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Radiographic morphometry of the Foot in clinically normal Donkeys (Equus asinus)

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Abstract

Radiography of the foot is considered a golden standard technique enables the veterinarians to render a subjective evaluation of the foot in donkeys. The current study aimed to characterize objectively the baseline radiometric data of normal forefeet in donkeys to assess both of the nature and extent of anatomical changes occurring in foot affections. Lateromedial and dorsopalmar radiographic examination were performed on 48 forefeet of 24 clinically normal donkeys of both sexes. Four angles and 10 morphometeric distances were measured in latromedial radiographs and 10 morphometric measurements were measured in dorsopalmer radiographs. All hoof components appeared in the radiographic films were described and morphometric measurements were reported as minimum and maximum values, mean ± standard deviation (SD). The study presented a descriptive reference data for morphometric radiographic parameters of the forefeet from lateromedial and dorsopalmer radiographs in clinically normal donkeys, to assess any changes in hoof conformation and biomechanics associated with hoof affections.

Keywords: donkey, foot, morphometry, radiography.

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Introduction

Donkeys (Equus asinus) significantly support socioeconomic development in developing countries. In rural areas donkeys still used in many tasks especially those related to traction and transportation (Thiemann and Poore, 2019). Hoof affections have great impact on the donkey performance and productivity (Thiemann and Rickards, 2013 and Reix (née Broster) et al., 2014). Hoof-related problems represent Up to 65% of the donkey population affections (Mendoza et al., 2018). Diagnosis of the foot lameness is a challenging process and requires to be carried out via the conjunction of clinical examinations and different diagnostic imaging modalities (Tucker and Sande, 2001).

Radiographic assessment of the distal phalanx is considered the backbone of the veterinary evaluation of the equine foot. Knowledge of the radiographic anatomy and methods to obtain optimal radiographs allow the veterinarian to approach a subjective evaluation of the foot (Linford et al., 1993; Redden, 2003; Turner, 2006, Burd et al., 2014).

Accurate diagnosis of anatomical change is dependent on a priori knowledge of normal radiographic morphometry (Linford et al., 1993). Many studies have described the radiographic anatomy of the foot in horses (Cripps and Eustace, 1999; Redden, 2003, Turner, 2003 and Burd et al., 2014). However, there is little reference data regarding the radiographic morphometry in donkey foot.

The aim of the present study is to characterize objectively the baseline radiometric data of normal forefeet in donkey to assess the nature and extent of anatomical change occurring in foot affections

Materials and methods

Animals and study design

A total of 24 donkeys (10 males and 14 females) were used for radiographic examinations of the both forefeet. Animals age ranged from 4-8 years (5.6 ± 1.4) and body weight ranged from 110-150 kg (131 ± 13.9). All donkeys were judged to be normal through absence of history of lameness and limb abnormality, physical and clinical examination.

Radiographic examination protocol

Radiographic examination of the forefeet was carried out by fixed x-ray machine (Philips, super 80 CP). The exposure factors were 12-15 MAs and 50-55 Kv. Both lateromedial and dorsopalmar standard exposures were performed for the area extending from the mid-metacarpus and downward. Care was taken to get straight lateromedial exposure without deviation by aligning the radiographic beam perpendicularly to the sagittal plane of the foot and being centered in the level of the coronary band. Focal film distance was 75 cm for both exposures. The frog sulci and the sole surface of the hoof were cleaned prior to radiography. All hoof components appeared in the radiographic films were described and morphometric measurements were reported.

Morphometric measurement of the radiographs

1- Lateromedial morphometric measurements

Two horizontal lines were drawn in each obtained radiograph (Fig. 1-A). The first line was drawn parallel to the solar aspect of the distal phalanx (DP) and the

second line was drawn parallel to the bearing surface of the hoof. Two vertical lines were drawn. The first line was parallel to the dorsal aspect of the hoof wall while the second line was parallel to the dorsal border of DP and neglects the extensor process.

