

OUTCOME OF KERATOMA REMOVAL USING DIFFERENT SURGICAL TECHNIQUES, INCLUDING A MODIFIED PARTIAL HOOF WALL RESECTION: A RETROSPECTIVE STUDY (2004–2025)

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Abstract

Keratomas are diseases of the equine hoof that can be associated with intermittent lameness and/or recurrent foot abscesses. Different surgical techniques for keratoma removal have been described. The aim of this retrospective study was to report the short- and long-term postoperative complications after keratoma removal using different surgical techniques: complete hoof wall resection (CR), partial hoof wall resection (PR) and a modified version of PR (MPR). The medical records of horses diagnosed with keratoma and space occupying lesion (SOL) of the hoof wall (2004–2025) at a Veterinary Teaching Hospital were reviewed. Fifty-five cases underwent surgery (18 CR, 35 MPR and 2 PR). Partial hoof wall resection cases were excluded from statistical analysis due to a very limited number. On the short term, 9/35 (25.7%) of MPR cases developed complications. Modified partial hoof wall resection showed significantly less complications (especially exuberant granulation tissue and hoof wall instability) than CR. Other short-term complications across surgical procedures included laminitis, infection, fracture, and colic. Long term follow-up (6–180 months) was available for 15 CR, 2 PR and 22 MPR cases. Modified partial hoof wall resection group showed significantly less hoof cracks than the CR group. Keratoma recurrence occurred in 3/15 cases in CR, 1/2 in PR, and only 1/22 in MPR groups. Return to activity was achieved in around 70% of CR and MPR cases. Mean time to return was significantly shorter in the MPR (6.5 months) than in the CR group and was in line with durations generally described in the literature for PR. In conclusion, MPR can be an effective alternative to traditional surgical approaches for keratoma removal.

Keywords

Equine Hoof, Disease, Surgery, Complications

1. Introduction

Keratomas are abnormal tissue growths in the hooves of horses, ponies and donkeys (Eggleston et al., 2020; Paraschou et al., 2023; Pickersgill, 2000; Thiemann and Poore, 2019). Typically, keratomas originate from the keratin-producing epidermal cells of the stratum germinativum in the coronary band (Hamir et al., 1992). However, keratoma can also develop on the surface of the hoof wall or from the sole (McDiarmid, 2007; Miller and Katzwinkel, 2015). They usually cause intermittent lameness combined with recurrent hoof abscesses (Agne, 2010; Honnas, 1997). In some cases, keratomas can also be incidental finding in a non-lame limb (Mair and Linnenkohl, 2012). Diagnosis is based on the history, the clinical signs (e.g. recurrent abscessation, deviation of the white line) and in some cases, on the detection of alteration of the profile of the distal phalanx during radiographic examination, magnetic resonance imaging (MRI), or computed tomography (Butler et al., 2017; Getman et al., 2011; Katzman et al., 2019; Mageed et al., 2020; Mair and Linnenkohl, 2012). Although conservative treatments have been reported, surgical options, specifically complete hoof wall resection (CR) or partial hoof wall resection (PR), are generally considered as the most effective solutions (Bosch et al., 2004; Fürst and Lischer, 2019; Jaworska, 2018). Reported post-operative complications following surgical treatment included: hoof wall instability, excessive granulation tissue, laminitis, hoof cracks, infection and keratoma recurrence (Boys Smith et al., 2006; Getman et al., 2011; Honnas, 1997; Ross et al., 2025).

Complete hoof wall resection has been associated with a higher complication rate and a longer recovery period compared to PR (Boys Smith et al., 2006). Partial hoof wall resection, when based only on radiographs, has been associated with a greater risk of keratoma recurrence (Getman et al., 2011; Mair and Linnenkohl, 2012). In order to reduce the number of complications, we have used a modified version of PR, that we have named modified partial hoof wall resection (MPR), which starts at the solar aspect of the lesion.

The aim of this study was therefore to report the short- and long-term postoperative complications in a series of keratomas or space occupying lesions of the hoof wall (SOL) in horses operated using different surgical techniques at the Equine Clinic of the University of Liège, Belgium, between 2004 and 2025. We hypothesized that horses treated with MPR for keratoma removal would experience fewer postoperative complications, have a lower rate of keratoma recurrence, and would quickly return to normal activity compared to horses treated with other techniques.

2. Materials and methods

This retrospective study included horses diagnosed with keratoma and SOL of the hoof wall in the Equine Clinic of the University of Liège, Belgium between November 2004 and February 2025. Medical records were reviewed by the same person (GCD). The following data were extracted: signalment, medical history, clinical signs such as foot abscesses and lameness (classified using the American Association of Equine Practitioners [AAEP] scale), diagnostic imaging findings (radiography +/- MRI), type of surgery (CR, PR or MPR), type of anaesthesia (standing sedation or general anaesthesia), and short-term postoperative complications (during hospitalization).

