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Clinical and radiographic evolution of horses with chronic laminitis subjected to deep digital flexor tenotomy and distal phalanx realignment

Evolução clínica e radiográfica de equinos com laminite crônica submetidos a tenotomia do flexor digital profundo e realinhamento da falange distal

Evolución clínica y radiográfica de caballos con laminitis crónica sometidos a tenotomía de flexores digitales profundos y realineamiento de falange distal

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Abstract
Deep digital flexor (DDF) tenotomy and realignment of the distal phalanx (DP) is a therapy used for the treatment of horses with chronic laminitis that, despite the few results described in the literature, presents with promising results. In view of this knowledge gap, this study aimed to describe and compare the clinical and radiographic findings of horses subject to this treatment. To this end, 7 horses with chronic laminitis that underwent tenotomy of the DDF in the metacarpal region and realignment of the DP by means of trimming and shoeing were included in this study. Data were obtained from the moments before and after the procedure. An improvement in clinical and radiographic parameters was observed when comparing the moment before and after the procedure, and it was concluded that this therapy is a viable option for the treatment of horses with chronic laminitis refractory to other therapies.
Keywords: Horses; Laminitis; Tenotomy; Prognosis.

Resumo
A tenotomia do flexor digital profundo (FDP) e o realinhamento da falange distal (FD) é uma terapêutica empregada para o tratamento de equinos com laminite crônica e apesar de poucos resultados descritos na literatura, é uma técnica que apresenta resultados promissores. Diante desta lacuna do conhecimento, este trabalho objetivou-se em descrever e comparar os achados clínicos e radiográficos dos equinos que foram submetidos a terapêutica em questão. Para tal, foram incluídos neste estudo 7 equinos apresentando laminite crônica que foram submetidos a tenotomia do FDP na região metacarpiana e realinhamento da FD por meio do casquemento e ferrageamento e foram obtidos dados do momento anterior e do momento posterior ao procedimento. Observou-se melhora dos parâmetros clínicos e dos parâmetros

radiográficos quando comparado o momento anterior ao momento posterior ao procedimento e concluiu-se que a esta terapêutica é uma opção viável para o tratamento de equinos com laminite crônica que se apresenta refratária a outras terapias.
Palavra-chave: Cavalos; Lamnite; Tenotomia; Prognóstico.

Resumen
La tenotomía flexora digital profunda (FDP) y el realineamiento de la falange distal (FD) es una terapia utilizada para el tratamiento de caballos con laminitis crónica y a pesar de los pocos resultados descritos en la literatura, es una técnica que presenta resultados prometedores. En vista de este vacío de conocimiento, este estudio tuvo como objetivo describir y comparar los hallazgos clínicos y radiográficos de los caballos que se sometieron a la terapia en cuestión. Para ello, se incluyeron en este estudio 7 caballos con laminitis crónica, a los que se les realizó tenotomía del FDP en la región metacarpiana y realineación de la FD mediante recorte y herrado, se obtuvieron datos del momento previo y posterior al procedimiento. Se observó una mejoría en los parámetros clínicos y radiográficos, al comparar el momento antes y después del procedimiento y se concluyó que esta terapia es una opción viable para el tratamiento de caballos con laminitis crónica refractaria a otras terapias.
Palabras clave: Caballos; Laminitis; Tenotomía; Pronóstico.

1. Introduction

Laminitis in horses is a well-recognized disease, and even with a large number of studies on this subject, it still presents with great challenges and difficulties for veterinarians and horse owners and causes great damage to the lives of the animals affected by it (O'Grady, 2006; Waguespack & Caldwell, 2009; Walsh & Burns, 2017).

In the search of better treatments for horses with laminitis, several therapeutic modalities have emerged, including drug therapies, hoof support and surgical therapies; unfortunately, there are few studies indicating the results of their efficacy or comparing the results between the techniques (Menzies-Gow, 2011; Moyer et al., 2000).

