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CORRELATION BETWEEN MORPHOMETRIC ASPECTS, BONE AND TENO-DESMIC LESIONS DETECTED BY MAGNETIC RESONANCE IMAGING EXAMINATION IN THE EQUINE FOOT

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CHAPTER 1

Foreword

1. Foreword

The foot provides the contact surface between the horse and the ground (Wilson and Weller 2011). The foot has three main functions: absorve the shock during contact with the ground, bear the weight during standing and assure propulsion during movement (Parks 2003). In the horse the forelimb foot is the most affected by lameness (Wilson and Weller 2011).

The equine foot is formed by a hoof capsule, the three phalanges, the navicular bone, a series of ligaments and tendons, a digital cushion, the foot cartilages and a complex network of vessels and nerves (Wilson and Weller 2011).

1.1 Biomechanics and foot conformation

During locomotion, the distal interphalangeal joint undergoes a combined movements in the sagittal plane (flexion and extension), in the frontal plane (collateromotion) and in the transverse plane (rotation and sliding), expecially during circling and on hard surfaces. Each movement induces stresses on the articular surfaces and related teno-ligamentous structures (Denoix 1999, Clayton 2007).

Each structures compounding the foot is subjected to and is optimized for one predominant force, but it has also to withstand other forces both during normal stride and exceptional instances (Wilson and Weller 2011).

During the weight bearing, the Distal InterPhalangeal Joint (DIPJ) undergoes a flexion and the passive movements of flexion are limited by the action of Deep Digital Flexor Tendon (DDFT) and the dorsal part of Collateral Ligaments (CLs) of DIPJ. During the locomotion, the DIPJ extension is induced by the tension of DDFT that provokes tension within CLs, Collateral Sesamoidean Ligament (CSL) and Distal Sesamoidean Impar Ligament (DSIL) and high pressure on the Navicular Bone (NB) (Denoix 1999).

Asymmetric displacement of foot during motion causes collateromotion movements on frontal plane and sliding and rotation on tansverse plane. The DDFT, DSIL and CL are the main stressed structures during this asymmetric propulsion (Denoix 1999 (Fig. 1).

Eliashar et al. (2004) demonstrated a correlation between foot conformation and the forces exerted on it, expecially on navicular bone. The author suggested that a poor conformation can predispose horses with poor foot conformation to navicular disease (Eliashar et al. 2004). A large number of studies on equine biomechanics reported the effects of different types of shoeing on foot kinematics (Chateau 2006, Rogers 2007, Crevier-Denoix 2001). On these bases, it is easy to gather that every alteration on foot conformation (depending from pathologies, congenital abnormalities or errors in the foot trimming-management) causes a non-physiological distribution of the loading and an abnormal dissipation of the forces (Chateau 2002, Viitanen 2003, McGuigan 2005). The external aspect of the hoof is different in non-lame and lame horses due to abnormal weight-bearing and loading (Dyson et al. 2010). The hoof shape influences the biomechanical forces acting on the structures of the foot (Dyson et al. 2010) but it is proved that there are poor correlations between external hoof capsule measurements and distal phalanx measurements (Dyson et al. 2011). Nevertheless it is also demonstrated that abnormal distribuition of forces can influence the normal bone modelling and induces bone remodelling and tendon degeneration (Birch et al. 2008, Księżopolska-Orłowska 2010).

Clinicians observed principally radiographic alterations due to modelling and remodelling processes.

Ducro et al. (2009) understood the importance of a good conformation of the foot as a prognostic factor on duration of competitive life in Dutch Warmblood horse (KWPN), used for showjumping and dressage. Authors considered the hoof shape, heel height, pastern angle and uneven feet and the duration of sports career.

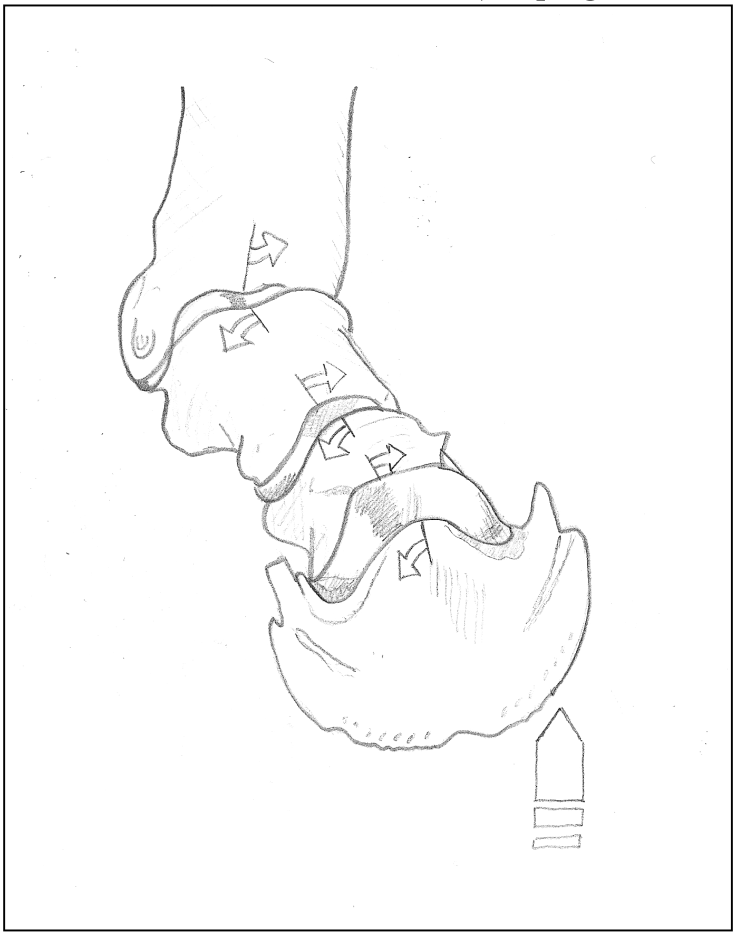

Fig. 1. Forces acting during the asymmetric displacement of foot: there is an association of movements of rotation and collateromotion.

Figure modified from Denoix J.M. “Functional anatomy of the equine interphalangeal joints”, 1999, AAEP proceedings, vol.45

Bowker (2003) investigated the different sturctural aspects of foot in sound and lame horses and the correlation between biomechanical findings and histological findings in healthy and pathological foot.

CHAPTER 2

Objectives

2. Objectives

We hypothesized that would be a correlation between foot conformation and incidence/presence of foot lesions. There are only few studies that examin the equine foot external characteristics (Bushe et al. 1987, Balch et al. 1993, Dyson et al. 2010, Dyson et al. 2011) or the radiographic measurements of the navicular bone (Verschooten et al. 1989, Biggi and Dyson 2011a) related to the presence of lameness but none provide a correlations between morphometric characteristics of foot and specific osseous, tendineous and ligamentous injuries. The aim of this study was to evaluate the correlations between some morphometric aspects of the equine foot radiographically evaluated and the presence of osseous and tenodesmic lesions observed on Magnetic Resonance Imaging and to investigate the predictive and prognostic value of the radiographics measurements in the diagnosis of both bony and tenolegamentous alterations.

CHAPTER 3

Materials and Methods

3. Materials and Methods

3.1 Inclusion criteria

In the study were included horses examined between Genuary 2007 and May 2011, with unilateral or bilateral lameness, a positive response to palmar digital nerve blocks or to intra-articular block of the distal interphalangeal joint that underwent to radiographic examination (Latero-Medial and Dorso-Palmar views) and to a Magnetic Resonance Imaging (MRI) scan.

The age, gender, breed, discipline, duration and grade of lameness were recorded.

Feet were excluded for the following reasons: 1) there was a slight obliquity in the Latero-Medial views, 2) x-rays were obtained with the horse shod, 3) MRI was performed using a reduced protocol, 4) horses had only partial positive response to palmar digital nerves blocks or intra-articular DIPJ block.

3.2 Radiographic examination

The shoes were removed. The feet were radiographed standing on a flat wooden block while bearing weight. Radiographic examination included two views, the Latero-Medial (LM) and the Dorso-Palmar (DPa). Radiographs were taken using a computerised high frequency x-rays system. In the LM projection the beam was centered 2 cm below the coronary band midway between the heels and the dorsal aspect of the hoof wall. In the DPa the beam was centered on midline at the coronary band. The exposure factors for the LM and DPa views were 70 kV and 12,5 mAs. A radiopaque marker of 25 mm in lenght was used to indicate the dorsal or the lateral aspect of the digit.

A total of 20 measurements were taken independently by two lecturers. Fourteen measurements were taken on the LM and 6 on the DPa view using a dedicated software that allowed to calibrate the linear measurement on a marker of known size.