2.1. Diagnostic imaging

Radiographs of the feet were performed by the Diagnostic Imaging Section of the University of Liège in most cases. In some instances, the radiographs were provided by the referring veterinarian. A keratoma/SOL was indicated by the presence of smoothly outlined defect or radiolucency of the distal phalanx caused by the space-occupying hoof lesion. In some cases where the radiographic demarcation of the keratoma/SOL was unclear or an associated lesion was suspected, a low-field MRI was considered. Keratoma/SOL of the hoof wall appeared on MRI images as a cone-shaped hypointense structure invaginating from the stratum medium into the dermis and causing pressure lysis on the distal phalanx.

2.2. Type of anaesthesia

Procedures were carried out either under general anaesthesia (GA) or standing sedation (SS). For GA, horses were premedicated with intramuscular (IM) acepromazine maleate (0.05 mg/kg bwt, IM) and intravenous (IV) xylazine hydrochloride (0.6 mg/kg bwt, IV). Anaesthesia was induced using a combination of ketamine hydrochloride (2.2 mg/kg bwt, IV) and either midazolam hydrochloride (0.06 mg/kg bwt, IV) or diazepam (0.08 mg/kg bwt, IV). After induction, orotracheal intubation was performed, and horses were mechanically ventilated and maintained with isoflurane in an oxygen/air mixture. For SS, intravenous detomidine hydrochloride (0.01 mg/kg) and morphine sulphate (0.05 mg/kg) were administered, followed by a constant rate infusion of detomidine hydrochloride (0.02 mg/kg/h, IV) and morphine sulphate (0.05 mg/kg/h, IV).

2.3. Type of surgery

The hoof was trimmed and thoroughly cleaned the day before, and a moist antiseptic bandage prepared with 5% chlorhexidine gluconate diluted 1:10 with water was applied overnight. On the day of the procedure, an abaxial sesamoid nerve block was performed using 5 ml of 2% mepivacaine hydrochloride per injection site to provide anaesthesia of the foot. After aseptic preparation of the foot, a tourniquet was applied between the middle and the distal third of the cannon region immediately prior starting the surgery.

2.4. Complete hoof wall resection

This technique, also described by Honnas et al. (2003) and Boys Smith et al. (2006), is schematically illustrated in Fig. 1. It involves removal of the keratoma/SOL and the adjacent part of the hoof wall by means of two parallel vertical cuts, which are connected proximally by a horizontal cut. After removal of the hoof wall flap, debridement was based on visual assessment of the lesion and was extended to include affected bone in cases of laminar necrosis and/or septic distal phalanx osteitis. The final appearance of the CR is shown in Fig. 2.

On each side of the operated area, the contact between the distal hoof wall and the ground was suppressed by a mild trimming.

In several cases of large complete resection, a metallic plate bridging with screws or a cerclage wire were placed between the edges of the hoof wall to help maintaining hoof stability during healing.

2.5. Partial hoof wall resection

This procedure, as described by Boys Smith et al. (2006), is schematically illustrated in Fig. 3. Briefly, it involves the creation of a lateral window in the hoof wall (with a trephine or motorised tool) to access and remove the keratoma/SOL, while preserving the distal hoof wall to maintain hoof stability. This lateral window was centred over a mark made preoperatively at the expected proximal extent of the abnormal tissue based on diagnostic imaging. The extent of debridement was based on intraoperative visual assessment of the lesion and presence of laminar necrosis. In some cases, enlargement of the initial fenestration using a hoof knife or creation of a small additional opening through the sole was necessary to ensure complete removal of the abnormal tissue and/or provide drainage.

The distal hoof wall under the operated area was slightly trimmed to reduce pressure on the surgical site.

The final appearance of the PR is shown in Fig. 4.

2.6. Modified partial hoof wall resection

This variant of the PR is schematically illustrated in Fig. 5.

Conversely to the traditional PR technique, the lesion was approached from the solar aspect of the hoof in the MPR technique. Under direct visualization, the horn around the keratoma was dug using a drill bit and/or a hoof knife (a thin layer of horn is removed) (Fig. 6A). The dissection progressed circumferentially proximad while preserving the external hoof wall and taking care to maintain the structural integrity of the lesion as much as possible (such as in the core sampling technique). This debridement was extended proximally along the hoof wall as far as possible to free the keratoma from the surrounding tissues. Once the apex of the keratoma has been reached, a 25 mm trephine was used to create a fenestration in the hoof wall to access the origin of the lesion. If necessary, the trephination site was slightly enlarged proximally to ensure complete removal of the abnormal tissue and to connect the solar and wall openings (Fig. 6B).

The final appearance of the MPR is shown in Fig. 6C.

