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# Long-term clinical and radiographic results after lag screw ostheosynthesis of short incomplete proximal sagittal fractures of the proximal phalanx in horses not used for racing

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**Abstract**

**Objective:** To determine long term outcomes of nonracing equines athletes treated for short incomplete proximal sagittal fractures of the proximal phalanx (SIPSFP1) by lag screw fixation.

**Study design:** Retrospective study.

**Sample population:** Thirty-one horses.

**Methods:** Medical records from horses with an SIPSFP1 (2008-2014) were reviewed. Long-term (≥12 months) outcomes were assessed with telephone interviews and clinical and radiographic examinations.

**Results:** Warmblood was the predominant breed in cases included in the study. Among horses with long-term interview information, 27 of 31 returned to previous athletic activity level. In total, 15 horses with 19 fractures had clinical and radiographic assessment after a minimum of 12 months. Among those, nine of 15 horses were sound at the trot, and six of 15 were mildly lame. Complete radiographic healing was confirmed in six limbs, and the facture line was evident in 13. The position of the proximal screw was not associated with radiographic fracture healing or return to soundness.

**Conclusion:** Most horses treated for SIPSFP1 with lag screw fixation returned to previous activity levels, although radiographic fracture healing remained incomplete 12 months or more after surgery.

**Clinical significance:** Lag screw fixation is a valid treatment for horses not used for racing that are experiencing an SIPSFP1 and results in a high rate of return to intended use, although complete radiographic fracture healing cannot be expected.

## 1 | INTRODUCTION

The sagittal groove of the proximal phalanx (P1) is exposed to a high stress concentration in equine athletes.[1] The metacarpophalangeal/metatarsophalangeal joints are hinge joints, allowing movement primarily in the sagittal plane.[2] Axial rotation, adduction, and abduction are limited by the anatomical congruence of the sagittal ridge of the distal third metacarpal/metatarsal bone with the sagittal groove of P1 as well as by the collateral ligaments and the suspensory apparatus.[2,3] In a finite element model, Von Mises stress increased mostly

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within the sagittal groove with increased load across the joint.[1] Furthermore, at midstance with maximal load on the metacarpophalangeal/metatarsophalangeal joint, the strain on dorsoproximal P1 increases exponentially as collateromotion and axial rotation increase.[3]

The bone surrounding the sagittal groove of P1 can be injured either acutely or chronically in response to repetitive trauma.[4-6] Osseous lesions such as simple incomplete sagittal fractures of P1, osseous cyst-like lesions, subchondral bone oedema, subchondral bone sclerosis, and thickening of the subchondral bone plate commonly develop distal to the sagittal groove of P1 and typically induce mild to moderate lameness.[4-9]

Simple sagittal fractures of P1 are common in race and sport horses.[5-9] Short incomplete proximal sagittal fractures of the proximal phalanx (SIPSFP1) are reported to have a length of less than 30 mm and arise from the midsagittal groove of the proximal articular surface of P1.[10] This fracture configuration is typically seen in horses used for athletic activities such as racing[10] as well as other disciplines such as show jumping.[7,9] A study of nonracehorses found that such fractures do not typically extend through both the dorsal and palmar/plantar cortex and are located more dorsally in forelimbs and more plantarly in hind limbs, respectively.[9] The precise fracture configuration can be detected only by using three-dimensional imaging, with computed tomography (CT) being the most accurate modality.[9,11,12]

Internal fixation with a lag screw technique is indicated in repair of complete and long incomplete sagittal fractures.[11,13] For SIPSFP1, both conservative and surgical treatments have been suggested.[7,9,10,14-16] Kuemmerle et al[7] showed in a case series in nonracehorses that conservative therapy can be associated with catastrophic fracture propagation. Nevertheless, there is a paucity of information describing the long-term outcome of lag screw fixation of these fractures, especially in horses not used for racing. Lipreri et al[17] recently reported no difference between surgical and conservative management of horses with high water signal within the proximal sagittal groove of P1 according to low-field MRI. However, such changes identified by low-field MRI are not necessarily consistent with SIPSFP1.

The objective of this study was to report long-term outcomes of horses not used for racing with SIPSFP1 fractures treated by lag screw fixation and to assess the effect of screw position in relation to the individual fracture configuration. We hypothesized that lag screw fixation would result in a favourable prognosis in terms of radiographic fracture healing and return to athletic activity. We further hypothesized that optimal position of the proximal screw in relation to the individual fracture configuration would have a positive effect on fracture healing and long-term soundness.