From these four lines, four angles and 10 morphometric distances were resulted and measured as follow (table 1):

Table (1): Definitions of the morphometric measurement derived from Lateromedial radiographs

Lateromedial morphometric measurements

No	Parameters	Anatomical definition
1	Hoof wall- DP distances 1 (HW-DP1)	The distances between the dorsal surface of the hoof wall and the dorsal cortex of the DP just distal to the extensor process
2	Hoof wall- DP distances 2 (HW-DP2)	The distances between the dorsal surface of the hoof wall and the dorsal cortex of the middle aspect of the DP
3	Hoof wall- DP distances 3 (HW-DP3)	The distances between the dorsal surface of the hoof wall and the dorsal cortex of the DP of the distal aspect of the DP
4	Middle phalanx-length (MP-L)	The perpendicular length of the MP at its midline
5	DP- length (DP-L)	The perpendicular length of the DP at its midline
6	Hoof wall angle (HWA)	The cranial angle formed between the vertical line parallel to the dorsal hoof wall and the horizontal line parallel to the solar aspect of the DP
7	DP angle (DP-A)	The caudal angle formed between the vertical line parallel to the dorsal aspect of the DP and the horizontal line parallel to the solar aspect of the DP.
8	Distal toe angle (DTA)	The cranial angle formed between the vertical line parallel to the dorsal hoof wall and the horizontal line parallel to the bearing surface of the hoof.
9	Cranial sole angle (CSA)	The angle formed between the vertical line parallel to the dorsal aspect of the DP and the horizontal line parallel to the bearing surface of the hoof.
10	S-founder	The perpendicular distance from the horizontal line parallel to the bearing surface to the highest point of the sole concavity
11	DP- ground distance (DP-G)	The perpendicular line between the tip of the DP and the bearing ground surface
12	Hoof thickness (HT)	The distance between the dorsal part of hoof wall till the heel at the widest area
13	Navicular bone dorsal prong length (NL-DP)	The length of the dorsal prong of navicular bone
14	Navicular bone palmar prong length (NL-PP)	The length of the palmar prong of navicular bone

2-Dorsropalmar morphometric measurements:

In each dorsoplamar radiographic film, 10 morphometric measurements were measured (Fig. 1-B) as follow (table 2):

Table (2): Definitions of the morphometric measurement derived from dorsopalmar radiographs

Dorsropalmar morphometric measurements

No	Parameters	Anatomical definition
1	Pastern joint width (PW)	The width of the pastern joint at the widest area
2	Coffin joint width (CW)	The width of the coffin joint at the widest area.
3	MP- width (MP-W)	The width of the middle phalanx at the widest area
4	DP- width (DP-W)	The distance between lateral and medial wings of the DP at the widest area
5	MP- length (MPh-L)	The length of the MP at its midline
6	DP- length (DPh-L)	The length of the DP at its midline
7	Navicular bone length (NBL)	The length of the navicular bone between its proximal and distal edges at the widest area
8	Navicular bone width (NBW)	The width of the navicular bone between its medial and lateral borders
9	hoof wall length (HWL)	The length from the highest proximal till the lowest distal point aspect of the hoof wall
10	Hoof wall width (HWW)	The width of the hoof wall between the medial and lateral borders at the widest area