As for the two other techniques, the debridement was extended deeper in cases of laminar necrosis and/or septic osteitis and the distal hoof wall under the operated area was slightly trimmed.

The main particularities of MPR (in comparison to PR) are a solar first approach under visual guidance, the care taken to preserve the integrity of the keratoma (coring technique), the relatively small size of the lateral hoof wall window. Furthermore, with the MPR technique, there are no attempt to keep the hoof wall distal to the fenestration site attached to the lamellae (which can be the case for a PR without distal drainage).

2.7. Perioperative medications

Horses received perioperative antimicrobial and nonsteroidal anti-inflammatory drug (NSAID) treatment. The choice of antimicrobial and NSAID was made by the surgeon, with treatment selection also depending on whether the horse was intended for human consumption or not. The most used perioperative antimicrobials were doxycycline (10 mg/kg bwt, per os -PO-, q12h) or procaine penicillin G (22,000 IU/kg bwt, IM, q12h) and gentamicin sulphate (8 mg/kg bwt, IV, q24h). The most used NSAID were

phenylbutazone (2.2 mg/kg bwt, IV, q12h) and flunixin meglumine (1.1 mg/kg bwt, IV, q12h). The duration of postoperative treatment was generally 5 to 7 days, although in some cases, this period was extended due to signs of infection or pain.

When required, additional analgesia was provided using one or a combination of the following drugs: ketamine (0.5 mg/kg bwt, IM, q6h), morphine (0.1 mg/kg bwt, IM, q6–8h), and gabapentin (10 mg/kg bwt, PO, q12h).

Horses showing signs of severe lameness also received acepromazine (0.033 mg/kg bwt, IM, q8h) and/or enoxaparin (0.3 mg/kg bwt, SC, q24h) as potential preventative treatment for laminitis.

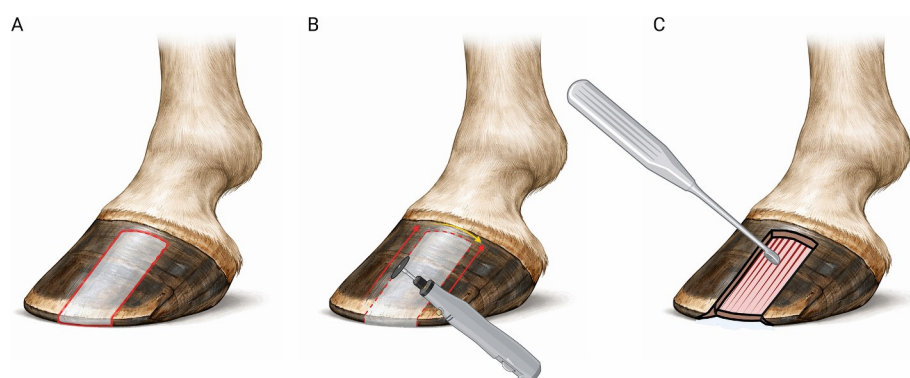


Fig. 1. Schematic illustration of the complete hoof wall resection (CR). (A) The area of the hoof wall to be removed is outlined on the hoof surface based on the preoperative radiographic localization of the lesion. (B) Parallel longitudinal cuts and a proximal transverse cut are performed to create a hoof wall flap, allowing removal of the hoof wall segment together with the keratoma using a motorised tool. (C) After removal of the hoof wall segment, the underlying laminar tissue is inspected and when necessary, curetted to remove any remaining abnormal tissue.



Fig. 2. Peroperative view of a complete hoof wall resection (CR). A large portion of the distal phalanx is exposed due to pressure lysis caused by the keratoma.

2.8. Postoperative foot care

The surgical site was packed with an antiseptic dressing, such as povidone-iodine gel, silver sulfadiazine, or cadexomer iodine ointment, and covered with sterile gauze. In cases of bone exposure, an alginate dressing was used to protect the underlying tissue. A foot bandage was applied immediately postoperatively. Thereafter, the bandage was changed every 2–3 days, and the dressing was adapted to the healing status of the operated site.

At the end of hospitalization, horses were discharged with recommendations for stall rest and continued application of a foot bandage until complete hoof healing, which is defined as the stage at which the hoof wall had fully re-cornified and regained a firm, stable consistency. The bandage/ shoeing management was performed at the discretion of the referring veterinarian. In some cases, a boot (hoof boot with gel insert orthotics) or an orthopaedic horseshoe (hospital plate) was applied to facilitate bandage management. Thereafter, some horses were left barefoot, whereas others were shod mainly with classic horseshoes with side clips.