In the LM view were measured the palmar angle (P3BA), the joint angle between the proximal and the second phalanx (JA2), the joint angle between the second and the distal phalanx (JA3), the distance between the dorsal surface of the third phalanx and the dorsal aspect of the hoof wall in the proximal third (HP3P), the distance between the dorsal surface of the third phalanx and the dorsal aspect of the hoof wall in the distal third (HP3D), the percentage of toe lenght (TL) on the foot lenght (FL) FL/TL=TFL), the navicular thickness (NT), the navicular cortex thickness (CNT), the navicular lenght (NL), the proximal extension of navicular cortex (NPEL), the distal extension of the navicular cortex (NDEL), the distal interphalngeal joint height (JH3), the distance between the tip of the toe and the ground (P3B) (Fig. 2 and Fig. 3).

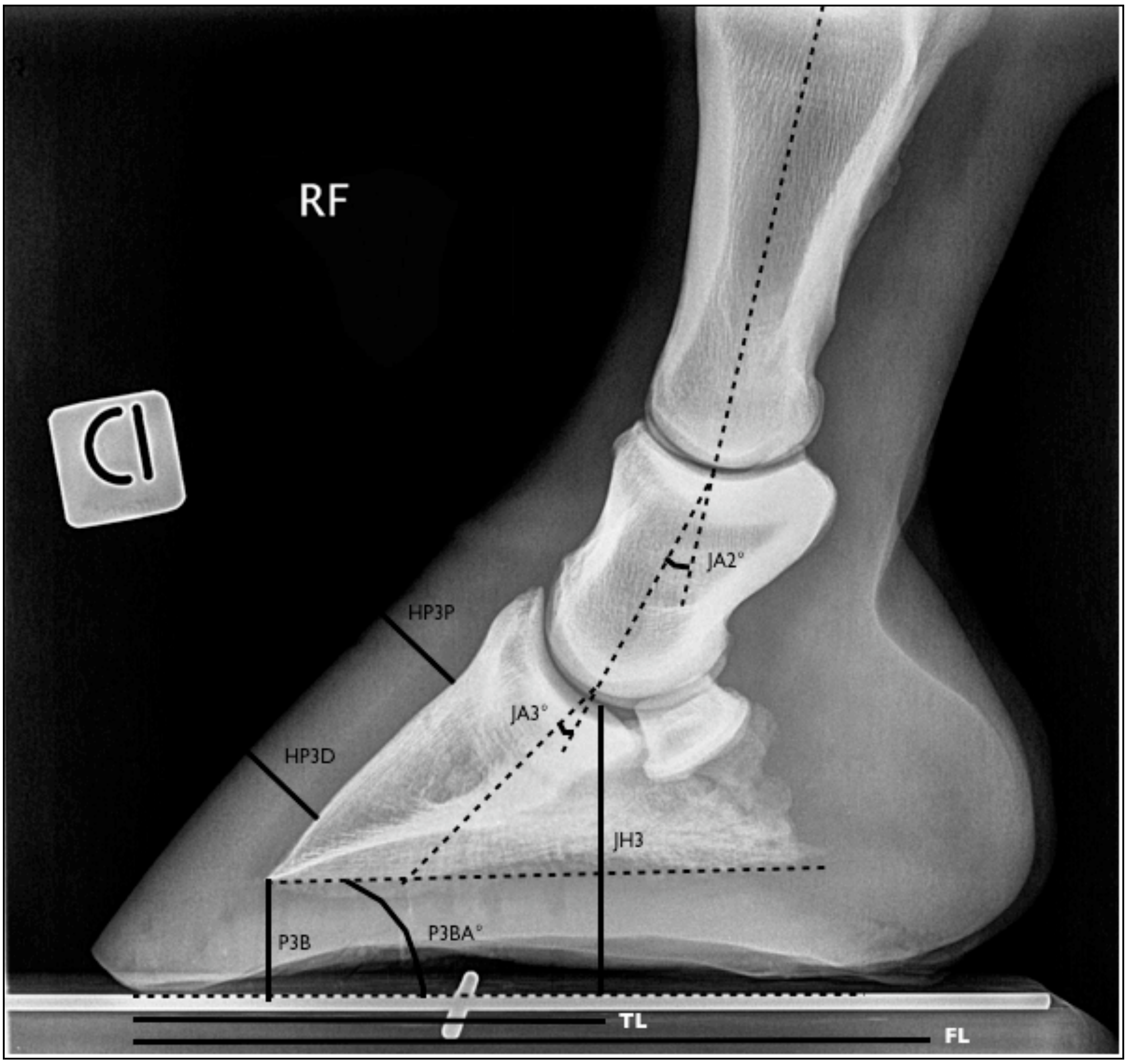

Fig. 2. LM view indicating parameters and angles measured. Parameters referred to navicular bone are not rapresented.

To avoid problems related to different weight height of horses and to uniform the samples, the following ratio were calculated on the basis of the measurements: HP3P/HP3D, NT/CNT, NL/NPEL, NL/NDEL, JH3/P3B.

In the DPa view were measured the lateral wall angle (LWA), the medial wall angle (MWA), the joint tilt angle between the second and the third phalanx (JT3), the distance between the lateral aspect of the solar aspect of third phalanx and the ground (LP3B), the distance between the medial aspect of the solar aspect of third phalanx and the ground (MP3B), the ratio between the height of the distal interphalangeal joint on lateral and medial aspect (DIJH) (Fig. 4).

To avoid problems related to different weight height of horses and to uniform the samples, the following ratio were calculated on the basis of the measurements: LP3B/MP3B.

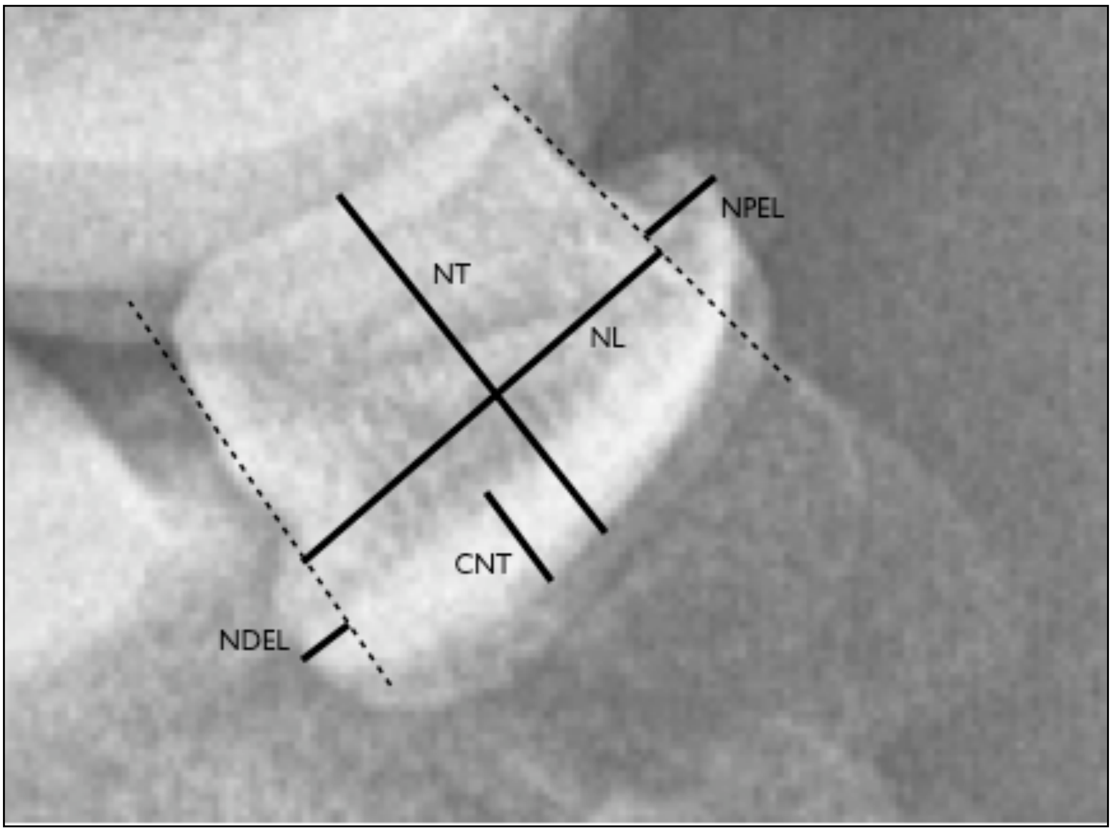

Fig. 3. Detail of LM view in which are indicated the parameters referred to navicular bone.