## 2 | MATERIAL AND METHODS

Horses were included if they had a lameness attributable to an SIPSFP1 diagnosed by using perineural and/or intrasynovial diagnostic anesthesia,[7] radiography, or CT and underwent lag screw fixation at our institution between 2008 and 2014. Treatment consisted of the placement of one or two 4.5-mm stainless steel cortical screws (DePuy Synthes) in lag fashion under general anesthesia and fluoroscopic guidance (Siremobil Iso C$^{3d}$; Siemens Medical Solutions) via a small stab incision. Surgery was performed by European College of Veterinary Surgeons board-certified surgeons. The planned location of this proximal screw was in the dorsopalmar/dorsoplantar center of the fracture plane, a maximum of 5 mm distal to the sagittal groove and parallel to the joint space. In several cases, dependent on fracture length and individual surgeon preference, a second 4.5-mm cortical screw was placed in lag fashion distal to the first screw. When CT revealed the presence of an SIPSFP1 in the contralateral limb, the contralateral limb was treated in a similar manner.

After surgery, a half-limb cast was applied, and assisted recovery was obtained by using head and tail ropes. The half-limb cast was removed within the following 2 days and replaced by a bandage. Perioperative antimicrobial prophylactic medication was provided by the administration of penicillin (30 000 IU/kg intravenously [IV] every 6 hours) and gentamicin (9 mg/kg IV every 24 hours) before surgery and continuing for 1 to 3 days postoperatively. The horses also received approximately 1 week of nonsteroidal anti-inflammatory therapy. Box rest was recommended for the initial 2 months after surgery. Short periods of hand-walking exercise were subsequently permitted, beginning 3 weeks postoperatively. The walking period was lengthened over the third and fourth months, and progressive training at the walk and trot was advised to commence 5 months after surgery, lasting another 2 months. After a total convalescence time of 7 months and provided that horses were determined to be sound, a progressive increase in training at all gait levels was recommended until the horses reached their previous level of activity.

Data obtained from the medical records included breed, age, sex, and the athletic use of each horse as well as any short-term complications (defined as complications that occurred between recovery from anesthesia and the end of the convalescence time of 7 months).

All preoperative and postoperative radiographic and CT studies were reevaluated by a board-certified radiologist (S.E.H.) and a board-certified surgeon (J.M.K.), both of whom were blinded to the clinical outcome of the horses, to determine fracture length (proximodistal and dorsopalmar/dorsoplantar). Each metacarpophalangeal/metatarsophalangeal joint was evaluated for presence and grade of osteoarthritis[18] (subjective grading system: none, mild, moderate, or severe). Both the changes in bone density and the spatial extension around the fracture were used to classify the degree of bone sclerosis on CT images subjectively from 0 to 3 (absent, mild, moderate, severe). Adequate screw placement in relation to the fracture configuration and whether the fracture line was still identifiable on long-term radiographs was assessed. The position of the proximal screw was graded as optimal when it was located in the dorsopalmar/dorsoplantar center of the fracture plane, located within 5 mm to the sagittal groove of P1, and oriented parallel to the articular surface.

Long-term (≥12 months) follow-up information[19] was obtained via telephone interview with the owners and an orthopedic and full radiographic examination whenever possible. All orthopaedic examinations were carried out by the same experienced veterinarian (M.F.B.) at the Vetsuisse Faculty, University of Zurich. Lameness at the trot was graded from 1 to 5, as recommended by Ross.[20] Postmortem CT results were available in two cases.

The influence of position of the proximal screw on fracture identification on long-term radiographs, on lameness at the trot, and on development of osteoarthritis was evaluated with Fisher's exact test in GraphPad software. The effect of age at fracture fixation on radiographic fracture healing (based on visibility of the fracture line on dorsopalmar/dorsoplantar radiographs and smoothing of dorsoproximal callus if present on lateromedial radiographs) was examined with a Mann–Whitney U test (Social Science Statistics). The level of statistical significance was set at $P < .05$.