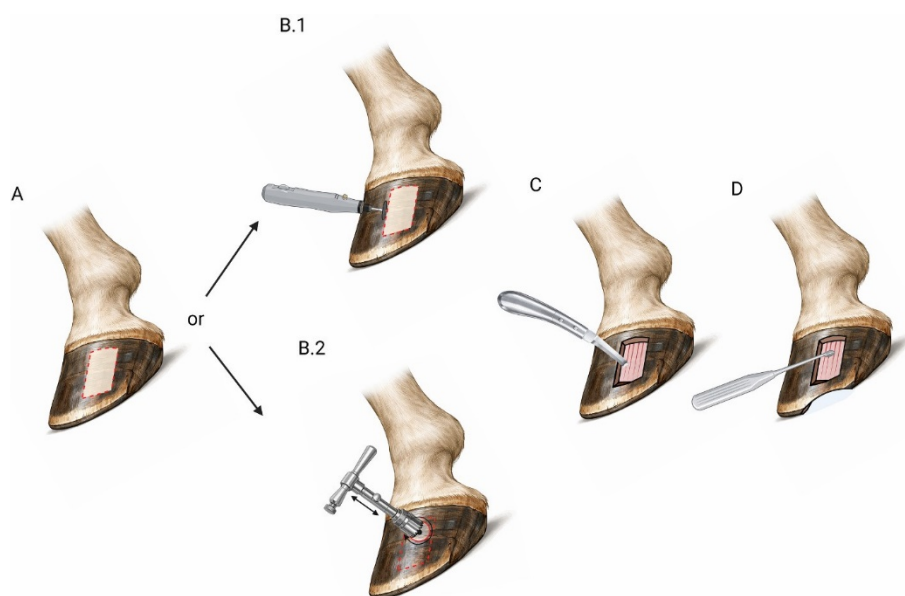


Fig. 3. Schematic illustration of the partial hoof wall resection (PR). (A) The area of the hoof wall to be removed is outlined on the hoof surface based on the preoperative radiographic localisation of the lesion. A fenestration of the hoof wall is created using either a motorised tool (B.1) or a trephine (B.2) to access the keratoma and allow its removal together with the adjacent hoof wall segment through the fenestration. (C) The margins of the fenestration may be enlarged using a hoof knife to ensure complete removal of the keratoma. (D) After removal of the affected hoof wall segment, the underlying laminar tissue is inspected and, when necessary, curetted to remove any remaining abnormal tissue.

2.9. Complications during hospitalization (short-term complications)

Short-term complications were defined as any adverse events occurring during the hospital stay following surgery. These included exuberant granulation tissue, hoof wall cracks, hoof wall instability, severe lameness of the operated limb requiring additional analgesic treatment, laminitis, superficial infection (mild quantity of secretions), deep infection (bone sequestrum, septic osteitis), pathological fracture of distal phalanx and colic. These complications were recorded through daily clinical examinations and surgical site evaluations at bandage changes.

2.10. Follow-up and post-discharge complications (long-term complications)

Follow up was obtained through a standardized telephone questionnaire with the owners at least 6 months postoperatively, with data collected until February 2025. In case of readmission of the horse in the clinic, the follow-up evaluation was obtained by both direct interview of the owner/rider and by examination of the horse. Owners of older cases were contacted several times over the years, which allowed for a more detailed and accurate postoperative follow-up than relying on a single update at the end of the observation period.

Questions pertained to whether the horse experienced complications such as chronic lameness of the operated limb, recurrence of hoof abscesses, hoof cracks, keratoma recurrence and laminitis after discharge from the hospital. Owners were also asked whether the horse was able to return to previous or intended use and time to return to work.



Fig. 4. Surgical site after partial hoof wall resection (PR). The distal part of the hoof wall is preserved.

2.11. Statistical analysis

Continuous variables such as age, weight, duration of hospitalization and time to return to previous or intended activity were reported as mean $\pm$ standard deviation (SD) with range or median values depending on distribution.

For comparison between surgical techniques, categorical variables, including exuberant granulation tissue, hoof wall instability, severe lameness, deep infection, superficial infection, laminitis, keratoma recurrence and abscess formation, were analysed using the chi-squared test.

Because of the low number of cases treated by PR, statistical comparisons could only be made between CR and MPR groups.

Normal distribution of the data was evaluated by Kolmogorov- Smirnov test. Group comparisons for continuous data were performed using Welch's *t*-test, because of unequal variances. For categorical data,

either Chi-square test or Fisher's exact test was used. Statistical significance was set at $p < 0.05$. All analyses were performed using Jamovi software (Version 2.6).

