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Carpal valgus angle deviation in thoroughbred foals corrected using single transphyseal screw implant

[*Correção de desvio angular valgo do carpo em potros puro-sangue com implante de parafuso transfiseal único*]

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ABSTRACT

The objective of this study was to demonstrate the effectiveness of the single transphyseal screw technique in foals diagnosed with carpal valgus deviation. This study included 22 thoroughbred animals of both sexes, with a mean age of 30 days. All animals had a carpal valgus deviation >5° with irregular development of the distal epiphysis of the radius. All animals were surgically treated to correct the carpal valgus deviation by creating a bridge using a single transphyseal screw. Surgical intervention was performed for 40 limbs, comprising 19 right and 21 left thoracic limbs. This corresponded to four animals with carpal valgus deviation >5° in only one of the limbs and 18 with the deviation in both limbs. It was observed that 38/40 treated limbs (95%) achieved normal angulation according to the literature, i.e., angulation between 0° and 5°. No statistical differences were observed between the affected limbs. The single transphyseal screw technique can be used for the correction of carpal valgus deviation in foals. It is indicated in animals with an average age of 30 days (20–55 days), as its main advantages are rapid application, simple execution, and limited trans- and post-surgical complications, making it an effective procedure in thoroughbred foals with carpal valgus angular deviation.

Keywords: horse, angular deviations, implant, transphyseal single screw, valgus

RESUMO

O objetivo do presente estudo foi demonstrar a viabilidade da aplicação da técnica de parafuso único transfiseal em potros, com diagnóstico de desvio valgo do carpo. Foram selecionados 22 animais, da raça PSI, com idade média de 30 dias, de ambos os sexos. Todos os animais apresentavam desvio valgo do carpo acima de cinco graus, com desenvolvimento irregular da epífise distal do rádio. Os animais foram submetidos à cirurgia corretiva para o desvio valgo do carpo por meio da realização de ponte com um único parafuso transfiseal. Foram submetidos à intervenção cirúrgica 40 membros, divididos entre membros torácicos direito e esquerdo 19 e 21, respectivamente, que corresponderam a quatro animais com desvio acima de 5 graus valgo do carpo em apenas um dos membros e 18 animais com o procedimento nos dois membros. Observou-se que 38 dos 40 membros tratados, ou seja, 95%, retornaram a uma angulação considerada normal, entre zero e cinco graus Dois animais apresentaram infecção do implante, de maneira que eles reduziram a angulação, porém não o suficiente para enquadrá-los na angulação normal estabelecida pela literatura. Não houve diferença estatística entre os membros acometidos. A técnica de aplicação do único parafuso transfiseal pode ser indicada para correção do desvio valgo do carpo em potros. Deve ser indicada em animais com idade média de 30 dias (20 a 55 dias de vida), por ter como principais vantagens aplicação rápida, execução simples e com limitadas intercorrências trans e pós-cirúrgicas.

Palavras-chave: equino, desvios angulares, implante, parafuso único transfiseal, valgo

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INTRODUCTION

Angular deviations are among the main orthopedic disorders associated with development in horses (Auer, 2012), with carpal valgus deviation being the most common. From a physiological point of view, the normal angulation of the carpal valgus in foals is 2–5°. This deviation is considered pathological or abnormal when it exceeds 5°, and it is associated with the irregular growth of the distal epiphysis of the radius (Robert *et al.*, 2013). The distal epiphysis of the radius is responsible for a large part of the longitudinal growth of the forelimb, especially in the distal portion, and its development is completed at around 29 months of age (range, 22–36 months). However, the highest growth rate occurs in the first 2 months of life (Auer, 2012).

Angular deviation caused by asynchronous growth of the distal radial epiphysis can be treated conservatively by waiting for the structures to return to normal within 1 year. The highest rate of spontaneous recovery tends to occur in the first 30 days of life (García-López, 2017), which indicates the need for rapid diagnosis and immediate surgical intervention, resulting in better and faster recovery of the foals (Auer, 2012).

Surgical interventions may have postoperative complications depending on the technique and type of implant, recovery time, and factors directly influencing the achievement of angular normality (Carlson *et al*., 2012; Baker *et al*., 2015; Modesto *et al*., 2015). Hypothetically, the single transphyseal screw technique can be used to correct the carpal valgus deviation, but most studies have used this technique only in older foals (Jansson and Ducharme, 2005; Gray *et al*., 2017).

