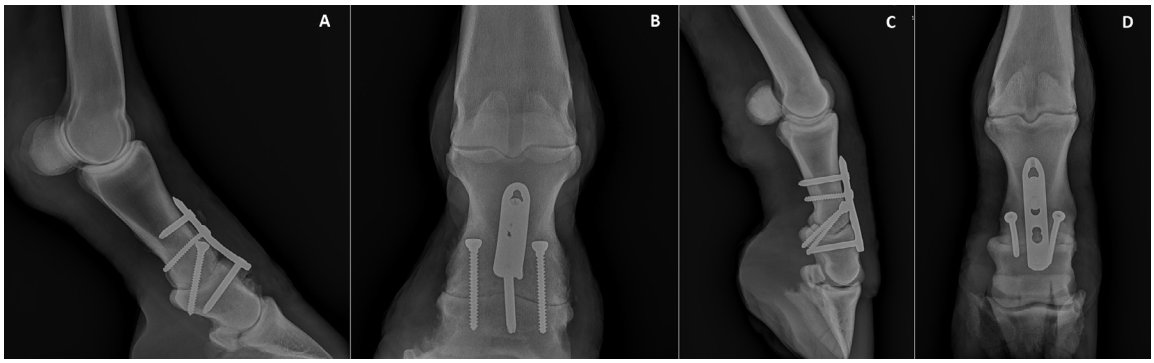

Figure 1 - Lateral-medial (A) and dorso-palmar (B) radiographs of horse 4, using a 3-hole plate (LCP) designed for the proximal interphalangeal arthrodesis. Note the placement of the proximal locking screw, only on the first cortical bone. Lateral-medial (C) and dorso-plantar (D) radiographs of horse 3, in which a 4-hole plate (LCP) was used.

was positioned in the first cortical bone in horses 4, 5, 6, and 7, and bicortically in horses 1 and 3.

Horse 6, which had a comminuted fracture in the middle phalanx, received two LCPs on the dorsolateral and dorsomedial surfaces, plus one lag screw. Table 2 shows a list of the implants used. The surgical times were documented in the anesthetic records for horses 3 to 7, and ranged from 90 to 300 min (199.0 ± 87.5 min) (Table 2).

Casting

According to their medical records, horses 1, 4, and 7 were kept in a cast for 59 ± 26 days. These horses were discharged after cast removal. Hospitalization lasted between 51 and 157 days (79 ± 45 days) for the discharged horses (horses 1, 2, 3, 4, and 7) (Table 2). After cast removal, the horses were kept in a stall or small paddock for 60 days.

Complications

Horse 1 was diagnosed with osteomyelitis, and the implants were removed 130 days after the procedure. Postoperative radiographic exams showed an intense mixed lytic-proliferative periosteal reaction, which resulted in ankylosis. Horse 2 developed chronic laminitis (sinking) in the contralateral limb, which was confirmed on radiographic images.

Horse 5 presented with signs of severe pain after anesthetic recovery, increasing progressively and was unresponsive to analgesic therapy. This horse subsequently developed laminitis, culminating in exungulation, followed by possible neurogenic shock and physiological exhaustion eight days after surgery; therefore, euthanasia was indicated. Horse 6 developed post-anesthetic myopathy during anesthetic recovery for which euthanasia was indicated.

Telephone contact

The owners of some of the horses were contacted to inquire about the following information:

Horse 2-Contact was made seven years after hospital discharge. The horse was moved to a public health unit, where it remained for a few more months, after which it was adopted. The horse died a few years later due to an acute abdomen condition.

Horse 3-Contact was made 19 months after hospital discharge. The owner reported that the horse had not shown lameness since its discharge and had returned to its role in high-level competition in barrel racing. It has participated in two competitions and had a similar level of performance as before surgery. While the owner did notice a slight swelling in the pastern after intense exercises, he was still satisfied with the outcome.

Horse 4-Contact was made 11 months after hospital discharge. The owner reported lameness of the affected limb; therefore, the animal was not used for any particular purpose. He also reported no morphological changes in the pastern and declared that he was satisfied with the outcome since the surgery improved the horse's overall well-being. He also expected to use the horse for some activities in the future, but he was aware of the serious condition that the animal had suffered from.