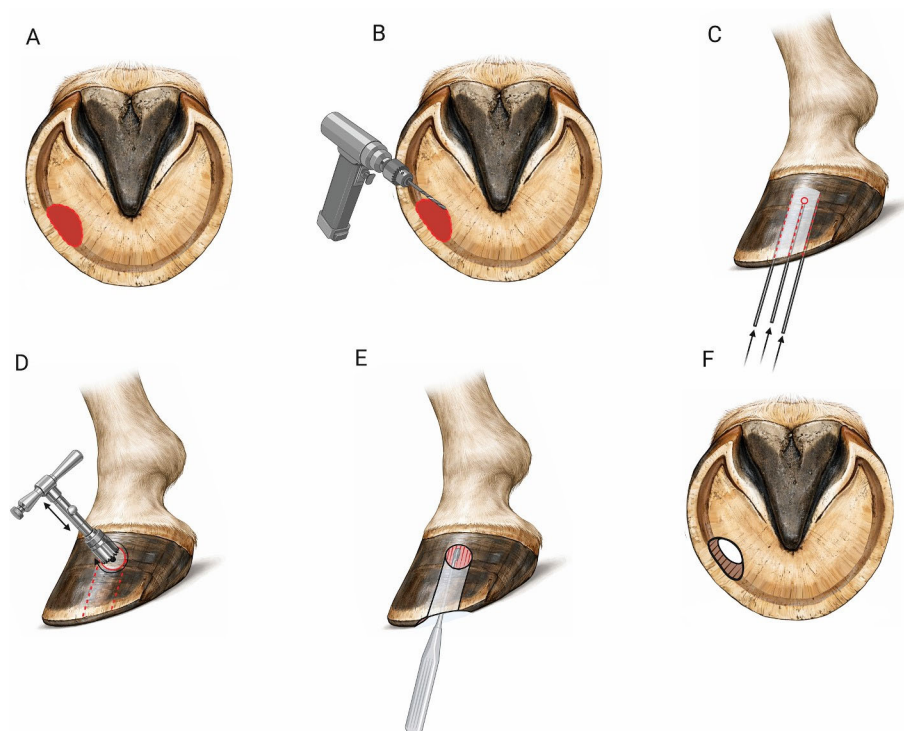


Fig. 5. Schematic illustration of the modified partial hoof wall resection (MPR). (A) The keratoma is visualized at the solar aspect. (B) A drill or hoof knife is used to carefully delineate the margins of the keratoma. (C) A narrow curette is placed around the keratoma from the solar aspect. (D) A trephine is used to remove the horn of the hoof wall, providing a second access to the origin of the keratoma. (E) The keratoma is dissected from the surrounding tissues and removed via the solar aspect. The remaining abnormal tissue is curetted. (H) View of the solar aspect at the end of surgery, preserving a bridge of the distal hoof wall.

3. Results

Seventy-two keratomas and SOL cases in 64 horses were retrieved from the medical records. Breeds consisted in 34 Warmbloods, 8 Draught horses, 6 ponies, 5 Friesians, 3 Standardbred, 3 Arabians, 1 Irish cob, 1 Merens, 1 Highland, 1 Appaloosa. The breed of 1 horse was not recorded. The most common type of work was leisure ($n = 25$), followed by sport activities such as jumping ($n = 5$), dressage ($n = 5$), driving ($n = 3$), eventing ($n = 1$), and endurance ($n = 1$). Nine cases were companion horses and 4 were used for breeding purpose. Information on use was not recorded in 11 horses. The mean weight was 562 ± 161 kg, and the mean age was 15 years ± 6 years at the time of presentation. The reason for consultation was recurrent abscesses ($n = 36$), suspected keratoma ($n = 11$), lameness ($n = 13$), laminitis ($n = 2$) and keratoma recurrence ($n = 3$). For 7 cases, the diagnosis of keratoma was made during hospitalization for pathologies unrelated to orthopaedic problem.

At admission, a foot abscess was identified in 58 cases (81%) and lameness was observed in 57 cases (80%). Lameness grades were recorded as follows: grade II ($n = 8$), grade III ($n = 16$), grade IV ($n = 31$), and grade V ($n = 2$). Radiographs were performed in all cases. Lesions typically appeared as smoothly outlined defect or radiolucency of the distal phalanx in 66 cases (Fig. 7). Irregular bone lysis was observed in 5 cases, and 1 horse had no radiological abnormalities. MRI was performed in 4 cases. In all of them, a cone-shaped

hypointense structure was found invaginating from the stratum medium into the dermis and causing pressure lysis of the distal phalanx. One lesion was irregular and ill-defined. In one case, MRI revealed an additional smaller SOL dorsal to the main one, which was subsequently confirmed at surgery. Lesions were located at the toe in 26 cases, in the quarters (24 lateral and 21 medial) in 45 cases, and at the heel in 1 case. The forefeet were affected in 51 cases (25 right forelimbs and 26 left forelimbs), while the hindfeet in 21 cases (8 right hindlimbs and 13 left hindlimbs). Five horses presented keratomas/SOL in 2 feet. Two horses had two keratomas/SOL in the same foot.