This study aimed to demonstrate the effectiveness of the single transphyseal screw technique in foals of mean age 30 days, who were diagnosed with carpal valgus deviation due to irregular development of the distal radial epiphysis.

MATERIAL AND METHODS

This study was approved by the Ethics Committee (Approval no.: 3294120117) after evaluation by the Ethics Committee on the Use of Animals (CEUA/UEM) of the State University of Maringá accredited by the National Council for the Control of Animal Experimentation in its opinion 126/2014 published in the Official Federal Gazette No. 131 of 7/11/2014.

This study included thoroughbred foals of both sexes aged between 20 and 55 days. Physical examinations and detailed orthopedic evaluations were performed before including the animals in this study (Auer, 2012). Foals presenting carpal valgus deviation >5° with irregular development of the distal epiphysis of the radius, without other alterations that could lead to this deviation, were included in the initial screening (Baker *et al*., 2015).

A radiographic examination of the carpal joint was performed using the dorsopalmar projection. The technique used was 70kv/2.5 mAs 60cm from the limb to be radiographed with an analogue FNX 90 cti Plus emitter with chassis and Kodak film® (23.8cm × 29.8cm and 17.8cm × 23.8cm, respectively). The radiographic films were developed in a Macrotec Mx2 processor/developer, all the films were photographed, and the angulations of the limbs were measured. Using the Meazure software®, version 2.0 a longitudinal line was drawn in the center of the radius and in the third metacarpal passing over the carpal joint. The point of intersection between these two lines indicated the angulation of the limb (valgus degree).

After weighing the animals, dissociative anesthesia was induced with 10% xylazine hydrochloride (1mg/kg) for sedation and 10% ketamine hydrochloride (2.2mg/kg), both administered intravenously. Anesthesia was maintained by administering ether-glyceryl-guaiacol (500mg/mL) as continuous intravenously infusion (1mL/kg/h) and ketamine hydrochloride[4] as a bolus of 1/3rd of the induction dose, with continuous monitoring of the anesthetic plane. Recovery occurred without support by leaving the foal with the mother in a stall until complete recovery from anesthesia, and it was then sent to the pasture. This protocol was used in both the screw placement and removal procedures.

Trichotomy was performed on the medial region of the radius and along the entire length of the medial carpus. After chemical containment, antisepsis was performed, and a fenestrated surgical drape was placed on the area of interest. A needle (30 × 0.8) gauge was introduced in the medial portion of the epiphyseal line to guide the surgeon regarding the anatomical location, and a 1-cm incision was made longitudinally using a #24 scalpel blade[6] in the proximal region of the styloid process. The skin, subcutaneous tissue, and periosteum covering the medial styloid were dissected. The limb was placed in an extended position, and the distal metaphysis of the radius was drilled in its medial portion toward the epiphysis, crossing the epiphyseal line with a 3.5-mm diameter surgical drill. The drill was positioned as parallel as possible to the limb (Kay and Hunt 2009) at an angle varying between 20º and 35º. The perforation ended at the distal epiphysis of the radius without reaching the joint.

Keeping the drill in place, a new radiographic image was obtained in the dorsopalmar projection to observe its positioning. After confirmation correct perforation, the drill was removed, the male part of the implant was introduced, and a 4.5-mm cortical screw was inserted. Following this, the skin was sutured using size 0 nylon[7] thread in a Wolff pattern.

Ganadol[8] ointment was used on the suture line, followed by a closed dressing with gauze, orthopedic cotton, and bandage. During the treatment, the animals were kept together with the batch to which they belonged before the procedure. The animals were not isolated, and there was no restriction of exercise for them.

The animals were medicated with Ceftiofur (2mg/kg) once daily for 7 days and Meloxicam (0.6 mg/kg) once daily for 3 days. The dressing was changed every 2 days. The surgical wound was cleaned with gauze soaked in topical povidone iodine followed by healing ointment and closed again with gauze, orthopedic cotton, and bandage; the sutures were removed 15 days after surgery.

The foals were visually monitored for deviation correction. After evaluation and radiographic confirmation of the new corrected angulation, a surgical procedure was performed to remove the screw. All animals were radiographically evaluated for 6 months after implant removal.