Among the techniques used for the treatment of laminitis, deep digital flexor (DDF) tenotomy aims to release the DDF tendon force, in conjunction with realignment of the distal phalanx (DP) by means of trimming and shoeing (Burba et al., 2006; R. J. Hunt et al., 1991). This method allows reduction of the separation of the dermal and epidermal laminae, improves the distribution of forces on the DP and relieves the pressure of the apex of the DP on the soleus corium and of the extensor process on the lamellar corium, contributing to the return of blood flow in the distal portion of the digit and a decrease in the degree of pain, with adequate growth of the hoof, in addition to preventing future displacement of the DP (Robert J. Hunt, 2011; Morrison, 2011; Waguespack, 2017; Waguespack & Caldwell, 2009).

Due to conflicting opinions among veterinarians about the DDF tenotomy technique and the small number of results reported in the literature, this topic needs to be studied to demonstrate the real effect of this technique (Moyer et al., 2000; Sikkel, 2020). Thus, this study aims to fill this knowledge gap by conducting a descriptive and comparative study between the period before and after DDF tenotomy and DP realignment to determine the efficiency of this therapeutic modality.

2. Methodology

Ethics Committee

The project was approved by the Ethics Committee on Animal Use (Comissão de Ética no Uso de Animais- CEUA) of the School of Veterinary Medicine and Animal Science (FMVZ/UNESP, protocol 0020/2021).

Animals and procedures

In the present study, seven Quarter Horses were evaluated, four females and three males. All animals presented with chronic laminitis that was not responsive to drug and hoof support therapies and were subjected to DDF tenotomy and distal phalanx realignment.

Trimming and shoeing were performed prior to the tenotomy, with the objective of inducing realignment of the DP and making the palmar angle close to zero degrees (Floyd, 2007; Nickels, 2003; O'Grady, 2006). To perform the procedure, trimming was initiated by removing all the surplus material from the groove of the hoof while maintaining its healthy appearance; the excision of this portion of the hoof allowed us to measure the amount of bulb to be removed. The second stage of the trimming technique involved the excision of the heel, with the objective of reducing the palmar angle of the DP (O'Grady, 2006; Stephen E. O'Grady, 2010). Subsequently, shoeing was performed using tenotomy-specific aluminum horseshoes (Tenotomy Horseshoes-Equiconfort®) with palmar extension and 5° elevation of the heel region Using a specific kind of glue (Equiglue- Equiconfort®) together with synthetic plaster (Hygia cast®). The fixation of the horseshoes parallel to the solar surface of the DP for animals that had a high degree of rotation and for whom it was not possible to make the palmar angle close to zero degrees with the trimming technique created a space between the horseshoes and the hoof that was filled with silicone grease (Siliconfort-Equiconfort®)(Morrison, 2011; S.E. O'Grady & Parks, 2008; Redden, 2007) (Figure 1). After hoofing and shoeing, the hoof was rested on an angled support (Ultimate-Nanric®) to promote relaxation of the DDF tendon for performing the tenotomy (O'Grady, 2006). The horseshoes and silicone remained in place for a period of 8 to 10 weeks (Floyd, 2007).

Figure 1: Representation of the DP realignment technique. Tenotomy-specific aluminum horseshoes (Tenotomy Horseshoes-Equiconfort®) provide plantar extension and heel elevation; a wedge-shaped silicone mass (Siliconfort- Equiconfort®) fills the space between the hoof and the horseshoe in its most dorsal portion, and the horseshoe and silicone mass are fixed to the hoof.

Source: Cestari *et al*. (2022).

Following the trimming and shoeing procedure, the DDF tenotomy was performed in the metacarpal region with the surgical field prepared aseptically and the animal in a quadrupedal position under sedation with 10% xylazine (0.5 mg/kg/iv) and injection anesthesia at the surgical site with 2% lidocaine (10 ml) (Burba et al., 2006; Redden, 2007). Thus, a skin incision of three to five centimeters in length was performed on the lateral aspect between the superficial digital flexor tendon and the DDF tendon,

in the middle third of the third metacarpal. Blunt divulsion of the tissues adjacent to the DDF tendon was performed, and the tendon isolated with a scalpel and the aid of two blunt-tipped curved rods (Figure 2). Finally, the skin was sutured with 2-0 nylon suture and separated with simple stitches, which were removed 15 days later (Burba et al., 2006; R. J. Hunt et al., 1991; Redden, 2007).