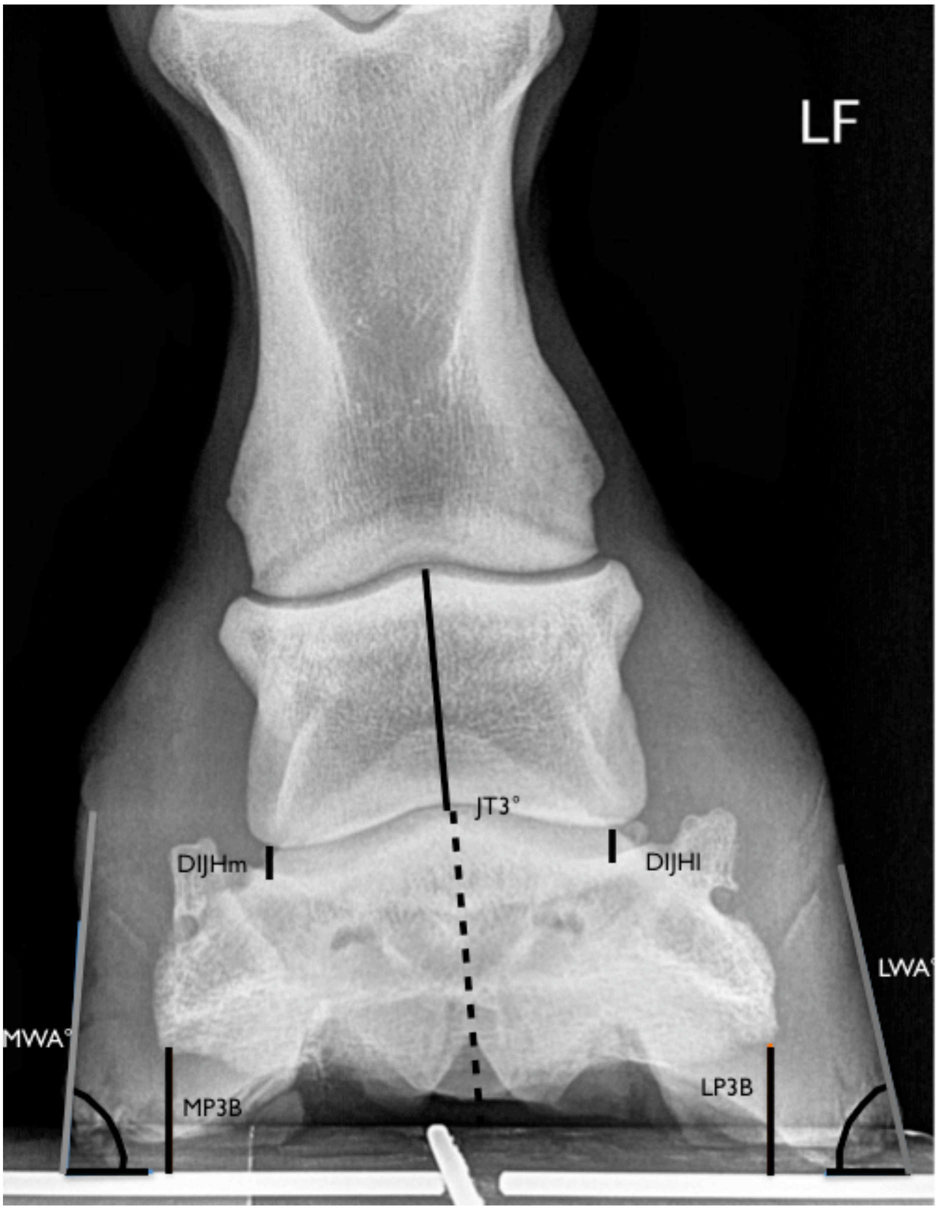

Fig. 4. DPa view inidcating the measured parametrs and angles.

3.3 Magnetic Resonance Imaging examination

MRI images were acquired using a low field magnet (0,18 Tesla) (Vet-MR, Esaote, Genoa, Italy) and a knee receiving coil. The acquisition protocol included sagittal and transversal three-dimensional T1 weighted gradient echo (T3DT1) sequences, sagittal and dorsal short tau inversion recovery sequences (STIR), transversal dual echo sequences (TME). Images were obtained using 1 mm slice thickness for the volumetric acquisition and 4 mm slice thickness with 0,4 mm gap thickness for all other sequences. Transverse T1 weighted images were oriented perpendicular to the navicular cortex while transverse TME were oriented parallel to solear surface and orthogonal to CLs. Dorsal images were oriented parallel to the dorsal cortex of the middle and distal phalanx.

MR images were evaluated by two lecturer independently. Structures evaluated included the DDFT, DSIL, CSL, CLs of the DIPJ, the flexor surface of navicular bone (NB FLEXOR), the medulla of the navicular bone (NB MEDULLA), the proximal border (NB PROXIMAL) and the distal border (NB DISTAL) of the navicular bone. Signal intensity and homogeneity, size, definition of anatomic margins and relationships with other structures were considered and each structure was graded as normal (0) or with mild (1), moderate (2), severe (3) abnormalities (Murray et al. 2006) (Table 1).

Abnormality in signal and/or in size of a structure was considered only if it was repeteable in more than one plane and in more than one sequences.

Table 1.

STRUCTURE	GRADE	DESCRIPTION
DDFT	0	Uniform low signal and defined margins
	1	Small (<1mm) areas of mild increased signal intensity or very mild irregularities of tendon margins
	2	Areas of moderate increased signal intensity involving less than one third of tendon area or moderate irregularities of tendon margins
	3	Areas of increased signal intensity involving more than one third of tendon area or severe irregularities of tendon margins
DSIL	0	Uniform low signal intensity with uniformly distributed areas of high signal intensity on GE sequences
	1	Mild asymmetry in signal omogeneity or mild irregularities of palmar margins
	2	Asymmetry in signal homogeneity and/or irregularities of palmar margins
	3	Marked asymmetry, marked evidence of adhesion formation and poor separation from DDFT
CSL	0	Omogenous signal, symmetrical shape and size, clearly defined margins
	1	Mild alterations in signal homogeneity, mild asymmetry or alterations in shape and size. Adherence in the axial part of CSL
	2	Moderate alterations in signal homogeneity, moderate asymmetry or alterations in shape and size. Evidence of some adeherences in the abaxial part of CSL
	3	Marked alterations in signal, asymmetry and alterations in size and shape. Extensive adhesion formation
CLs DIPJ	0	Uniform low signal intensity, clear margins, lateromedial symmetry in size and shape
	1	Mild increase in signal intensity, mild asymmetry or mild margins irregularities
	2	Increased signal intensity and distortion in shape and size
	3	Marked high signal intensity, enlagement, loss definition of margins
NB FLEXOR	0	Clear cartilage layer, uniform cortical thickness, smooth endosteal surface

	1	Mild irregularities in cartilage thickness and signal intensity
	2	Moderate loss of signal definition at site of fibrocartilage with defects in the flexor surface of the cortex or moderate irregularities on endosteal surface
	3	Severe fibrocartilage loss, large defects in the flexor surface cortex,, severe irregularities in the endosteal surface with extension into the medulla
NB MEDULLA	0	Uniform high signal intensity on T1 weighted sequences, low signal intensity on STIR. Clear definition form cortex
	1	Less uniform high signal intensity on T1 weighted. Mild focal or very mild generalized increase in signal intensity on STIR sequences
	2	Mild to moderate signal etherogeneity on T1w or moderate localized or generalized increase in signal intensity on STIR sequences
	3	Marked low signal intensity on T1 weighted or marked increase in signal on STIR sequences
NB PROXIMAL	0	Smooth indentation into cortical surface immediately dorsal to insertion of CSL, smooth endosteal surface
	1	Mild irregularity of cortical surface and of endosteal surface, mild variability in cortical thickness
	2	Moderate irregularity of cortical surface and of endosteal surface, moderate variability in cortical thickness
	3	Severe marked cortical irregularity and enthesiophyte formation, severe irregularity of endosteal surface
NB DISTAL	0	Smooth indentation into cortical surface immediately, smooth endosteal surface
	1	Mild irregularity of cortical surface and of endosteal surface, mild variability in cortical thickness
	2	Moderate irregularity of cortical surface and of endosteal surface, moderate variability in cortical thickness
	3	Severe large defects into the cortex, distal border fragment, severe irregularities to the endosteal surface

3.4 Statistical analyis

3.4.1 Simple Linear Correlation

For statistical analysis, the SAS 9.2 statistical software was used. Simple linear correlations between each measurement and each pathology were estimated using PROC CORR of SAS. Statistical significance was set at $P<0.05$.

3.4.2 CART (Classification and Regression Trees)

CART is a nonparametric statistical technique that can select from among a large number of variables those and their interactions that are most important in determining the outcome variable to be explained.
We build a classification tree for each pathology using raw data. Afterwards the raw data and the normalised data were explored using a Principal Component Analysis (PCA). CART were also obtained using PCA scores based on raw data and PCA scores based on normalised data.