Descriptive statistics were used to evaluate the study sample with respect to the age of the animals, implant permanence time, and angulation values before implantation and after implant removal. These data were evaluated using Assistat® software.

The data were analyzed using the Mann–Whitney test (Assistant®) at a significance level of 5%. The angulation values of the limbs before and after the surgical procedure were compared. Furthermore, the implant permanence time between the right and left limbs was compared to verify if there was a difference in the time required for correction between them. The Mann–Whitney test (Assistant®) was used to assess whether the angulation values before and after the placement of the implant were significant. The Spearman correlation test was used to determine whether the angulation degree presented before screw placement could be corrected to the normal angulation after treatment.

RESULTS

In this study, 22 foals (40 limbs) underwent corrective surgery for carpal valgus deviation by creating a bridge using a single transphyseal screw. Four animals presented valgus deviation >5º in only one of the limbs, with the left thoracic limb affected in three animals and the right thoracic limb in one. On the other hand, 18 animals (36 limbs) underwent the corrective surgical procedure for both the limbs. In total, the 40 limbs comprised 19 right and 21 left forelimbs. The data are summarized in Table 1.

Statistical analysis showed that the average age of the animals in this study was 32 days (20–55 days), as was the mode and median, with a standard deviation of 7.62 days. The results are shown in Figure 1.

Table 1. Age, angulation before and after treatment, and implant permanence time of thoroughbred foals undergoing surgery to correct carpal valgus angular deviation with single transphyseal screw implant

Animal	Age of animals (days)	Angulation before treatment (°)		Implant permanence time (days)		Angulation after treatment (°)	
		Right	Left	Right	Left	Right	Left
1	45	--	7.7°	--	31	--	6.6°
2	35	7.8°	--	50	--	0°	--
3	32	--	8.7°	--	32	--	0.1°
4	29	6.6°	11.8°	30	43	4.1°	4.9°
5	27	10.8°	8°	31	31	3.1°	1.8°
6	25	--	6.8°	--	21	--	3.1°
7	30	14.2°	11.7°	21	49	1.3°	1.6°
8	25	17.9°	11.7°	41	41	3.7°	3.2°
9	33	10.7°	10.7°	51	51	1.8°	3.4°
10	55	11.1°	11.8°	30	30	3.7°	4.7°
11	26	9.4°	11.3°	31	31	3.7°	1.4°
12	38	5.7°	8.9°	18	54	0.2°	2.2°
13	32	9.2°	12.7°	28	28	2.5°	3.6°
14	32	11.4°	6.4°	21	21	5.7°	2.2°
15	30	10.6°	8.9°	16	16	2.1°	3°
16	30	7.1°	8.2°	19	19	2.1°	0.2°
17	40	11.4°	8.5°	16	16	2.9°	3°
18	32	7.1°	6.2°	34	63	2.1°	4.7°
19	37	8.7°	5.7°	20	20	3°	3.3°
20	24	10.5°	13°	18	18	4.8°	1.8°
21	20	7.9°	9.6°	53	53	4.6°	1.9°
22	32	7.7°	9.8°	30	30	0°	1°
Mean	32.23	9.78	9.43	29.37	33.23	2.7	2.75

Descriptive statistical analysis for implant permanence time was performed separately for the right and left limbs because some animals showed a variation in the implant permanence time between both their limbs. The average implant permanence time until its removal was 31.4 days, with the shortest time being 16 days and the longest being 63 days. The mode and median measures were similar to the mean measure of the sample (mode = 30 and 31; median = 30), with a standard deviation of 13.12 days (Figure 1).

The Mann–Whitney test (5% probability) showed that there was no statistical difference between the right and left limbs with respect to the implant permanence time until deviation correction. Additionally, there was no significant difference between the right and left limbs in the degree of angulation both before implantation and after removal. The data obtained showed that 72% of the animals subjected to the procedure for both limbs. It is unclear if this means that the implant permanence time was same for both limbs or that all animals undergoing surgery in both limbs showed the same implant permanence time.

Analysis of the angulation data before implant placement showed a mean deviation of 9.6°, with a mean standard deviation of 2.53°, minimum value of 5.7°, and maximum value of 17.9°. The sample mean was classified as moderate deviation, and the median was 9.3°.