## 3 | RESULTS

Thirty-one horses were included. Breed distribution was 28 warmbloods, one Arabian, one Andalusian horse, and one quarter horse. Mean age was 9.5 years (range, 4-17), and there were 17 mares, 13 geldings, and one stallion. Show jumping was the most common athletic use of the horses, followed by pleasure riding and dressage. Compared to our hospital population, show jumping horses were overrepresented. Clinical findings associated with SIPSFP1 and response to diagnostic anesthesia were as reported previously.[7,9]

An SIPSFP1 of the contralateral limb was detected by CT in seven horses. Therefore, lag screw fixation was performed in 38 limbs. Mean fracture length in the proximodistal extension as determined by CT was 5.1 mm (range, 1.7-13.8). Osteoarthritis of the fetlock joint was present and mild in four of 38 limbs. The sclerosis in the proximal P1 region around the fracture was mild in 19 cases, moderate in 17, and severe in two. The fracture was incomplete in the dorsopalmar/dorsoplantar direction (did not involve both cortices) in 34 limbs and complete in four limbs as assessed with CT transverse plane images. The mean fracture length in the dorsopalmar/dorsoplantar extension was 20.8 mm (range, 12.2-41.9). Two screws were implanted in 28 limbs, and a single screw was used in 10 limbs.

Short-term complications occurred in four horses. One mare developed cellulitis in the surgically treated limb, and another horse developed diffuse acute periosteal proliferations in the proximal P1 region associated with mild lameness at the walk 1 month postoperatively; both horses were treated medically with success. One horse that had two screws implanted to treat a unilateral SIPSFP1 of the right front limb experienced fracture propagation with a resultant comminuted P1 fracture that occurred when the horse broke free during grazing 2 weeks postoperatively and was euthanized. Screw removal was performed in one case because of profuse periosteal reaction around the screw tips 6 months postoperatively.

Long-term information was available for 27 horses, and three horses were lost to follow-up (Figure 1). The rate of horses returning to intended use was 24 of 27 (89%) at a mean of 9.5 months (range, 7-18) after surgery, corresponding to full

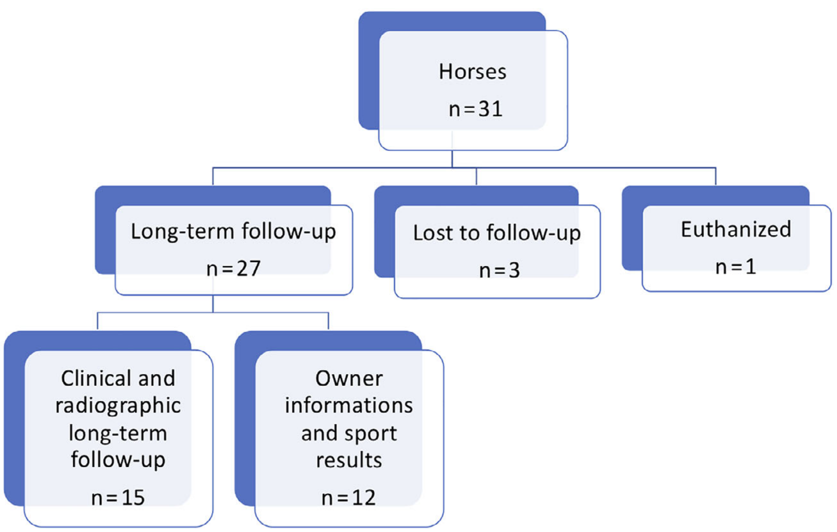


**FIGURE 1** Overview of the follow-up information and the number of horses included in each group

function (defined as "restoration to, or maintenance of, full intended level and duration of activities and performance from preinjury or predisease status without medications").[19] Twenty-four of 27 owners reported being very satisfied with the outcome of surgical treatment.

Clinical and radiographic long-term follow-up examination was performed a mean of 3.2 years after surgery in 15 horses with a total of 19 fractures (Table 1). In total, 12 horses were lost to follow-up clinical and radiographic examination. In four of these horses, an examination was not possible because of logistical reasons. In seven horses, death or euthanasia was reported unrelated to the affected limb. In one horse, euthanasia for lameness of the affected limb was reported. The affected P1 of two of the deceased or euthanized horses was imaged with CT (Figure 2).

At follow-up examination, the fetlock joint was mildly effused in five and moderately effused in two surgically treated limbs. All horses were sound at the walk. At the trot,