3.4.3 Classificatory Performance

The classificatory performance of CART was calculated using the classification trees build with raw-data, PCA raw data and PCA normalised data.

CHAPTER 4

Results

4. Results

4.1 Horses included in the study

One hundred and twenty-five feet from 93 horses were examinaed. Fifty-one feet were excluded from the study because of the slight obliquity in the LM view (20 cases), x-rays were obtained with the horse shod (15 cases), MRI was performed using a reduced protocol (12 cases) and horses had only a partial positive response to palmar digital nerve blocks, or intra-articular DIPJ block (4 cases).

Seventy-four feet from 52 horses, including 30 feet from unilateral lame horses and 44 feet from 22 bilateral lame horses were included in the present study.

Breed, gender, age, occupation, lame limb/limbs and degree of lameness were summarised in Table 2.

Case	Breed	Age	Gender	Occupation	Limb	Lameness Grade
1	Standardbred	2	f	race	RF	2
2	Appaloosa	7	f	reining	RF	2
3	Belgian warmlood	12	mc	show jumping	LF	3
4	Hungarian warmblood	12	mc	show jumping	LF	4
5					RF	1
6	Selle Fraincais	15	f	show jumping	LF	4
7					RF	1
8	Anglo-Arabian	8	m	show jumping	LF	2
9					RF	2
10	Dutch warmblood	13	mc	show jumping	RF	2
11	Standardbred	3	m	race	LF	2
12					RF	1
13	Belgian warmlood	9	f	show jumping	LF	2
14					RF	1
15	Italian warmblood	8	f	show jumping	LF	2
16					RF	1
17	Hannover	8	mc	dressage	LF	2
18					RF	1
19	Oldenburg	6	f	dressage	LF	2
20	Lipizzan	22	mc	general purpose	LF	2
21	Belgian warmlood	8	f	show jumping	LF	2
22	Belgian warmlood	9	mc	show jumping	RF	3
23	Arabian	12	f	general purpose	LF	2
24					RF	2
25	Italian warmblood	5	f	show jumping	LF	2
26	Italian warmblood	4	m	show jumping	LF	2
27	Selle Fraincais	9	mc	show jumping	LF	1
28					RF	1

Table 2. Breed, Age, Gender, Occupation, Lame Limb and degree of lameness of horses included in the study (continue in the following page.)

29	QH mixed breed	3	f	western pleasure	LF	2
30					RF	1
31	QH	5	f	reining	LF	2
32	QH	3	m	reining	LF	2
33					RF	1
34	Irish warmblood	20	mc	general purpose	LF	2
35	Bardigiano	11	f	general purpose	RF	1
36	Thoroughbred	10	mc	hunter	LF	2
37	Italian warmblood	13	mc	dressage	LF	2
38					RF	1
39	QH	5	m	reining	LF	3
40					RF	2
41	Criollo	7	f	general purpose	RF	2
42	Hannover	9	m	show jumping	RF	1
43	Selle Fraincais	9	mc	show jumping	RF	2
44	Belgian warmlood	11	mc	show jumping	LF	4
45					RF	1
46	Pony	10	mc	show jumping	LF	2
47					RF	1
48	Italian warmblood	8	f	show jumping	RF	2
49	Dutch warmblood	8	f	show jumping	RF	3
50	Arabian	13	f	endurance	LF	2
51	Dutch warmblood	7	f	show jumping	LF	2
52					RF	1
53	Italian warmblood	11	f	show jumping	LF	2
54	Trakehner	12	mc	show jumping	RF	2
55	KWPN	7	f	show jumping	RF	2
56	KWPN	12	f	show jumping	LF	1
57	Appaloosa	5	f	reining	LF	2
58					RF	1
59	KWPN	13	f	show jumping	LF	2
60	Pony	8	mc	show jumping	LF	1
61					RF	1
62	KWPN	14	mc	show jumping	LF	2
63					RF	1
64	Pony	16	f	general purpose	LF	3
65	Italian warmblood	13	f	show jumping	RF	4
66	Belgian warmlood	11	mc	show jumping	LF	2
67	Hannover	10	f	show jumping	RF	3
68	Appaloosa	7	mc	general purpose	LF	2
69					RF	2
70	QH	3	f	western pleasure	LF	3
71					RF	1
72	KWPN	9	f	show jumping	LF	2
73	Selle Fraincais	13	mc	show jumping	LF	2
74					RF	1

Table 2. con't

Horses were aged two to twenty-two years and the mean age was 9.4 years.

Fifty-two percent were mares (27 horses), thirty-five and one-half percent were geldings (19 horses) and eleven and one-half percent were stallions (6 horses).

Sixty percent of the lame horses examined were used in showjumping competition at medium/high level (120-140 cm).

There was no difference in distribution of lameness on right or left foot.
Lameness grade was included in a range between 1 and 4, with a mean of 1,9 degree. The lower degree of lameness (1) was recorded only on bilateral lame horses.

4.2 Radiographic Measurement

All parameters and angles were measured in each horses on both radiographic views by two lecturer. Interobserver agreement was 80% and intraobserver reliability was 94%. The ratio between navicular bone thickness and cortical thickness was not recorded in four cases because of the impossibility to determine the cortical thickness due to the sclerosis of the medulla of navicular bone.

The medial wall angle (MWA) was greater than the lateral in 62% of foot and a medio-lateral imbalance was present in 84% of cases (62 foot) and in the 90% of these, the distance between the solar aspect of third phalanx and the ground was greater laterally.

In 35% of foot was evident a joint tilt of the second phalanx on the third one. In 31% (26 cases) of cases there was a slightly difference between the distal interphalangeal joint thickness on lateral an medial aspect.

No correlation was observed between the presence of joint tilt, medio-lateral imbalance and difference between the distal interphalangeal joint thickness on lateral an medial aspect.

In a large number of cases (>90%) there was phalanges malalignement on lateral view with axis broken palmarly.

Extension of the proximal border of the navicular bone was recorded in all feet examined and vary from a minimum of 1 mm to a maximum of 6 mm with a mean of 2.4 mm. Extension of the distal border was also seen in all cases and the range was the same but the mean corresponded to 2.7 mm.

All measurements wer recorded in Table 3.