Analysis of the angulation data after implant removal showed an average deviation of 3.3°, with a standard deviation of 1.59°, minimum value of 0°, and maximum value of 6.6°. Both the mean and median values of the sample (2.95) were classified as mild or normal deviation.

Figure 2 shows the data dispersion obtained before and after the treatment.

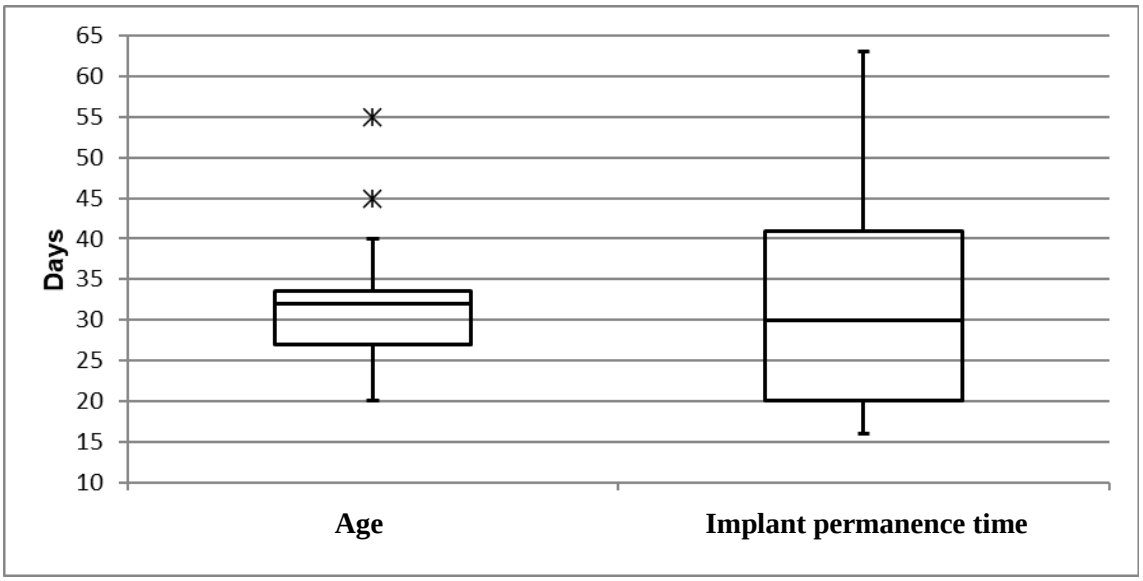

Figure 1. Boxplot graph for age and implant permanence time.