Figure 2: Representation of the DDF tenotomy technique performed in the middle third of the metacarpal region. This shows the use of two blunt rods with curved ends for isolating the DDF tendon as auxiliary material.

Source: Cestari *et al*. (2022).

After the surgical procedure, a sterile bandage was placed on each animal for 20 days and changed weekly; they received three applications of benzathine penicillin (30,000 IU/kg/IM/48 h) and tetanus serum (10,000 IU). The first three days, the animals received phenylbutazone at a dose of 4.4 mg/kg/IV, and for the next four days, they received phenylbutazone at a dose of 2.2 mg/kg/IV. The animals were kept in a stall to restrict movement for 15 days, after which the animals were allowed short walks on soft ground. After 8 to 10 weeks, the tenotomy-specific horseshoes were removed, and trimming was performed to maintain the DP realignment. After the recovery period, the animals were released to pasture along with other animals.

Clinical and radiographic analysis

The seven animals included in this study underwent clinical and radiographic evaluation immediately before and after DDF tenotomy and DP realignment to monitor the therapeutic response.

Before the tenotomy, the clinical variable degree of claudication was obtained according to the Obel scale (Obel, 1948) (Table 1), and variables obtained from the radiographic examination included the degree of rotation and the palmar angle of the distal phalanx.

Table 1: Description of the degree of claudication according to the Obel scale (Obel, 1948).

Grade	Obel
1	No claudication at the step and alternates limbs
2	Artificial walking
3	Reluctance to walk and to allow the raising of one of the limbs
4	Moves only if forced and refuses to allow the raising of one of the limbs

Adapted from Obel (1948).

After the tenotomy, the following variables were obtained: time of evolution after tenotomy, degree of claudication according to the Obel scale (Obel, 1948) (Table 1), body condition score (Henneke et al., 1983; Thatcher et al., 2012) (Table 2), functional performance and the variables obtained from the radiographic examination (degree of rotation and palmar angle of the DP).

Table 2: Description of the body condition scores according to the Henneke scale (Henneke et al., 1983).

Grade	CCS
1	Extremely thin
2	Very thin
3	Thin
4	Moderately thin
5	"Normal"
6	Slightly overweight
7	Overweight
8	Obese
9	Extremely obese

Adapted from Henneke (1983).

Statistical analysis

The results are expressed as absolute and mean values.

The variables were subjected to the Shapiro–Wilk test to assess the normality of their distribution ($p > 0.05$). The homogeneity of the data was checked by the Levene test.

To compare the parameters obtained before and after tenotomy, the paired t test was performed for variables with a normal distribution, and the Wilcoxon test was performed for nonparametric variables.

Statistical analysis was performed using SigmaPlot® 12.0 software, and a significant difference was considered when $p < 0.05$.

3. Results and Discussion

A descriptive and comparative evaluation was performed of seven Quarter Horses that presented with chronic laminitis that was not responsive to other treatments and who underwent DDF tenotomy and DP realignment through trimming and shoeing in both thoracic limbs. The animals were evaluated at a mean interval of 17 months after tenotomy.

Of the animals included in this study, 100% (7/7) of the animals did not return to athletic activity but were released for grazing without the use of orthopedic shoes; 85.7% (6/7) were destined for reproduction, and only 14.3% (1/7) did not develop reproductive function because they were castrated males; 100% (7/7) had a body condition score between 4 and 6 on a scale of 1 to 9.

The study by Hunt *et al*., 1991, corroborates the descriptive finding found in this study, in t that none of the seven animals included in this study returned to athletic activity during the interval between evaluations. Similar to the results presented in other studies, the present study also indicates that animals subjected to the tenotomy procedure may have a good quality of life when loose on pasture without the use of orthopedic horseshoes (Allen et al., 1986; Morrison, 2011).