**TABLE 1** Horses presented for clinical and radiologic long-term follow-up examination

| Horses | Affected legs | Athletic use | Numbers of srews and screw length from proximal to distal, mm | Optimal proximal screw placement | DJD preoperative | DJD progression | Lamness at long-term follow-up | Radiologic fracture healing at long-term follow-up | Follow-up time, y |
|---|---|---|---|---|---|---|---|---|---|
| 1 | Front right | PR | 56<br>52 | no | yes | yes | no | no | 3 |
| 1 | Front left | PR | 56<br>52 | no | yes | yes | 2/5 | yes | 3 |
| 2 | Hind right | D | 58 | no | no | no | no | yes | 1 |
| 3 | Hind left | SJ | 54<br>58 | no | no | no | no | yes | 6 |
| 4 | Front left | SJ | 56<br>48 | no | no | no | no | no | 5 |
| 5 | Front right | SJ | 52<br>56 | yes | no | no | 2/5 | yes | 5 |
| 6 | Hind left | PR | 52<br>44 | no | yes | yes | 2/5 | no | 5 |
| 7 | Hind left | D | 64<br>54 | yes | no | no | 1/5 | no | 4 |
| 8 | Hind right | SJ | 54<br>54 | no | no | no | no | no | 4 |
| 8 | Hind left | SJ | 54<br>52 | no | no | no | 2/5 | no | 4 |
| 9 | Front left | PR | 46<br>48 | no | yes | yes | no | no | 4 |
| 10 | Front right | PR | 60 | yes | no | no | no | no | 4 |
| 10 | Front left | PR | 64<br>54 | yes | no | no | no | no | 4 |
| 11 | Front right | SJ | 56 | no | yes | no | no | no | 3 |
| 12 | Hind left | SJ | 58 | no | no | no | no | yes | 1.5 |
| 13 | Hind left | SJ | 64<br>48 | no | no | no | no | yes | 1 |
| 14 | Front left | PR | 52<br>46 | yes | yes | no | no | no | 1 |
| 15 | Hind right | D | 64 | no | no | no | no | no | 1 |
| 15 | Hind left | D | 58 | no | no | no | 2/5 | no | 1 |

*Note*: Follow-up is time between surgery and long-term follow-up.
Abbreviations: D, dressage; DJD, degenerative joint disease; PR, pleasure riding; SJ, show jumping.

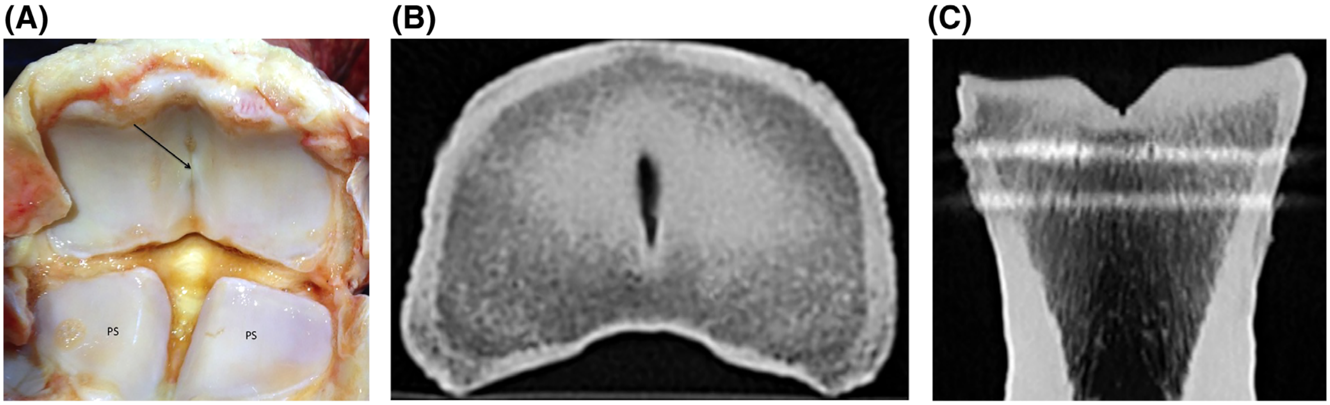


**FIGURE 2** Images of horse No. 17, which was euthanized 4 years after surgery for reasons unrelated to the fracture. This horse was clinically sound and returned to show jumping. A, Necropsy image of the metacarpophalangeal joint with the fracture line visible in the sagittal groove (arrow) of the proximal phalanx (P1) that had been treated by implantation of two lag screws 4 years previously. PS, proximal sesamoid bone (courtesy of Thomas Wagner). B, Transverse CT image in bone window of the proximal part of the same P1. A widened and smoothly delineated unhealed fracture line is identified just distal to the sagittal groove. C, Dorsal multiplanar reconstructed CT image in bone window of P1 with a clear indentation in the sagittal groove. The two parallel hyperattenuating lines are metal-related artifacts from the screws. CT, computed tomography