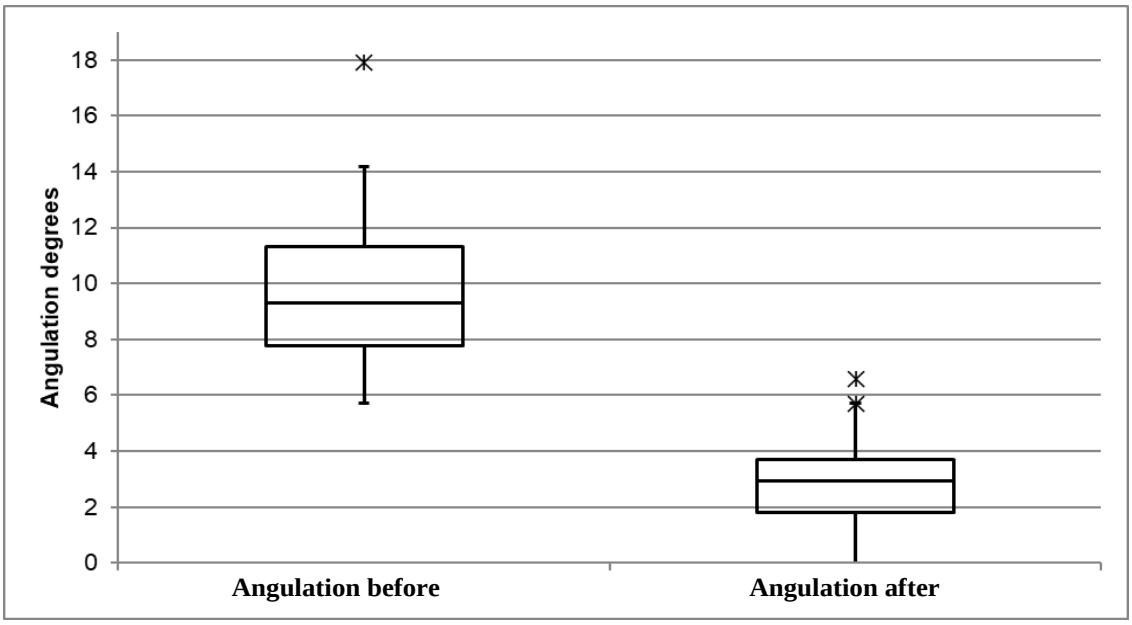

Figure 2. Boxplot graph for limb angulation data

The Mann–Whitney test, which is usually used for non-parametric data analysis, was used to evaluate the angulation data before and after treatment at 5% probability. A statistical difference was observed, indicating that the angulation was different before and after treatment.

The Spearman correlation test was performed for the data related to angulation improvement to assess the likelihood of the animals with greater or lesser angulations achieving normality; however, the test results were not significant, which demonstrates that in this model, all animals, regardless of the angulation before

implantation, had the same chance of achieving angular normality. This could be because the implant permanence time was not considered in the Spearman correlation test.

Achieving angular normality was the ideal result to be obtained. In this study, 38/40 treated limbs (95%) achieved the angulation considered normal, i.e. 0–5°. The remaining two animals presented implant infection; hence, although the angulation had reduced in them, it was not adequate to be classified as the normal angulation established in the literature.

DISCUSSION

Transphyseal bridges are commonly used for the treatment of carpal valgus angular deviation in foals. Moreover, they are indicated in the most severe cases that have a limited time for correction due to the closure of the epiphyseal line or in those subjected to conservative or non-responsive treatment, hemicircumferential transaction, or periosteum lifting (Gray *et al*. 2017).

Previously, staples were used for creating the bridge, which has now been replaced by screws with cerclage. Screws with cerclage are easier to handle than staples, as the latter are rigid and make it difficult to choose the region to be drilled. Furthermore, cerclage allows greater compression in the line of growth, which can improve and provide better results during recovery (Taralyn and McCarrel 2017). The combination of a bridge with a screw and cerclage allows for aggressive correction, but it has the disadvantages of the need for a second surgical intervention to remove the implant and the risk of overcorrection if the implant is not removed at the correct time (Greet 2000).

Compared to these techniques, the single transphyseal screw technique, as used in this study, presented advantages such as ease of application, low operating cost, and less amount of implant material, which results in reduced severity of tissue reactions and promotes better aesthetic results. Several authors (Carlson *et al*. 2012; Gray *et al*. 2017; Modesto *et al*. 2015) reaffirmed that this technique not only provides better aesthetic results but also has a shorter correction time than that of bridges with screws and cerclage.

The main complications associated with this technique include the risk of infections from the implant, which leads to failures in correction, metaphyseal collapse, unwanted deviations to the opposite side, difficulties in screw removal, breakage of intraosseous screws, and overcorrection. This is based on the data compiled from various studies by Kay and Hunt (2009), Carlson *et al*. (2012), Modesto *et al*. (2015), and Gray *et al*. (2017). However, these studies were conducted for foals of ages different from those used in this study. This explains the 5% (2/40 limbs) incidence of complications in our study, reiterating that 95% (38/40) of the treated limbs achieved the angulation considered normal in the literature, i.e. 0–5°. Furthermore, 9% (2/22) of the animals had implant infection; hence, although the angulation deviation had reduced, it was not adequate to be classified as the normal angulation established in the literature.

In this study, all animals were thoroughbreds, and those showing moderate (5–10°) or severe (>10°) carpal valgus deviation underwent surgical treatment. The mean age of the patients undergoing surgery was approximately 32 days. Other authors have highlighted that carpal valgus deviation of up to 10° is commonly found in neonatal foals; however, it can significantly reduce in the first 4 weeks of life without any interventions (Santschi *et al*. 2006).

Santschi *et al*. (2006) observed that valgus deviations are normal in foals and are naturally corrected up to 1 year of age without surgical interventions. However, other authors (Ruggles and Mcilwraith 2008) state that animals with deviations >10° should be treated immediately, since it can cause epiphyseal collapse in the lateral portion due to the poor distribution of weight and force and adversely affect this line of growth. Some researchers argue that deformities caused by asymmetric growth of the distal radial epiphysis should be treated before 4 months of age (Auer 2012; Jansson and Ducharme 2005) with the assertion that earlier the surgical intervention, faster is the deviation correction, and greater is the chance of achieving normal angulation (Smith, 2015).