CASO	P3BA	JA2	JA3	HP3P/HP3D	TFL	NT/CNT	NL/NPEL	NL/NDEI	JH3/P3E	LWA	MWA	JT3	.P3B/MP3E	DIJH
1	-2	13	5	1	1,58	2,6	8,5	17	2,81	76	75	1	1,37	0,33
2	10	4	4	1	1,68	5	7,5	5	2,46	84	78	3	1,09	2
3	0	17	12	1,15	1,58	4,67	11	11	2,23	73	71	2	1,3	1
4	6	6	10	1,04	1,68	2,8	3,6	3,6	3	72	86	0	1,21	1
5	4	12	16	1,09	1,67	3,5	6,66	5	2,7	70	78	2	1,21	1
6	0	19	18	1	1,69	3,75	19	19	2,5	66	68	4	0,92	1
7	3	17	15	1	1,57	5	9,5	4,75	2,57	70	71	0	1,04	1
8	4	15	2	1,11	1,67	-	9,5	9,5	2,58	75	80	0	1,1	1
9	2	17	10	1,05	1,65	3,25	10	10	2,45	74	75	2	1,17	2
10	6	14	9	1,04	1,57	3,75	5,66	17	2	75	78	0	1	1
11	3	9	5	1	1,5	2,8	15	7,5	2,56	81	81	0	1,04	2
12	-3	17	7	1,06	1,47	5	17	5,66	2,19	77	78	0	0,93	1,33
13	0	16	9	1,06	1,48	4,33	19	19	2	72	77	0	1,15	1
14	4	11	3	1,06	1,42	4,33	19	9,5	2,41	75	82	0	1,17	1
15	3	17	4	1,05	1,58	3,2	5,67	3,3	2,28	71	72	0	1	1
16	1	19	2	1,04	1,55	4,66	20	5	2,29	73	76	5	1,11	2
17	1	19	9	1,12	1,51	7,5	16	8	2,19	71	71	4	1	1,67
18	14	9	-3	1	1,84	6	5,33	8	3,23	78	76	0	1	1,67
19	4	9	7	1,06	1,62	3	3,2	5,33	2,84	78	75	0	1,04	1
20	1	12	4	1	1,66	2,2	7	7	2,3	77	74	1	1,24	1
21	5	13	4	1,05	1,57	4,67	4,25	4,25	2,89	70	78	0	1,56	0,75
22	3	15	8	1	1,69	4,25	8,5	3,4	2,36	69	74	1	1,08	1,2
23	3	20	17	1,06	1,52	2,8	8	16	2,71	68	80	0	1,06	1
24	5	12	9	0,93	1,53	3,25	16	16	3,5	80	77	0	1	1
25	0	16	8	1	1,57	3,75	17	8,5	2,43	68	75	0	1,2	1
26	5	6	1	1	1,61	-	8	16	2,75	79	74	0	1,12	1,4
27	1	16	11	1,06	1,54	2,5	5	3	2,23	71	72	2	1,19	1
28	0	16	13	1,12	1,52	-	18	9	2,5	69	73	2	1,22	1
29	1	14	9	1	1,59	2,5	9	9	3,21	70	78	0	1,31	1
30	2	9	30	1	1,52	2,33	5,67	8,5	3,92	74	82	2	0,95	1
31	4	11	11	1	1,52	3	15	15	2,55	80	84	0	1	1
32	5	14	15	1	1,55	4	7	3,5	2,84	81	79	1	1	1
33	2	17	25	1,14	1,41	4	7	3,5	3,25	79	78	0	0,91	1,25
34	6	17	10	1	1,66	2,8	7,5	15	2,75	81	81	0	1,05	1
35	10	19	1	1	1,56	2,5	11	5,56	2,5	77	80	0	1,13	1
36	6	22	9	1	1,43	3,5	5	1,67	3,5	72	76	0	1	1
37	0	16	0	1	1,47	4,67	7,5	5	2,76	85	79	0	0,9	1
38	4	8	11	1,07	1,47	4,67	7	7	3	79	90	4	1,26	3
39	-1	16	8	1,06	1,5	3	4,67	14	2,37	77	88	0	1,16	1
40	-1	14	17	1,25	1,54	2,75	14	4,67	2,24	82	84	0	1,09	1
41	2	18	12	1	1,47	-	3,5	14	2,42	76	73	0	1,17	1
42	7	12	3	0,95	1,63	4,67	4	5,33	3,13	73	80	0	1,22	1
43	5	14	11	1	1,57	3,4	8,5	8,5	2,54	77	72	1	1,11	1,2
44	-3	18	7	1	1,62	3	6,67	4	2,45	80	75	0	1	1
45	-2	15	24	1	1,58	2,5	3,67	7,33	2,21	72	84	0	1,28	1
46	5	21	0	1	1,65	4,33	3,25	13	3,2	79	88	0	1,05	1
47	6	14	1	1	1,6	3,5	2,17	6,5	3,31	78	88	0	1,45	1
48	2	21	9	1	1,6	3	7,5	15	2,33	66	71	0	1,09	1
49	1	18	-3	1	1,49	3,75	5,67	4,25	2,88	79	76	0	1,05	1
50	9	11	3	0,9	1,64	2,4	4,33	6,5	2,94	85	87	0	1,11	0,6
51	3	12	10	1	1,45	3,2	5,67	8,5	2,48	74	76	1	1,07	0,67
52	-1	20	12	1,11	1,48	3	5,67	8,5	2,23	68	67	0	1,32	1
53	7	17	-13	1,13	1,7	3,2	16	8	2,5	78	77	1	1,21	1
54	2	22	-6	1,06	1,61	4,67	7	3,5	3	72	74	2	1,06	1,33
55	9	17	8	1	1,78	3,2	6	6	3,2	67	68	1	1,04	1
56	4	23	1	1,16	1,54	3,5	16	5,33	2,48	72	68	0	1,03	1
57	-1	19	2	1,27	1,58	2,75	7,5	15	1,92	71	67	5	1	3
58	4	13	21	1,19	1,49	2,75	5	15	1,96	70	77	0	1,07	1
59	2	20	4	1	1,58	4	9	9	2,5	75	74	0	1,27	1
60	6	9	3	1,12	1,76	4,33	12	12	2,5	76	82	0	1,14	1
61	5	20	2	1	1,65	3	6,5	13	2,41	76	84	0	1,09	0,8
62	4	14	4	1	1,64	2,83	5	5	2,5	79	74	2	1,1	1,5
63	3	16	-2	1,05	1,59	3	8	5,33	2,33	74	81	0	1,1	1,25
64	8	12	12	1	1,42	2,4	13	6,5	2,21	84	85	4	1,22	1
65	-2	13	11	1	1,47	3,5	8,5	17	2,48	82	79	1	1,29	0,75
66	-1	23	10	1	1,59	3,4	6,33	3,17	2,8	72	73	0	1,1	1
67	2	10	10	1	1,55	3,5	5,67	8,5	2,29	80	80	4	1,04	1
68	9	11	11	1	1,56	3,25	16	16	2,75	81	76	2	0,96	1
69	6	10	12	1,06	1,61	3,25	7,5	3,75	2,39	75	83	0	1,25	1
70	6	17	3	1,07	1,38	3	15	5	2,36	77	74	0	1,04	1
71	3	15	15	1,07	1,42	2,4	8	8	2,21	84	73	0	1,04	1
72	2	19	3	1	1,52	3,2	2,83	4,25	2,9	66	76	2	1,1	1,25
73	3	18	15	1,2	1,6	2,8	5,33	4	3,31	73	73	0	1,24	1
74	0	21	10	1,06	1,56	3,5	5,33	5,33	3,06	68	84	0	1,27	1

Table 3. Radiographic parameters and angles

4.3 MR Examination

MRI of foot were examined by two lecturer. Interobserver agreement was 82% and intraobserver reliability was 92%.

Lesions involving more than two structures were present in the 98.6% of cases.

The structures more affected resulted the DDFT (91% of cases, 68 feet) and the NB DISTAL (85% of cases, 63 feet), then the NB FLEXOR (78.4%, 58 feet) and the NB MEDULLA (76%, 56 feet). CLs of the DIPJ and the CSL were the less involved: no lesions at level of CLs in the 47,3% of foot and no alterations of CSL in the 44,6% of cases.

The largest number of high grade lesions (grade 3) were seen at level of the medulla and distal border of the navicular bone and DDFT (63.5% of grade 3 lesions).

Alteration in the signal intensity on STIR sequences at level of the navicular medulla was observed on both foot in bilateral lame horses even if the degree of pathology were different in one respect the other feet.

In bilateral lame horses, the most serious lesions were seen in the more lame limb. Lesions of grade 1 were detected principally in the in the less lame feet in bilateral lame horses or, in unilateral lame horse, at level of proximal border of navicular bone and flexor cortex of navicular bone.

In Table 4 were summarized the lesions detected on MR examination.

CASO	DDFT	DSIL	CSL	CL DIP	NB FLEXOR	NB MEDULLA	NB PR BORDER	NB DST BORDER
1	1	1	0	2	0	1	0	0
2	2	2	0	0	2	3	0	2
3	1	2	1	3	0	1	0	1
4	3	2	0	0	1	2	1	3
5	1	1	0	0	1	2	0	3
6	1	0	1	2	2	0	0	0
7	0	0	0	1	3	0	0	1
8	3	2	1	0	2	1	1	1
9	2	0	0	0	1	1	1	1
10	0	1	1	3	0	1	0	0
11	2	0	0	0	0	0	0	0
12	0	0	0	2	0	1	0	1
13	1	3	0	1	1	0	0	1
14	3	3	1	0	1	2	1	2
15	2	0	0	2	3	3	1	3
16	0	1	0	0	0	1	0	3
17	1	2	0	0	1	0	0	2
18	1	2	0	0	1	0	0	2
19	2	2	2	0	2	3	1	3
20	3	3	2	1	3	3	2	2
21	0	0	1	0	1	1	1	2
22	2	1	0	1	1	0	0	1
23	2	0	2	0	2	2	1	2
24	3	1	2	0	3	3	2	2
25	2	2	0	1	1	0	1	1
26	1	1	1	0	1	2	1	2
27	3	0	2	2	2	2	2	2
28	2	0	2	2	1	3	2	2
29	1	2	0	0	2	3	1	3
30	2	2	1	0	2	3	2	1
31	0	0	1	2	2	3	1	0
32	1	0	0	2	1	3	0	0
33	2	2	0	2	1	3	0	0
34	2	0	0	2	1	1	0	1
35	2	2	2	3	1	0	0	1
36	2	0	1	2	0	3	2	2
37	1	1	0	1	1	1	2	2
38	1	1	0	2	1	2	2	1
39	2	1	2	2	2	2	1	2
40	2	2	2	2	2	2	1	3
41	3	1	3	1	2	2	1	1
42	1	1	2	1	1	2	1	3
43	2	2	0	0	0	0	1	1
44	3	2	0	1	1	1	1	3
45	3	3	2	2	3	3	1	3
46	3	2	0	0	3	1	1	2
47	2	3	0	0	3	3	1	2
48	1	2	0	2	0	1	0	1
49	1	2	1	2	0	1	1	3
50	1	2	2	0	1	3	1	2
51	3	1	1	2	1	0	0	1
52	1	2	0	3	0	1	2	3
53	2	0	1	0	1	1	1	1
54	1	2	2	0	2	2	3	3
55	1	0	1	0	1	0	1	2
56	1	0	0	3	1	1	1	1
57	2	2	2	0	3	3	2	2
58	3	1	2	2	3	2	3	3
59	1	0	1	2	0	0	1	0
60	1	0	0	2	0	0	0	0
61	1	0	0	1	0	0	0	0
62	1	0	1	2	0	0	1	1
63	2	1	2	3	0	1	1	1
64	2	1	0	0	1	0	0	0
65	3	3	0	2	3	3	2	3
66	2	1	0	2	1	0	1	1
67	1	1	1	2	2	1	2	2
68	2	1	3	0	2	2	1	1
69	2	2	3	0	2	1	1	2
70	1	0	0	0	1	2	1	1
71	2	1	2	0	2	3	2	3
72	2	2	1	0	2	2	2	2
73	2	0	2	0	0	0	2	2
74	1	0	0	0	1	1	1	1