Table 2 - Orthopedic implants, surgical time, hospital stay, time of casting, and return to activity for the seven horses that had undergone proximal interphalangeal arthrodesis, included in this retrospective study.

Horse	Implant	Surgical time	Hospital stay (days)	Outcome	Time of casting (days)	Return to activity
1	One lag screw/4.5 mm 4-hole DCP, and 4.5 mm transarticular screw	NA	157	Discharge	78	NA
2	5.0 mm 7-hole pediatric plate for hips (LCP)	NA	51	Discharge	NA	Yes
3	4.5 mm 3-hole LCP* and two 4.5 mm transarticular screws	2h30	55	Discharge	NA	Yes
4	4.5 mm 4-hole LCP and two 4.5 mm transarticular screws	5h	79	Discharge	69	No
5	4.5 mm 4-hole LCP and two 4.5 mm transarticular screws	3h	08	Euthanasia	NA	NA
6	Two 4.5 mm 4-hole LCP	4h35	NA	Euthanasia	NA	NA
7	4.5 mm 4-hole LCP and two 4.5 mm transarticular screws	1h30	54	Discharge	30	No

DCP: dynamic compression plate; LCP: locking compression plate.
*specific plate for proximal interphalangeal arthrodesis. NA: unavailable.

Horse 7-Contact was made 4 months after hospital discharge. The owner reported mild lameness of the affected limb. He said that the animal was in the final third of gestation and would return to work only after weaning her foal. He reported slight pastern swelling, but was fully satisfied with the outcome. We were unable to obtain information from the owners of the other horses.

DISCUSSION

This study described for the first time clinical experience of proximal interphalangeal arthrodesis in horses in Brazil. The number of cases in this report was low, when compared to previously published reports, which show that this technique is poorly disseminated and chosen by equine practitioners for managing PIJ injuries.

Pastern disorders, which had an indication for arthrodesis comprised only one-fifth of all cases surveyed with diagnoses related to this area of the limb, including joints, bone, and soft tissue. Previous worldwide retrospective studies have provided information on 82 cases (HERTHEL et al., 2016), 30 cases (MCCORMICK & WATKINS, 2017), 29 cases (SAKAI et al., 2018), and 22 cases (SCHAER et al., 2010), showing a different reality in PIJ disorders and; therefore, requiring arthrodesis. It is possible that PIJ disorders occur more frequently in Brazil; however, the few horses referred to the veterinary hospital had been initially treated conservatively without success. This may partly explain the outcomes of this study, since more complicated cases with a longer period of evolution and worse prognosis were included. Early diagnosis of joint injury and referral to the veterinary hospital allowed for the successful treatment of horse 3, which was the only horse to return to its full athletic activities at the same intensity as before the injury.

Horse 1, which had a uniaxial fracture of the plantar eminence of the middle phalanx, was unsuccessfully treated due to implant failure of the first intervention to maintain the function of the PIJ. Lag screw repair did not allow visualization of the PIJ, reconstructing the articular surface of the middle phalanx could not be accurately. Furthermore, a single cortical screw does not provide rotational stability of the fragment, even when combined with a cast and does not properly support tensile forces on the fragment (WATKINS, 2020a). As the fracture line involved the joint, a degenerative condition could be inevitably established, and clinical therapy and posterior arthrodesis would then be needed (KNOX & WATKINS, 2006). Horse 1 also presented a surgical site infection (SSI) after a second intervention, requiring the removal of the implant to resolve it.

The postoperative SSI rate was 14.5% (1/7) for all included horses, which decreased to 20% (1/5) when considering only horses discharged from

the hospital, similar to 17.0% reported by Sakai et al. (2018) and slightly higher than 11.3% reported by Knox and Watkins (2006). It is worth noting; however, that this single case (horse 1) involved two interventions. As the time between the first and second interventions was only 18 days, healing had not yet been achieved, which made the tissue more susceptible to infection due to subsequent aggravations and implant placement.