Surgical intervention is suggested with periosteal lifting or transphyseal bridge creation in animals with angulation deviations >6°, when the

physiological functional closing time is short, or in animals destined for auction. It is vital to discuss the drawbacks with the owner, such as possible scars and cosmetic deficit due to the intervention.

The growth of the distal radial epiphysis can occur up to 22–36 months of age (Jansson and Ducharme, 2005). The highest growth rate in this region occurs in horses up to 10 weeks of life, with the radius being responsible for 75% of the longitudinal growth of the limb in its distal portion (Fretz *et al*., 1984; Auer, 2012). Animals with deviations can undergo corrective surgery up to 15 months of age, if the growth line is not completely closed yet (Auer, 2012).

Considering that the greatest activity of the distal epiphyseal growth line of the radius occurs in the first 10 weeks after birth (Barr, 1995), and the observations of the aforementioned authors, the animals in this study underwent surgery in an opportune time. This was done to ensure a better response to the procedure, consider the period of 4 weeks where most of the corrections can occur, reduce the chances of collapse of the lateral epiphysis, and take advantage of its high growth rate.

According to the Mann–Whitney test, there was no statistical difference between the right and left limbs with respect to the implant permanence time until deviation correction. Additionally, there was no difference between the right and left limbs in the degree of angulation before implantation or after implant removal.

The lack of a difference in the severity of angulation deviation between the right and left limbs before implant placement suggests that there is no correlation between the severity and the side of the affected limb. Likewise, the test results suggest that the limbs of both sides have the same possibility of achieving normality with this technique, since there was no statistical difference between them after correction nor did their implant permanence times differ; thus, the correction time is similar for the affected limbs of both sides.

Most authors do not use single transphyseal screw in animals under 1 month of age. Instead, they use only clamps or screws with cerclage due to the reduced retention potential of the single transphyseal screw in the developing epiphyseal bone (Auer, 2012). Another concern associated with the single transphyseal screw is the formation a spot weld between the diaphysis and epiphysis, resulting in a permanent bridge (Roberts *et al*., 2009). In association with rapid growth, this could lead to overcorrection in the limb, thus harming the development of the animal (Fretz *et al*., 1984; Auer, 2012). Kay and Hunt (2009) reported that implants that delay growth could lead to excessive correction due to the compression of the plate, physeal dysplasia, and continuous deviation due to the collapse of the growth plate.

In another study, Gray *et al*. (2017) described the use of a single transphyseal screw in foals without the aforementioned observations. In our study with 40 limbs subjected to carpal valgus deviation correction, none of the previously reported complications were observed, corroborating the results by Kay and Hunt (2009). Likewise, the case report by Ryu *et al*. (2022) supports the previous findings in the literature regarding the efficiency and correction time of the single-screw transphyseal bridging technique without lateral periosteal transection of the distal radius.

In another study (Carlson *et al*., 2012), 921 transphyseal bridge implants were performed. Among them, 522 cases were treated with single transphyseal screws and 399 with screw and cerclage in valgus and varus animals, with infection incidence of 5.1% and 5.5%, respectively. Moreover, they highlighted the occurrence of metaphyseal collapse only in the animals subjected to the single transphyseal screw technique, with an incidence of 4.4%. In these cases, the animals showed a sudden change in the angulation in the direction opposite to that being treated within 2–5 months after implant removal, and they were subjected to another surgical procedure to correct the deviation. The same authors suggested a deficiency in the blood supply that could promote cartilage proliferation without being replaced by bone matrix, which would weaken the epiphysis and lead to collapse.

In this study, the animals were clinically observed for 6 months, but the previously reported findings were not observed. This could be because the animals undergoing corrective surgery in our study were younger (average age,

31 days) than those in the previous study (just over 1 year old). Furthermore, in the study with 921 implants, most of the animals were treated for varus deviation of the carpus, with the implant placed on the lateral face of the radius; however, in this study, all the foals had carpal valgus deviation, with the implant placed on the medial surface of the radius. Nevertheless, it is suggested that in addition to the difference in the age of the animals, the weight could be a decisive factor for the occurrence of collapse.