Table 4. Grading score assigned to each structure. DDFT: Deep Digital Flexor tendon; DSIL: Distal Sesamoidean Impar Ligament; CSL: Collateral Sesamoidean Ligament; CL DIP: Collateral Ligament of Distal Intephalangeal Joint; NB Flexor: Flexor Surface Navicular Bone; NB Medulla: Medulla of Navicular Bone; NB PR Border: Proximal Border of Navicular Bone; NB DST Border: Distal Border of Navicular Bone.
Grading system: 0: no lesion detected; 1: mild; 2:moderate; 3: severe

4.4 Statistical analyis

4.4.1 Simple Linear Correlation

Linear correlations between each radiographic parameters and angles and alterations involving each structure evaluted by MRI were investigated using the software Statview (STAT) statistical analysis.

Anatomical structures (and their alterations) were considered the dependent variables while radiographic measurements were considered as independent one

Analysing SAS data, we found that between the joint angle between the proximal and the second phalanx (JA2), the ratio between the distance along the dorsal surface of the third phalanx and the dorsal aspect of the hoof wall in the proximal third and in the distal third (HP3P/HP3D), the lateral and medial wall angle (LWA, MWA), the joint tilt angle between the second and the distal phalanx (JT3), the ratio of distance between the lateral and medial aspect of the solar aspect of distal phalanx and the ground (LP3B/MP3B), the ratio between the height of the distal interphalangeal joint on lateral and medial aspect (DIJH) there were not a statistically significant relationship with pathology involving different structures (Table 5).

Pearson Correlation Coefficients Prob > |r| under H0: Rho=0 Number of Observations	P3BA	JA2	JA3	HP3P_HP3D	TFL	NT_CNT	NL_NPEL	NL_NDEL	JH3_P3B	LWA	MWA	JT3	LP3B_MP3B	DIJH
	X1	X2	X3	X4	X5	X6	X7	X8	X9	X10	X11	X12	X13	X14
DDFT	-0,05246 0,6571 74	-0,09638 0,414 74	0,15757 0,18 74	0,03981 0,7363 74	-0,0711 0,5472 74	-0,41597 0,0003 70	-0,18396 0,1167 74	0,01802 0,8789 74	0,01498 0,8992 74	0,10467 0,3748 74	0,13294 0,2589 74	-0,11825 0,3157 74	0,03284 0,7812 74	-0,09404 0,4255 74
DSIL	-0,11843 0,3149 74	-0,19426 0,0972 74	0,00659 0,9555 74	-0,03715 0,7533 74	-0,0361 0,7599 74	0,03685 0,762 70	-0,12888 0,2738 74	0,05075 0,6676 74	-0,01817 0,8779 74	0,10644 0,3667 74	0,16798 0,1525 74	-0,00055 0,9963 74	0,17497 0,1359 74	0,01559 0,8951 74
CSL	0,07084 0,5487 74	-0,06618 0,5753 74	0,10158 0,3892 74	0,12439 0,291 74	-0,0642 0,5871 74	-0,35137 0,0029 70	-0,12342 0,2948 74	0,10144 0,3898 74	-0,05566 0,6376 74	0,02134 0,8568 74	-0,01183 0,9203 74	-0,04075 0,7303 74	0,01127 0,924 74	-0,1218 0,3012 74
CL_DIP	-0,30536 0,0082 74	0,24596 0,0347 74	0,14523 0,217 74	0,10518 0,3725 74	-0,1897 0,1054 74	-0,06986 0,5655 70	-0,00237 0,984 74	0,08795 0,4562 74	-0,33667 0,0034 74	-0,06122 0,6043 74	-0,11512 0,3287 74	-0,12657 0,2826 74	-0,04182 0,7235 74	-0,18402 0,1165 74
NB_FLEXOR	-0,04631 0,6952 74	-0,13174 0,2632 74	0,20294 0,0829 74	0,00606 0,9592 74	-0,0068 0,9542 74	-0,15626 0,1964 70	-0,16056 0,1718 74	0,14868 0,2061 74	0,02993 0,8002 74	0,03336 0,7778 74	0,11883 0,3133 74	0,06609 0,5758 74	-0,04501 0,7034 74	-0,00506 0,9658 74
NB_MEDULLA	-0,05199 0,66 74	-0,24876 0,0326 74	0,20893 0,074 74	0,03111 0,7924 74	-0,2492 0,0322 74	-0,27749 0,02 70	-0,2073 0,0764 74	-0,00963 0,9351 74	0,21293 0,0685 74	0,19292 0,0996 74	0,19649 0,0934 74	-0,01471 0,901 74	0,00567 0,9617 74	0,02944 0,8034 74
NB_PR_BORDER	-0,193 0,0995 74	0,05837 0,6213 74	0,03409 0,7731 74	0,17466 0,1367 74	-0,2335 0,0453 74	-0,29154 0,0143 70	-0,2632 0,0235 74	-0,0913 0,4391 74	0,17565 0,1344 74	-0,04738 0,6885 74	-0,0606 0,608 74	0,02979 0,8011 74	0,08051 0,4953 74	0,05171 0,6617 74
NB_DST_BORDER	-0,12545 0,2869 74	-0,05389 0,6484 74	-0,03685 0,7553 74	0,12059 0,3061 74	0,01482 0,9002 74	-0,02804 0,8178 70	-0,28956 0,0123 74	-0,26613 0,0219 74	0,06778 0,5661 74	-0,08853 0,4532 74	-0,03856 0,7443 74	-0,02898 0,8064 74	0,14863 0,2063 74	0,00658 0,9556 74

Table 5. SAS analysis of correlations between radiographic parameters (independent variables) and the presence of pathological findings at level of different structures of the foot. Abbreviations are the same described in chapter 3.3 and 3.4

On the other hand, a deep correlation between NT/CNT and presence of pathological findings at level of DDFT, CSL, NB MEDULLA, NB PROXIMAL, between TFL and alterations at NB MEDULLA and NB

PROXIMAL, between NL-PEL and lesions involving NB PROXIMAL and NB DISTAL. There was also a relationship between JH3-P3B and CL-DIP and NB MEDULLA. The P3BA and JA3 angles was related only with alteratons detected on CL DIP and NB MEDULLA respectively. NL-NDEL was identified as related to NB DISTAL pathology.

4.4.2 CART Analysis and Classificatory Performance

For each pathology a classification tree (CART) was built using raw data. Other CART trees were also obtained using PCA scores based on raw data and PCA scores based on normalized data. We evaluated the classificatory performance of each CART tree using "re-substitiution" validation method. Results were summarized in Table 6.

	Classificatory Performance		
Structure involved	**Raw Data**	**PCA scores (raw data)**	**PCA scores (normalised data)**
CL_DIP	**0,8429**	0,8000	**0,8429**
CSL	0,7857	**0,9143**	0,8571
DDFT	0,8429	**0,8857**	0,8286
DSIL	0,7286	0,8143	**0,8714**
NB_DST_BORDER	0,7143	0,7714	**0,8000**
NB_FLEXOR	0,7000	**0,8000**	**0,8000**
NB_MEDULLA	0,7714	0,7571	**0,8571**
NB_PR_BORDER	**0,8857**	0,8571	0,7857

Table 6. Classificatory performance of CARTs. Trees with higher classificatory performance were highlighed in blue.

On the basis of classificatory performance results, CARTs based on raw data were used to study CL DIP and NB Proximal. To investigate influence of radiographic measurements on CSL, DDFT and NB Flexor, CARTs of PCA scores (raw data) were used. CARTs built using PCA scores based on normalised data were referred to DSIL, NB MEDULLA and NB DISTAL.