Among the 72 keratomas/SOL cases identified in the medical records, 17 cases were excluded from the final analysis: 4 cases were euthanized due to coexisting pathologies with a poor prognosis, and 13 cases were managed conservatively at the owner's request. Consequently, 55 cases treated surgically were included in the final analysis. Among the surgical cases, the CR technique was performed in 18 cases (14 under GA and 4 under SS), the MPR technique in 35 cases (11 under GA and 24 under SS), and the PR technique was performed in 2 cases (1 under GA and 1 under SS).

3.1. Short-term complications

Data on short-term complications rates are presented in Table 1.

Modified partial hoof wall resection group showed significantly fewer occurrences of short-term complications than the CR group ($p = 0.004$), with 25.7% of MPR cases developing short-term complications. Cases operated by CR exhibited significantly more exuberant granulation tissue ($p = 0.004$) and hoof wall instability ($p = 0.007$) than those in the MPR group.

Complete hoof wall resection was significantly more often performed under GA than MPR ($p = 0.003$). However, no significant effect of type of anaesthesia was observed on short-term complications when each technique was analysed separately.

Fifty-two cases (95%) across all surgical techniques were discharged: 16 cases (89%) in the CR group, 34 cases (97%) in the MPR group, and 2 cases (100%) in the PR group. The mean hospitalization duration in the CR group was 33.6 ± 5.29 days (range 8–74) compared to 25.3 ± 2.93 days (range 4–90) in the MPR group ($p = 0.110$). The mean hospitalization duration in the PR group was 40.5 ± 3.5 days (range 37–44).

3.2. Long-term follow up

Long-term follow-up information was available for 39 horses that underwent surgical treatment. The overall median follow-up duration was 36 months (range 6–180 months). This included 15 cases in the CR group, 22 in the MPR group, and 2 in the PR group.

3.3. Long-term complications

Data on long-term complications rates are presented in Table 2.

The long-term complication rate was 27.3% in the MPR group and 46.7% in the CR group. Hoof cracks were significantly more frequent in the CR group than in the MPR group ($p = 0.029$) and hoof abscesses tended to be less frequent in the MPR group ($p = 0.053$). Keratoma recurrence was observed in only 1 case over 22 in MPR group while 3 recurrences were diagnosed over 15 in CR group, but this difference was not statistically significant ($p = 0.137$).



Fig. 6.

- A. Modified partial hoof wall resection (MPR): The surgery is initiated at the solar aspect of the foot. The keratoma (white arrows) is carefully delineated with hoof knives and removed while preserving the external part of the hoof wall.
- B. Modified partial hoof wall resection (MPR): Intraoperative image of the hoof wall fenestration created at the proximal extent of the lesion to remove the keratoma origin. A curette is used from the solar aspect to remove residual abnormal tissue
- C. Modified partial hoof wall resection (MPR): Communication between the distal (solar) and proximal (parietal) surgical orifices after keratoma removal.



Fig. 7. Dorsoproximal–plantarodistal oblique radiographic view of the left hind foot showing a smoothly outlined defect at the distal phalanx solar margin resulting from pressure lysis, compatible with a keratoma.

Table 1

Rate of short-term complications during hospitalization following different surgical techniques.

	CR (n = 18)	PR (n = 2)	MPR (n = 35)
No complication	6/18 (33.3%)	1/2 (50.0%)	26/35 (74.3%)
Complications	12/18 (66.7%)	1/2 (50.0%)	9/35 (25.7%)
Exuberant granulation tissue	10/18 (55.6%)	1/2 (50.0%)	6/35 (17.1%)
Hoof wall instability	5/18 (27.8%)	0	1/35 (2.9%)
Laminitis	2/18 (11.1%)	0	1/35 (2.9%)
Deep Infection	1/18 (5.6%)	0	4/35 (11.4%)
Superficial infection	5/18 (27.8%)	1/2 (50.0%)	7/35 (20.0%)
Distal phalanx fracture	1/18 (5.6%)	0	0
Colic	1/18 (5.6%)	0	2/35 (5.7%)

The mean duration of hospitalization across all techniques was 29 days. Abbreviations: CR = complete hoof wall resection; MPR = modified partial hoof wall resection, PR = partial hoof wall resection.

Table 2

Rate of long-term complications following different surgical techniques.

	CR (n = 15)	PR (n = 2)	MPR (n = 22)
No complication	8/15 (53.3%)	1/2 (50.0%)	16/22 (72.7%)
Complications	7/15 (46.7%)	1/2 (50.0%)	6/22 (27.3%)
Lameness	6/15 (40.0%)	1/2 (50.0%)	5/22 (22.7%)
Hoof abscess	4/15 (26.7%)	1/2 (50.0%)	1/22 (4.5%)
Hoof crack	3/15 (20.0%)	0	0
Keratoma recurrence	3/15 (20.0%)	1/2 (50.0%)	1/22 (4.5%)
Laminitis	1/15 (6.7%)	0	1/22 (4.5%)

Abbreviations: CR = complete hoof wall resection; MPR = modified partial hoof wall resection, PR = partial hoof wall resection.