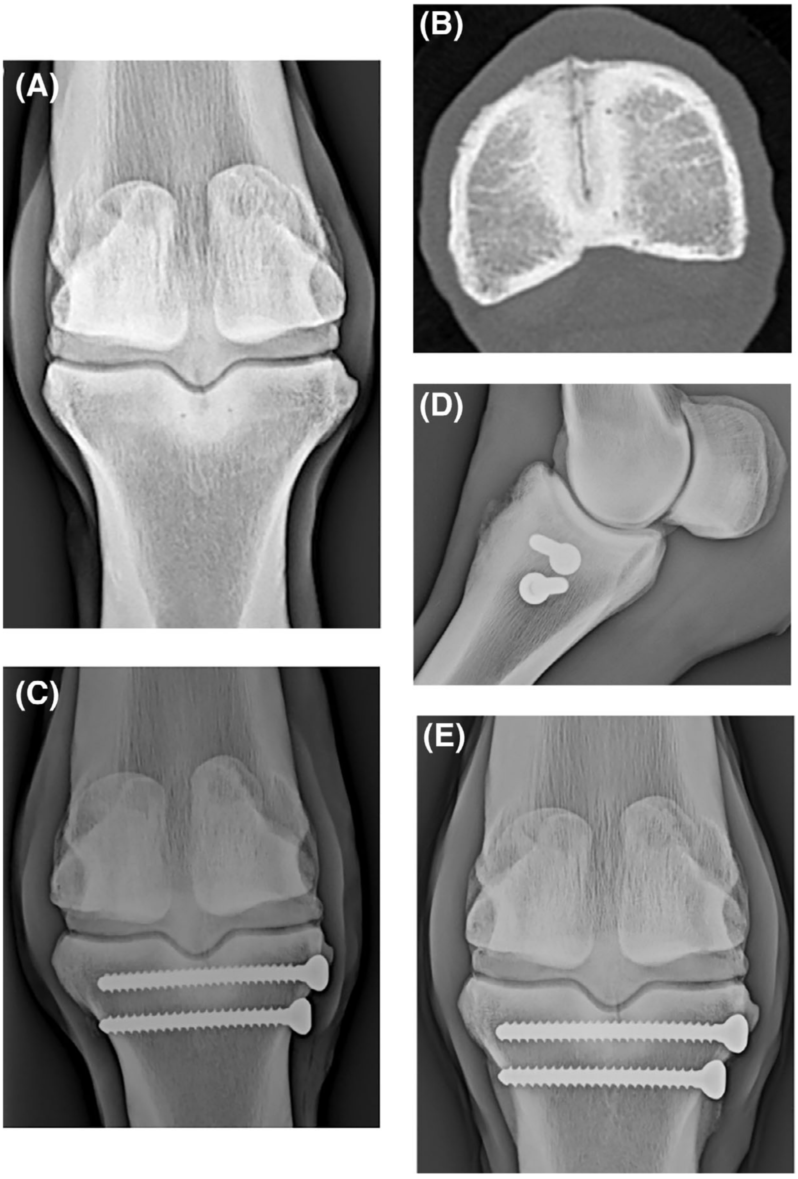


**FIGURE 3** Radiographic and CT images of horse No. 14. A, Preoperative palmarodorsal radiographic image with a fracture line just distal to the articular margin of the sagittal groove of P1 with moderate peripheral sclerosis. B, Transverse CT image in bone window. This fracture penetrated the dorsal but not the palmar cortex. C,D, One-day-postoperative palmarodorsal and lateromedial radiographic images. The proximal screw is positioned dorsally corresponding to the individual fracture configuration, located within 5 mm distal to the sagittal groove and is oriented parallel to the articular surface. This classified the position of the proximal screw as optimal. E, The fracture line is still visible on long-term follow-up radiographic images (15 months postoperatively), clearly providing evidence of nonunion of the fracture and no lameness. This horse returned to intended use and showed no lameness at long-term follow-up clinical examination. CT, computed tomography

nine of 15 horses were sound, one was graded as 1 of 5 lame, and five were graded as 2 of 5 lame. Distal limb flexion test results returned positive responses in seven of 19 treated limbs.

The fracture gap remained visible on long-term follow-up radiographs for 13 of 19 (68%) limbs. Complete radiographic healing, whereby the fracture line was no longer identified with smoothing of any associated callus, was noted in six limbs. Progression of osteoarthritis between preoperative and long-term follow-up radiographs was present in four horses.

Proximal screw placement was graded as optimal in five of 19 fractures fixations according to postoperative radiographs. There was no effect of position of the proximal screw on radiographic fracture healing, long-term soundness and development, or progression of osteoarthritis (Figure 3). There was no influence of age on long-term radiographic fracture healing ($P = .51$).