All CARTs chosen had classificatory performances equal or superior to 80%. It means that the probability of each case to be categorized in the correct pathology group/groups was equal or superior to 80%.

To read a CART, we had to consider that each node was represented by a radiographic parameters and offered a dichotomous choice. If the measured parameter was superior or inferior to the threshold value indicated by the node, the choice was redirected to a child node, depending on the value of the parameter considered.

Reference values used to built CART based on PCA raw data and CARTs based on PCA normalised data were different from radiographic measurement because parameters were transformed using the Principal Component Analysis and normalization of statistical data.

The best classificatory performance to evaluate the influence of radiographic measurements on pathology involving the navicular bone proximal border (NB PROXIMAL) was obtained using a CART built on raw data (84%) (Fig. 4).

Considering the NB PROXIMAL, the first choice was the ratio between total lenght of navicular bone and lenght of the extension of the navicular proximal margin (NL/NPEL). If the measured ratio was inferior to 4.835 the second node was the one on the left of figure 5, in which we had to consider the value of Lateral Wall Angle (LWA). If this value was superior to 68°, the incidence of

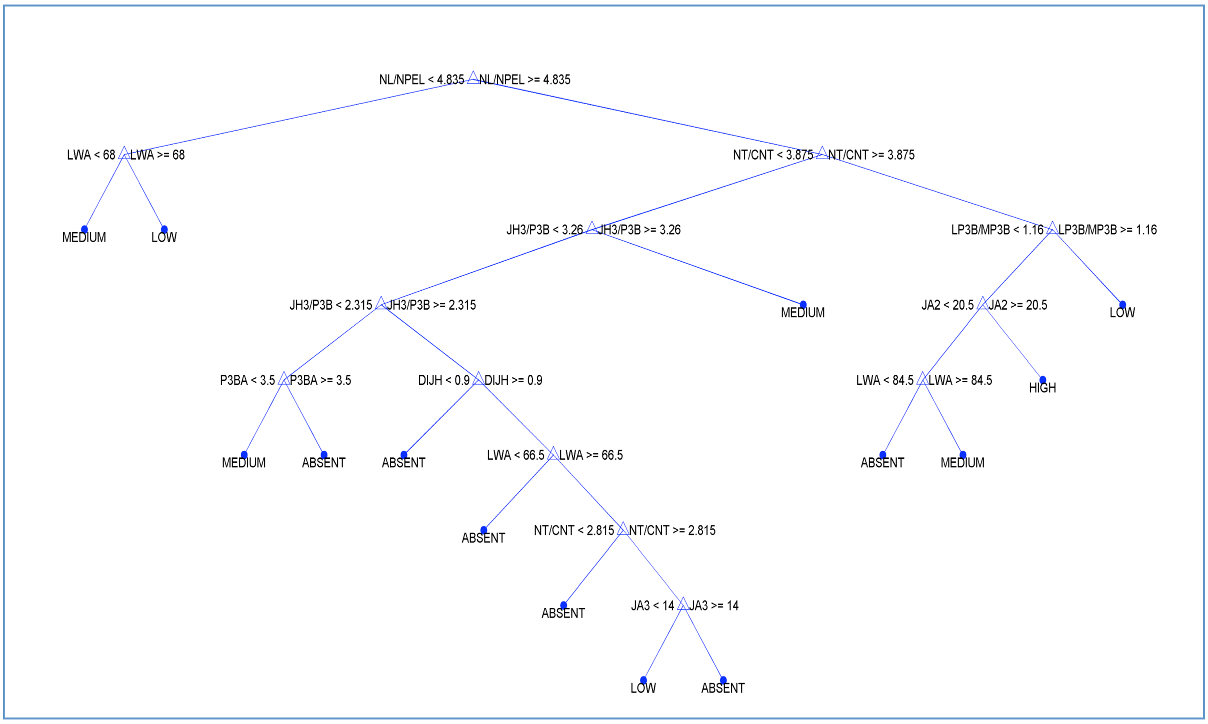

Fig. 5 CART-Navicular Bone Proximal Border. Radiographic measurements had to be considered to read this CART.

pathology involving the NB PROXIMAL was low. On the contrary, if the value of LWA was inferior to 68°, the possibility that the horse had an alterations involving the NB PROXIMAL was medium. If at the first node the measured ratio was superior to 4.835 the second parameter to consider was the ratio between Navicular Thickness and Thickness of the navicular cortex (NT/CNT) and so on until the end of dichotomous choices.

Not all parameters were included in the dichotomous choiche. In NB PROXIMAL CART had been considered NL/NPEL, LWA, NT/CNT, LP3B/MP3B, JH3/P3B, JA2, P3BA, DIJH and JA3. Each parameter included in the CART contributed to the chance to develop a pathology involving the structure for which the CART was built for.

Unlike what happened for the CART based on raw data, to read a CART built using PCA-transformed data, parameters to consider were not directly related to single radiographic measurements. In the latter case, we had to consider transformed data as reference.

In the following example, for diagnosis on Collateral Sesamoidean Ligament (CSL) pathology a CART built using PCA scores based on raw data was reported (Fig. 6).

In this case, the first node, called the parental node, was referred to the 10th Principal Component. If the value of PC_10 was inferior to -0,395, the probability to have a CSL alteration was medium. If the value was superior, we were redirected to a child node in which was considered the 4th Principal Component, and so on for the subsequent nodes.

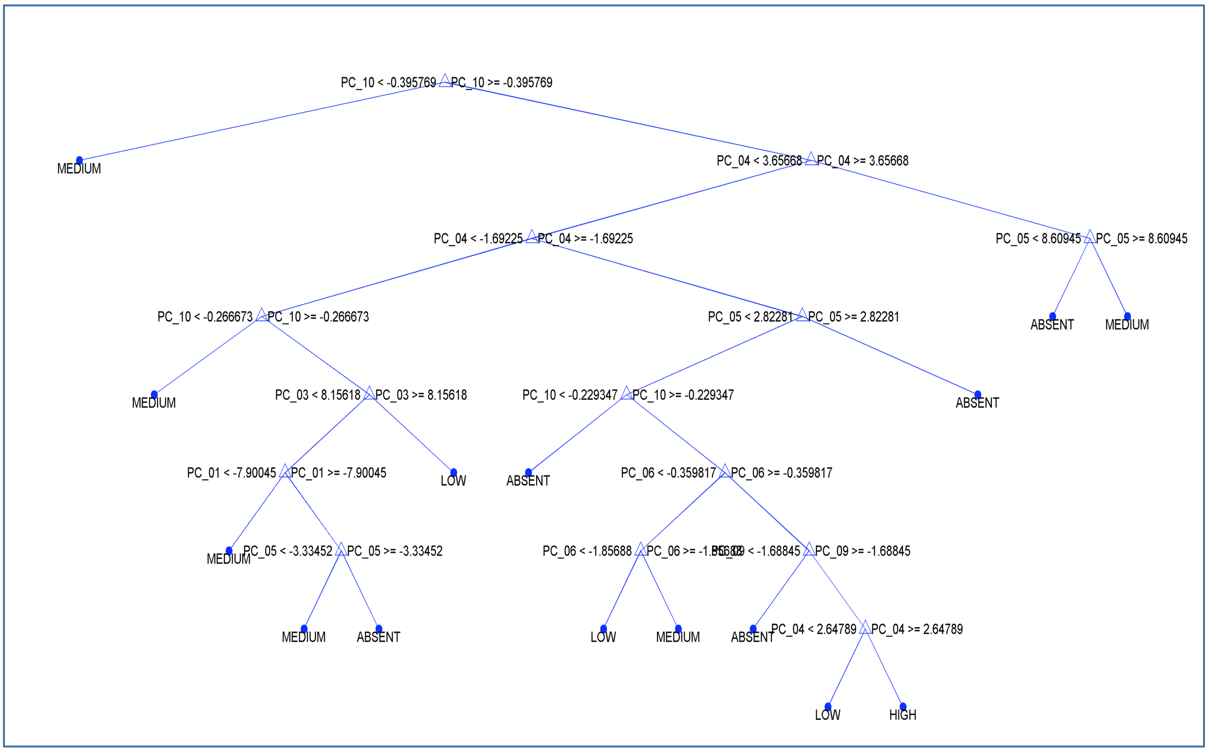

Fig. 6. CART-Collateral Sesamoidean Ligament. PCA Scores based on raw data had to be considered to read this CART.

In the case of Distal Impar Sesamoidean Ligament (DSIL), CART with best performance was built with PCA scores based on normalized data (Fig. 7).

As it can be seen from the graph, the major influence on DSIL pathology was given again by 10th and 4th Principal Components.

Considering only CARTs built on raw data, the parameters that influenced a large number of nodes of the *dichotomous* choices were DIJH (14.5% of nodes), NT/CNT and JA3 (11.8%), LWA and MWA (7.9%).