3.4. Return to previous activity

A total of 26 out of 39 horses (66.7%) returned to their previous level of activity after treatment. In the CR group ($n = 15$), 11 horses (73.3%) resumed normal activity, 2 had persistent lameness, and information regarding return to activity was unavailable for 2 horses. In the MPR group ($n = 22$), 15 horses (68.2%) returned to normal activity, 1 horse was still in the recovery period, 2 did not return due to persistent lameness, and information was unavailable for 4 horses. Among the two PR cases, one horse experienced a recurrence of keratoma within 6 months. The other horse was young and not yet at work at the 6 months follow up and was lost thereafter. Horses operated using the MPR technique returned to normal activity significantly faster than those operated by CR ($p = 0.037$), with a mean duration of 6.5 ± 3.3 months for the MPR group vs 12.7 ± 8.3 months in the CR group.

4. Discussion

Postoperative complications following keratoma removal have been listed in several studies (Boys Smith et al., 2006; Getman et al., 2011; Honnas, 1997; Ross et al., 2025). Although these studies described short- and long-term outcome, most reports generally provide limited follow-up duration and rarely differentiate between early and late postoperative complications.

In contrast, in the present study, short-term complications were observed directly by veterinary staff during hospitalization (mean 29 days), and long-term complications were identified via structured follow-up questionnaire over an extended observation period. This approach allows a more detailed and objective description of postoperative complications.

Over the years, surgical techniques for keratoma removal have been developed or refined, aiming to reduce the occurrence and the severity of postoperative complications and to accelerate recovery. Complete hoof wall resection provides excellent surgical exposure but requires removal of a large hoof wall segment, which may predispose to hoof wall instability and prolonged convalescence (Turner, 2016). To avoid these drawbacks, less invasive approaches, such as PR, have been developed. While the complications after PR have been described in the literature (Boys Smith et al., 2006; Katzman et al., 2019; Mair and Linnenkohl, 2012), previous reports did not differentiate between traditional PR and the modified PR ('solar first' approach). For this reason, the present study compared the outcomes of the MPR approach to those of other surgical techniques.

In our cases, the choice of the surgical technique was not only influenced by clinical presentation but also by previous interventions performed by referring veterinarians or farriers. In several horses, a large portion of the distal hoof wall had already been removed before referral due to a suspected abscess rendering PR or MPR technically unfeasible. This likely orientated part of our case distribution toward CR, potentially depriving some cases of less invasive techniques such as PR and MPR.

Our results indicate that MPR caused fewer short-term complications than CR. Specifically, MPR was associated with lower rate of hoof wall instability and exuberant granulation tissue, in agreement with previous literature indicating that hoof wall instability predisposes to the development of exuberant granulation tissue (Honnas et al., 2003). Although not statistically significant in this study, MPR lower rate of long-term complications (27.3%) compared to CR (46.7%) suggest a clinical advantage. Additionally,

horses treated with MPR were less likely to develop hoof cracks and returned to their previous level of activity more quickly than those treated with CR.

Various techniques have been described to preserve hoof stability, including different types of shoeing (Getman et al., 2011; Greet, 2016; Katzman et al., 2019). The most commonly reported techniques include shoes with clips at the site of the resected defect, heart-bar shoes with or without a bolted-on hospital plate, and egg-bar shoes with toe clips to reduce instability at the hoof wall defect (Boys Smith et al., 2006; Christman, 2008; Honnas et al., 2003). A more recent study (Ross et al., 2025) describes the use of wooden shoes to reduce torque on the lamellae, which may translate into a reduced instability in the operated area. In our case series, orthopaedic shoeing was left at the discretion of the referring veterinarian and was only applied in some cases. In the future, this strategy could be considered more systematically as a recommendation to prevent hoof wall instability in horses.

The low number of PR cases in our study was mainly due to the high proportion of horses (81%) presenting with solar abscesses at admission. In such cases, we preferred the MPR technique, which starts from the sole, providing direct visualization of the lesion and allowing proximal dissection of the abnormal tissues for 'en bloc' resection. Simultaneously, it is providing abscess drainage.

Because statistical comparison between PR and MPR was not possible in our cases, we have attempted a comparison of outcomes of MPR with those reported for PR in the literature.