The animals included in this study had a body condition score between grades 4 and 6, which is considered a good range for horses (Henneke et al., 1983; Thatcher et al., 2012).

The evaluation of the locomotor system showed that at the time before the tenotomy, 100% (7/7) of the animals had grade 4 claudication on a scale of 1 to 4 and that after the tenotomy, the animals mostly had a degree of claudication ≤ 2, with a statistically significant difference between the time periods ($p = 0.016$), as shown in Table 3.

Table 3: Descriptive data on the degree of claudication according to Obel (1948) before and after tenotomy.

Animals	Degree of claudication prior to tenotomy	Degree of claudication after tenotomy	P value
1	4	2	-
2	4	2	-
3	4	2	-
4	4	2	-
5	4	2	-
6	4	3	-
7	4	0	-
Mean	4	1,8	0,016

Source: Cestari *et al*. (2022).

The degree of claudication of the animals was significantly different ($p = 0.016$) between the periods before and after tenotomy, suggesting that the therapeutic technique in question reduces the degree of pain of the animals, thus improving locomotion and reducing the degree of claudication (Dryden, 2013; Eastman et al., 1998, 1999; Floyd, 2007).

The radiographic evaluation of the mediolateral position of the digits of the horses showed a mean degree of rotation of the DP of 16 degrees before DDF tenotomy and of 8 degrees after the procedure, and this difference was significant ($p = 0.007$), as shown in Table 4, which also shows the specific values for each animal.

Table 4: Descriptive data of the degree of rotation of the DP before and after tenotomy.

Animals	Degree of DP rotation before tenotomy		Degree of DP rotation after tenotomy		P value
	RF	LF	RF	LF	
1	15	17	1	22	-
2	24	17	1	2	-
3	14	14	-6	1	-
4	10	13	15	4	-
5	8	10	0	1	-
6	37	30	35	36	-
7	12	7	7	0	-
Mean	16		8		0.007

DP = distal phalanx, RF = right forelimb, LF = left forelimb, degree of rotation of the distal phalanx = angle of the distal phalanx-hoof angle. Source: Cestari *et al*. (2022).

The degree of DP rotation was also significantly different (p = 0.007) between the periods before and after the tenotomy, demonstrating a decrease in the degree of DP rotation. The post-DDF tenotomy degree of DP rotation differ from that described by another study, which found higher values after the procedure. This suggests that the discrepancy between the results is due to differences between the techniques used, where the present study applied DDF tenotomy together with the DP realignment through trimming and shoeing, unlike in the other study (Allen et al., 1986).

The mean palmar angle of the DP before tenotomy was 16 degrees and was significantly different (p = 0.001) from that obtained after tenotomy, which was 5 degrees (Table 5).

Table 5: Descriptive data of the DP palmar angle before and after tenotomy.

Animals	Palmar angle of the DP before tenotomy		Palmar angle of the DP after tenotomy		P value
	RF	LF	RF	LF	
1	17	15	-4	10	-
2	17	18	3	3	-
3	13	17	-6	4	-
4	11	7	12	0	-
5	18	19	17	0	-
6	22	25	16	16	-
7	20	11	4	2	-
Mean	16		5		0,001

DP = distal phalanx, RF = right forelimb, LF = left forelimb. Source: Cestari *et al*. (2022).

The palmar angle of the DP was significantly lower after the tenotomy before the tenotomy (p = 0.001) and indicates that the DDF tenotomy and the DP realignment reduced the palmar angle of the distal phalanx to a mean value similar to that of healthy animals (3-8°) (Dyson et al., 2011; Sherlock & Parks, 2013).

4. Conclusion

DDF tenotomy and DP realignment through trimming and shoeing proved to be an efficient technique for the treatment of horses with chronic laminitis refractory to other therapies. This technique also provided a significant improvement in the degree of claudication and a reduction in the degree of rotation and palmar angle of the DP, providing physical conditions for these animals to freely pasture.

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