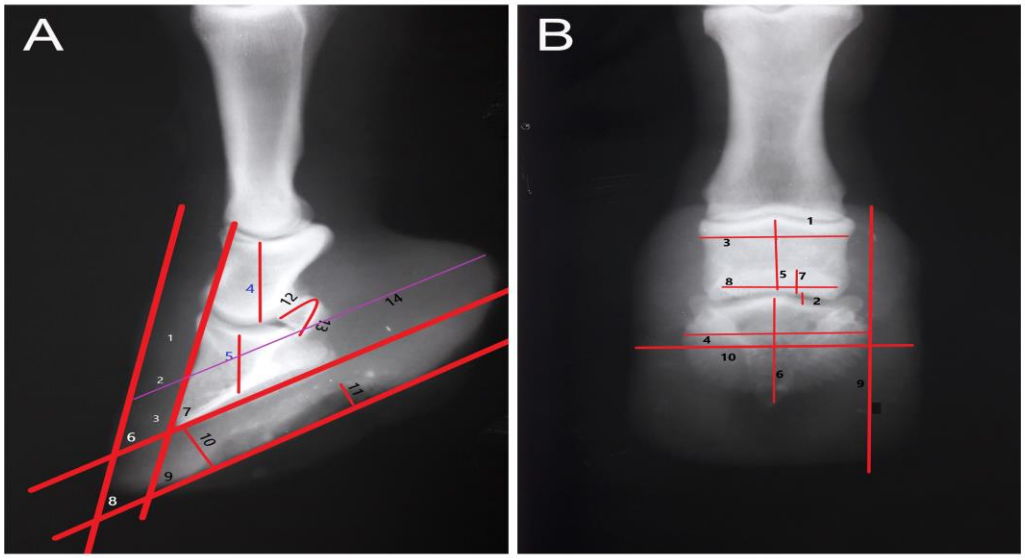

Fig. 1: Illustrate morphometric measurements in lateral radiographic film (A); 1: HW-DP1, 2: HW-DP2, 3: HW-DP3, 4: MP-L, 5: DP-L, 6: HWA, 7: DP-A, 8: DTA, 9: CSA, 10: DP-G, 11: S-founder, 12: NL-DP, 13: NL-PP, 14: HT and morphometric measurements in dorsopalmar radiographic film (B); 1: PW, 2: CW, 3: MP-W, 4: DP-W, 5: MPh-L, 6: DPh-L. 7: NBL, 8: NBW, 9: HWL, 10: HWW.

Results

In lateromedial radiographic films, hoof enclosed middle phalanx, distal phalanx, coffin joint and navicular bone. MP was a radio-opaque elongated bone attached to the pastern joint proximally and coffin joint distally, its proximal border located at 2-4mm under the level of the hoof coronary band dorsally and located at the same level 1-2mm above the level of coronary band palmarly. DP appeared as a triangular radio-opaque bone tapered at its distodorsal aspect. Its proximal border was wide concave line forming the distal articulation of the coffin joint while its palmar border was more radio-opaque than other borders with some irregularity at the proximal aspect of this border. Navicular bone appeared as inverted-U shape with more radio-opaque dorsal and palmar prongs. Its dorsal prong was attached to the palmar aspect of the MP while its palmar prong was attached to the proximal palmar aspect of the DP. Navicular bone, distal end of MP and proximal border of DP articulated together to form the coffin joint.

In dorsopalmar radiographic films, hoof enclosed middle phalanx, distal phalanx, pastern joint, coffin joint and navicular bone. MP appeared as a rectangle radio-opaque, bone density structure with more radio-opacity at its proximal and distal borders. DP appeared as half circle radio-opaque, bone density structure (head of hedgehog). It was more radio-opaque above semilunar line and two semilunar forminea appears as radiolucent dots at its proximal third. Navicular bone appeared as a radio-opaque boat like appearance superimposed above the distal extremity of MP. Pastern joint located inside hoof in all dorsopalmar radiographic films, while coffin joint formed by articulation of MP and navicular bone proximally and DP distally.

All morphometric measurements in lateromedial and dorsopalmar radiographic films are summarized in Table (3).

Table 3: Morphometric measurements in lateromedial and dorsopalmar radiographic imaging in donkeys (n= 24)

Lateromedial morphometric measurements				**Dorsopalmar morphometric measurements**			
Measured parameters	Minimum	Maximum	Mean± SD	Measured parameters	Minimum	Maximum	Mean± SD
HW-DP1	10.00	14.00	12.0 ±1.3	PW	2.00	3.00	2.4±0.5
HW-DP2	10.00	14.00	12.0±1.3	CW	3.00	3.50	3.1±0.2
HW-DP3	10.00	14.00	12.0±1.3	MP-W	27.00	32.00	30.5±2.1
MP-L	22.00	30.00	25.0±2.8	DP-W	34.00	45.00	41.5±4.1
DP-L	18.00	26.00	21.7±2.4	MPh-L	21.00	26.00	23.8±2.3
HWA	41.00	58.00	45.7±5.7	DPh-L	26.00	33.00	28.7±2.4
DP-A	41.00	58.00	45.8±5.7	NBL	26.00	32.00	29.2±2.3
DTA	41.00	58.00	45.7±5.7	NBW	7.00	9.00	8.2±0.7
CSA	41.00	58.00	45.8±5.7	HWL	79.00	88.00	81.8±3.6
S-founder	6.00	10.00	7.8±1.5	HWW	59.00	69.00	64.5±3.4
DP-G	11.00	17.00	13.6±2.4				