Our results on MPR seem to describe more complications, such as exuberant granulation tissue and infection, than other studies using PR (Boys Smith et al., 2006; Getman et al., 2011; Katzman et al., 2019; Ross et al., 2025). However, comparison across studies is challenging because complications definitions, reporting criteria, and follow-up protocols vary considerably between publications. Moreover, several studies reported very short hospitalization periods, which likely limited the opportunity to identify complications that may manifest later in the postoperative period (i.e., after the first few days). In contrast, our hospitalization time was markedly longer than in previous reports (Getman et al., 2011; Katzman et al., 2019; Ross et al., 2025). This discrepancy likely reflects differences in postoperative management and discharge criteria rather than the surgical technique itself. In our series, hospitalization was often prolonged because some owners lacked the facilities or experience to perform daily foot care at home, even if in other cases, extended stays were required to manage complications. This prolonged hospitalization allowed a more objective and continuous evaluation of the postoperative course, enabling clearer identification of complications occurring during the hospital stay, rather than relying solely on owner-reported impression once the horse returned home.

Furthermore, beyond the surgical intervention itself, complications may arise from an underlying disease, or result from combination of both (Jacobs et al., 2007). In particular, if an abscess remains unresolved for an extended period, it may progress to septic osteitis (Leise, 2021). Therefore, postoperative deep infection may reflect pre-existing conditions rather than the surgical techniques itself. Some horses referred to our clinic had extensive foot abscesses, which could predispose them to postoperative complication independently of the procedure performed. These factors highlight the need to interpret outcome in the context of each horse's clinical history.

Concerning the average time to return to previous activity, our results about MPR aligns with those previously published after PR (Boys Smith et al., 2006; Katzman et al., 2019). Nevertheless, one smaller study (10 cases) reported a shorter mean time to return to previous activity (3.6 months) following CT- or MRI-assisted PR (Getman et al., 2011), with 7 horses resuming their previous level of use. In our study, more

horses could have benefited from advanced diagnostic imaging. However, the additional costs of CT or MRI often limited its use. Difference in lesion size and location of the keratoma may also account for the variation in recovery time between studies and techniques used.

On the long-term follow-up, keratoma recurrence was only reported in one case of MPR ($n = 22$), vs in 3 cases in the CR group ($n = 15$) and one case in the PR group ($n = 2$), suggesting a low recurrence rate in our MPR series. This recurrence rate was calculated over only horses for which follow-up information was available ($n = 22$) and not over all horses operated by the MPR technique ($n = 35$) to guarantee the accuracy of the recurrence rate. Recurrence has also been reported in previous studies using the PR technique, whether performed under advanced imaging guidance or relying solely on radiography. Keratoma recurrence was reported in 2 cases ($n = 12$) by Boys Smith et al. (2006), in 2 cases on a series of 31 horses by Katzman et al. (2019) despite CT- assisted planning, and Mair and Linnenkohl (2012) recorded nine recurrences ($n = 21$), although the exact surgical approach (PR or CR) was not specified. Although advanced imaging can provide detailed mapping of the lesion to help prevent recurrence, when it is not available and the lesion is visible from the solar aspect, the MPR approach allows direct visualization of the keratoma, guiding thorough dissection and enabling more complete removal of abnormal tissue, which might also help reduce the risk of recurrence.

This study has several limitations. Being conducted at a single centre, our results may not be directly translatable to other institutions. Some data were missing, and several horses were lost to follow-up, which is inherent to the retrospective nature of the work. Histopathological examination was not routinely performed to confirm the keratoma nature of the lesion. For this reason, we used the term 'keratoma or space occupying lesion of the hoof wall. Follow-up lameness assessment relied on owner reports and was not systematically investigated by a veterinarian. Therefore, it cannot be confirmed that lameness could be related to the consequences to the surgical excision of the keratoma and not to another unrelated lesion. Moreover, as advanced imaging such as CT or MRI was not routinely performed; the presence of other underlying pathologies that could contribute to long-term lameness cannot be excluded.

In conclusion, our results provide evidence supporting MPR as an effective alternative to traditional approaches for keratoma removal. Based on our experience, this technique appears particularly indicated in case of keratoma visible on the solar aspect of the hoof. By using combined distal and lateral hoof wall approaches, it might help reduce the risk of recurrence, especially when advanced imaging is not available for providing a precise mapping of the lesion.

CRedit authorship contribution statement

Guillermo Caballero Delgado: Writing – review & editing, Writing – original draft, Methodology, Investigation, Formal analysis, Conceptualization. **Sigrid Grulke:** Writing – review & editing, Validation, Methodology, Investigation. **Laurence Evrard:** Writing – review & editing, Validation, Methodology, Data curation. **Charlotte Sandersen:** Writing – review & editing, Validation, Methodology. **Geoffroy de la Rebiere de Pouyade:** Writing – review & editing, Validation, Methodology, Investigation, Formal analysis. **Alexandra Saliccia:** Writing – review & editing, Validation, Project administration, Methodology, Investigation, Data curation, Conceptualization.

Declaration of competing interest

The authors declare that they have no competing interests.

Appendix A. Supplementary data

Supplementary data to this article can be found online at <https://doi.org/10.1016/j.rvsc.2026.106308>.

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