A previous study has described positive results in three cases when using a lag screw to fix uniaxial fractures in the plantar eminence of the middle phalanx, with horses returning to their preoperative activities soon after intervention (TURNER & GABEL, 1975). However, COLAHAN et al. (1981) reported a study in which only two of six horses with palmar or plantar eminence fractures returned to competition post-intervention. Currently, when deciding for a similar scenario, surgical arthrodesis would be the first option (WATKINS, 2020b). This technique reduces costs by reducing the length of the hospitalization, which in this case (horse 1) was the longest of all - almost three times longer than those of the other discharged horses.

The negative outcome for horse 5 may have been the result of physiological exhaustion triggered by orthopedic trauma, stress, and pain. This exhaustion can be associated with transport, the change of environment, fasting, and anesthesia, leading to an inflammatory response that the body could not handle (MORRISON, 2019). A few hours after anesthetic recovery, the horse showed severe pain, with little response to opioids. Radiographs of the limb showed no failure of the implant. The horse's condition devolved to laminitis with distal phalanx sinking in all limbs, and even exungulation.

When an LCP was used, a monocortical locking screw was used in the proximal hole (horses 4, 5, 6, and 7). In horse 3; however, the proximal hole was filled with a bicortical locking screw (Figure 1). These approaches differ from current recommendations (AUER, 2020; WATKINS, 2020a), which advocate using a cortical screw in the first cortical bone. LISCHER and AUER (2019) have reported that this could minimize stress riser formation, where the tension lines of applied forces are concentrated, increasing chances of fracture.

It is worth mentioning that horse 3 returned to its normal activities with a similar performance as before the injury, even with a bicortical proximal locking screw, which could cause a stress riser in the proximal phalanx while exercising. Therefore, placing a bicortical screw (mainly locking) in the proximal hole may not be critical. Biomechanical studies can verify this, as once a 3-hole LCP is used, the placement of only locking screws could generate more stability and comfort to the patient (SAKAI et al., 2018).

The surgical time, recorded in 5 of 7 cases, was higher for horses 4 and 6, and in the other cases it was similar to the values presented by HERTHEL et al. (2016). Horse 4 was admitted with advanced OA and a lot of associated bone proliferation (Figure 1A and 1B), which made it difficult to remove the remaining cartilage and shape the plate. Since horse 6 had a comminuted fracture in the middle phalanx, the fixation of multiple fragments required more surgical time, considering that more advanced imaging resources were not available (tomography or fluoroscopy). The increased surgical time contributed to the development of post-anesthetic myopathy (WAGNER, 2008).

The small number of reported cases may be a limitation of our study. However, this seems to be characteristic of this intervention in Brazil. Another limitation of this report is the limited number of horses from which we could obtain long-term information, hindering conclusions on outcomes.

In Brazil, equine orthopedic surgery has evolved over the past few years, but there are still many challenges to overcome, and the data from retrospective studies can contribute significantly to this. Therefore, training, investments in good quality implants and instruments, and increased experience for postoperative conduct will increase the number of successfully treated horses (SOUZA et al., 2020; ZOPPA et al., 2020).

CONCLUSION

Surgical arthrodesis of the PIJ may improve the well-being of affected horses, with a potential return to their previous level of function, especially when early intervention is considered, minimizing the chances of immediate postoperative complications such as irresponsive pain, soft tissue damage, and surgical site infection. Additional cases must be evaluated in the long term to better characterize the outcomes of this procedure in Brazil.

AUTHORS' CONTRIBUTIONS

A. F. Souza and A. L. V. Zoppa were responsible for the conception of the study. G. M. Marcondes, N. F. Parestsis, J. D. Spagnolo, and R. R. Corrêa contributed to case management, procedure performance, and data acquisition/interpretation. All authors have approved the submitted manuscript.

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DECLARATION OF CONFLICT OF INTERESTS

The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be interpreted as a potential conflict of interest.

BIOETHICS AND BIOSECURITY COMMITTEE APPROVAL

Not applicable.

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