## 4 | DISCUSSION

This study provides evidence that lag screw fixation of SIPSFP1 is associated with a good long-term result and a high proportion of nonracehorses returning to intended use.

Most horses in this study were show jumping horses, similarly to other reports in such a population.[5,9] This likely represents an overrepresentation beyond differences in horse populations presented to specific equine hospitals. Show jumping horses perform narrow turns, and this activity may be associated with an increase in the torsional forces in the area of the sagittal groove.

The return of 89% of horses to intended use after a mean rehabilitation period of 9.5 months in this study is superior to numbers reported with conservative treatment.[7,17] Lipreri et al[17] reported a lower success rate in a warmblood-dominated population with respect to surgical therapy with lag screw osteosynthesis compared to our study. This can be attributed to several factors. In their study, an SIPSFP1 was visible on radiographs or MRI in only six of 21 horses, while other horses had different pathologies in the proximal P1 region such as bone oedema or cyst-like lesions.[17] In addition, three of nine horses of the surgical group were treated conservatively before surgery.[17] However, because the duration of lameness before surgery was not recorded for all horses in our study, it is possible that chronic fractures may have been included. Furthermore, seven of nine horses underwent surgery in a standing position in the study by Lipreri et al.[17] Due to the axial pressure applied to P1 in the weight-bearing standing horse, it is possible that the compressive effect of the lag screw is less than that achieved with a recumbent horse. Achieving an optimal screw placement may also be more difficult in the standing horse. In racehorses, good results of lag screw fixation have been described, with 71% of horses reported returning to racing in one article,[16] and 92% of horses with at least one race start after surgery and a shorter rehabilitation period compared to conservative therapy reported in another article.[21]

Our report is one of the few that provides information on long-term outcome based on clinical and radiographic follow-up examinations. Our study identified two interesting aspects. First, the proportion of horses that remained lame was quite high at 40%. However, this was based on visual lameness detection by an experienced veterinarian. It should be noted that lameness was deemed mild in all cases, did not limit the horses in their athletic function, and was often missed by the owners, riders, and trainers.

Second, it revealed an unexpectedly high rate of incomplete radiographic healing. Before this study, radiographic nonunion of these fractures had been reported only in cases treated conservatively.[7] The rationale for performing lag screw osteosynthesis is to minimize interfragmentary strain, compress the fracture gap, promote primary bone healing, and prevent microcrack propagation.[22] However, CT confirmed that most fractures were very short, and it may not have been possible to compress the articular margin of the fracture with the lag screw.[1] In addition, the presence of synovial fluid in the fracture may have hindered bone healing.[23-26] Nevertheless, because many SIPSFP1 are centered either dorsally or palmarly/plantarly and do not engage both cortices,[9] adapting the position of the proximal screw to the individual fracture configuration facilitates placement of this screw in the dorsopalmar/dorsoplantar center of the fracture. This placement could promote optimal mechanical effects of this implant. Another modification of the standard technique that is used to optimize mechanical effects of lag screws in these fractures is to implant two proximal screws immediately distal to the articular surface.[27] In contrast to the technique described in our study, this approach does not rely on CT-based detection of the individual fracture configuration.

This study did not provide evidence of a significant effect of an ideal position of the proximal screw on lameness reduction, fracture healing, or progression of osteoarthritis. This may be associated with limited case numbers, a limited number of cases with optimal screw placement, and low statistical power to detect such potential effects. An alternative explanation may be due to the strict definition of optimal screw placement. All screws were placed adequately, so the difference between screws with a position deemed optimal and those deemed suboptimal may be too subtle. Additional limitations of the study include its retrospective nature and the absence of a standardized follow-up period. In four horses, more than one limb was affected, which may have affected the lameness examination. Another limitation is that the surgical treatment of SIPSFP1 was not compared to a control group treated with conservative management.

Furthermore, unintended variations in radiographic projections and technique may have affected measurements such as the distance between the articular surface and the proximal screw as well as the radiographic visibility of the fracture line that was used as the main variable to determine fracture healing.

In conclusion, minimally invasive lag screw fixation of SIPSFP1 in horses has a very good prognosis with regard to functional outcome. However, complete radiographic healing does not commonly occur. It remains unclear whether adaption of implant position to the individual fracture configuration is associated with improved outcome.

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## CONFLICT OF INTEREST

The authors declare no conflicts of interest related to this study.

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