Among the advantages of the single transphyseal screw reported by Carlson *et al*. (2012), better aesthetics and less thickening of the soft tissues were also observed in this study. Perhaps, the ease of implantation, small-sized incision, and reduced amount of implant material were associated with these results. As observed in other studies (Kay and Hunt, 2009) with a single transphyseal screw implanted in the metacarpal and metatarsus, complications such as difficulty in finding the screw head and breakage of the intraosseous screw were described, with higher incidence associated with a longer implant permanence time. Furthermore, they described how superficial infections associated with the implant are rare.

Only one case of infection was reported with the placement of implants in 12 limbs. Those cases required another surgical intervention with the screw and cerclage while avoiding the use of the same contaminated orifice of the first implant (Gray *et al*., 2017). In our study with 40 implants, infection was observed in only 5% (2/40) of the implants. Although the limbs in these cases showed decreased angulation, it was not adequate to be classified as anatomically normal during implant removal. Regarding screw removal, there were no difficulties in finding and removing any of the implants, which could be attributed to the short implant permanence time (approximately 31 days). Implant infection seems to be associated with the maintenance of dressings in the surgical area for at least 16 days, according to an experiment with a single transphyseal screw in the metacarpal and metatarsal bones (Kay and Hunt, 2009). In this study, the dressing was kept only for 6 days, with the dressing changed every 48h, showing a low incidence of infection as already reported.

There was no statistically significant difference in the prevalence between the right and left limbs, with an incidence of 47.5% and 52.5%, respectively. This was comparable to the incidence reported by Canola *et al*. (1997) of 50.31% in the right limbs and 49.68% in the left limbs. Likewise, the occurrence of bilateral valgus in the study by Canola *et al*. (1997) was approximately 89%, which is very close to the 90% reported in this study. In animals with varus deviation (Carlson *et al*., 2012), a prevalence of 62% of bilateral deviations was observed.

In foals requiring correction of valgus metacarpal deviation >2° persistent at 45 days of life or 45 days after periosteal elevation (Roberts *et al*., 2009), the use of the single transphyseal screw technique was compared with the screw and cerclage technique in 73 limbs. In that study, the average time for angular correction was approximately 31 days in animals subjected to the single transphyseal screw technique and approximately 43 days in those treated with a cerclage screw. In addition to a shorter time for deviation correction, the authors highlighted reduced surgery time and better cosmetic results with the single transphyseal screw technique.

The retrospective study by Kay and Hunt (2009) on the use of the transphyseal screw in valgus and varus deviations of the metacarpal and metatarsus, between 2004 and 2006, showed good results. When comparing the single transphyseal screw and the screw and cerclage techniques, the animals showed an average of 372 and 386 days, respectively (Carlson *et al*., 2012). In our study, the average implant permanence time of the single-screw implant was approximately 44 days (median, 38 days), which was lower than that of the screw and cerclage technique of just over 61 days (median, 54 days).

A retrospective study by Modesto *et al*. (2015) gathered data of animals treated with a single-screw transphyseal implant in a private clinic between 2009 and 2013 while standing and sedated. They reported an implant permanence time of 46 days.

In another study, Gray *et al*. (2017) evaluated the medical records of animals subjected to angular deviation correction between 2010 and 2015. They found that the animals subjected to carpal valgus correction with a single transphyseal

screw showed an average angulation correction of 15° in an average time of 35 days. In this study, the average withdrawal time was approximately 31 days, and during this period, the angulation was corrected from an average of 9.6° to 2.7°.

This research reiterates that it was possible to correct the carpal valgus angular deviation under experimental conditions in thoroughbred foals (mean age, 31 days) using the single transphyseal screw technique. This technique was safe and easy to execute and presented a low rate of trans- and post-surgical complications; hence, which it can be considered a therapeutic modality in such cases. The limitations of this study include the determination of the sample universe for convenience as well as difficulty in following the progress of these animals over several years and monitoring the sporting performance of those subjected to the surgical procedure in the initial months of life.

CONCLUSIONS

This study shows that the single transphyseal screw technique could be used to correct the carpal valgus deviation in foals. Moreover, it is indicated in animals of average age 30 days (20–55 days). The single transphyseal screw technique has the advantages of easy application, simple execution, and limited trans- and post-surgical complications, thus enabling its use in thoroughbred foals with carpal valgus angular deviations.

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