HT	87.00	121.00	96.1±11.5				
NL-DP	7.00	10.00	9.1±1.1				
NL- PP	10.00	11.00	10.6±0.5				

Discussion

Donkeys serve mainly as working animals, so its productivity depends basically on the soundness of their limb's components specially the foot (Sargentini et al., 2012 and Solomon et al., 2019). Scientific research was mainly directed to horses and often studying for other species such as mules and donkeys are scanty (Senior, 2013) Donkeys have specific anatomical radiographic features of the digit (Collins et al., 2011; El-Shafaey et al., 2017; Thiemann and Poore, 2019), which differ from those reported for horses (Redden, 2003, Turner, 2003, Thiemann and Rickards, 2013 and Burd et al., 2014). The present study directed to provide standard database for radiometric and morphometric parameter of normal forefeet in donkey.

Radiography of the digit is considered a golden standard technique enables the veterinarian to render a subjective evaluation of the digit in donkeys (Salem et al., 2017). In the present study, pastern joint of donkey was located inside the hoof in all dorsopalmar radiographic film. The same results were previously mentioned by Collins et al. (2011) who illustrated that the DP is positioned more distally within the donkey hoof than it is in the equine hoof. Hence, the extensor process is not in alignment with the coronary band, as is the case of the horse. The results of the present study were in agreement with that previously mentioned by Parks (2003), O'Grady and Poupard (2010) and Vosugh et al. (2017) that the dorsal hoof wall is parallel to the dorsal surface of the pastern region (the two horizontal lines). In a broken-back, long-toe/low-heel conformation, the dorsal hoof angle is smaller than that of the pastern. Increase in the Hoof wall- DP distances refer to presence of acute laminitis and accumulation of exudate in the dorsal aspect of the pedal bone (Stashak, 2002).

Regarding to angles measurements in the present study, HWA and DP-A (45.7 ± 5.7 and 45.8 ± 5.7degrees, respectively) were close to that previously described by Cripps and Eustace (1999) and Vali (2014) who found that the mean HWA and DP-A in the front feet of horse were 48.6 degrees and 47.6 degrees, respectively. Smaller angles degree in our results may be attributed to the smaller size of donkey than horses. Any decrease in HWA, DP-A angles measurements may be an indicator for chronic laminitis with dropped or rotated DP (Tanaka et al., 2002). However, in the present study S-founder (7.8 ± 1.5mm) was less than that previously measured in horse (10.4 ± 0.36 mm) (Vosugh et al., 2017) which attributed to the differences in size between horse and donkey. However, changes in DP- ground distance (DP-G) and S-founder measurements than normal indicate presence of hoof laminitis with rotation and/or sinking of DP (Rocha et al., 2004 and Masoudifard et al., 2014). Any hoof wall overgrowth can be easily detected through lateromedial or dorsoplamar radiographic films which represent increase in the hoof

wall length (HWL). This phenomenon of long-toe/low-heel conformation may lead to weakened heel and their angle relative to the ground is decreased, resulting in the heels sinking (Colles, 1983). It has been suggested that this change in conformation increases the load on the palmar aspect of the foot during weight bearing, producing biomechanical changes including permanent extension of the coffin joint (Parks, 2003). Furthermore, some authors contend that these changes increase the force exerted by the DDFT on the navicular bone predisposing to navicular disease (Wright and Douglas, 1993 and O'Grady and Poupard, 2010).

Conclusion

Based on the present study, we can conclude that, morphometric evaluation of the lateromedial and dorsopalmer radiographic parameters of the forefeet in clinically normal donkeys, provide a reference data for diagnosis any changes in hoof conformation and biomechanics associated with hoof affections.

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