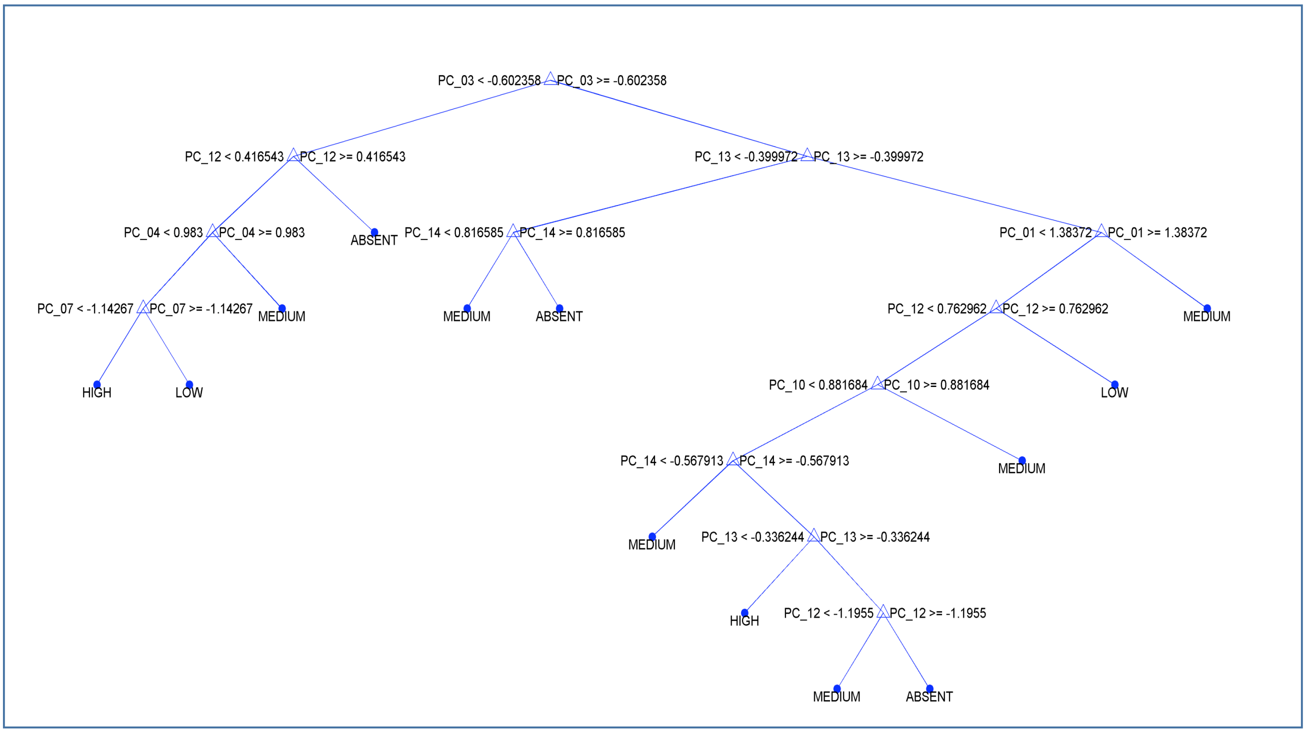

Fig. 7. CART-Distal Impar Sesamoidean Ligament. PCA Scores based on normalized had to be considered to read this CART.

CHAPTER 5

General Discussion

5. General discussion

In accordance to our hypothesis, in the present study was found a correlation between morphometric aspects of the equine foot and presence of bone and teno-desmic lesions.

5.1 Simple Linear Correlation

A linear correlation was observed between radiographic measurements regarding navicular bone (NT/CNT, NL/NPEL, NL/NDEL) and MRI alterations to navicular bone medulla, proximal and distal navicular margins and structures as CSL and DDFT.

A decrease in NT/CNT ratio reflected an increase in navicular cortex thickness due to an increase in forces exerted on it, mainly by DDFT. In fact, it was proved that the forces and stress exerted by the DDFT on navicular bone were 2-fold higher in horses suffering from navicular disease compared to control horses (Eliashar et al. 2004). In our study we found that DDFT alterations were strongly related to an increase in thickness of navicular cortex and that there was a correlation between increased thickness of NB cortex and NB Medulla and NB Proximal alterations. When measuring the NT/CNT ratio, care must be taken in draft horses and light ponies, because in these type of horses the navicular cortex was thicker and stronger (Gabriel et al. 1998)

In the second part of the stance phase, during DIPJ extension, CSL was stressed by the contraction of Deep Digital Flexor muscle and, subsequently, increasing tension of DDFT (Denoix 1999). This theory could explain the relationship between NT/CNT and CSL alteration observed in this study.

The presence of proximal and distal extensions of navicular border may reflect entheseophyte formations at insertion sites of CSL and DSIL (Dyson 2008). In the current study we observed a correlation between the elongation in proximo-distal direction of NB and presence of alterations of the NB DISTAL, supporting what asserted by Biggi and Dyson (2011a). In their study they observed an association between size of a distal extension of the navicular bone and the presence of a fragment of the distal border using an high-field magnet but they didn't confirm their findings using a low-field MRI (Biggi and Dyson 2011b). In our study we considered NB DISTAL as pathologic not only in case of a presence of a bony fragment but also when irregularities of the cortical and endosteal surface were observed.

Alterations in the NB PROXIMAL was related, as previously described, with NT/CNT and NL/NPEL but also with TFL. In fact, toe length influence the point of force application on DIPJ: a long toe resulted in an increase in the moment around DIPJ and, subsequently, in an increase of stress on navicular bone (Wilson and Weller 2011). This relationship was confirmed in the present study too because was found a significative association between increased toe length (and a reduced TFL) and alterations induced by higher forces exerted on NB, expecially NB PROXIMAL and NB MEDULLA.

The incidence of pathological changes on CLs DIP was influenced by P3BA and JH3-P3B. Collateral ligaments were stressed mainly during asymmetric displacement of the foot (Denoix 1999) when collateromotion movements occurred and during the second phase of the stance. Tension on CLs were therefore evoked by movements on the sagittal, frontal and transverse planes (Denoix 1999). In our study there was not a correlation beween medio-lateral imbalance or joint tilt and CLs lesions. On the contrary, it has been observed a deep association beween parameters (P3BA, JH3/P3B) that influence the position of the third phalanx on sagittal plane.

The authors did not find any correlation between radiographic measurements and DSIL. This could be explained by two reasons; first of all, because the lower resolutions of low-field magnet compared to the high field ones in the diagnosis of DSIL alterations could understimate the presence of lesions and, secondly, findings referable to the presence of enthesiophytes were recorded as NB DISTAL alterations.

5.2 CARTs

In the current study also CART technique was used to assess the influence of morphometric parameters on presence/incidence of pathological disorders.
The added value of CART in comparison to a simple linear correlations analysis was the possibility to investigate complex relationships between all radiographic measurements and a specific pathology. In fact, even if did not exist a linear correlation between a radiographic parameter and lesion on a structure, sometimes this parameter was implicated in the development of an alterations. As it was evident, in the current study, there was not any simple linear correlation beween some parameters and lesions but, using CARTs, it was evident that all radiographic parameters were involved.

Each structure considered was analysed using the three different types of CARTs. In our study we considered only the CART that had the higher classificatory performance. CARTs based on raw-data offered a ready-reference for radiographic evaluation but, however, were not the best analysis method for all pathologies. Nevertheless, classificatory performance of CARTs based on raw data was at least 70%. This type of CART could be useful for the clinician during radiographic evaluation of a subject. CART could be employed during a clinical evaluation of a lame horses in order to establish which structure had the major probability to be involved and how to assess the proper corrective trimming.

In non-lame horses the "CART approach" could have a prognostic value and could help both veterinarians and farriers in the management of foot in order to prevent the development of pathological disorders.
Often, the trim plane could be not properly made only on the base of external hoof examination (Caudron et al. 1997) because is already proved that there is no the relationship between radiological morphometric parameters of the distal phalanx and shape of the hoof capsule (Dyson et al. 2011). Nevertheless Dyson et al. (2010) reported that may be a relationship between foot pain and presence of an increased ratio between dorsal and palmar coronary band height and concave contour of the coronary band.
On the basis of CART analysis the farries could act on several parameters influenced by trimming as P3BA, JA3, HP3P/HP3D (modifing HP3D), TFL, JH3/P3B, LWA, MWA, JT3 and LP3B/MP3B. Other parameters were not altered by trimming procedures. The farrier and the veterinarian operating on parameters influenced by trimming can influence the foot morphometric aspect and the incidence to develop a specific pathology as CART predicts.

5.3 Radiographic measurements and MRI interpretation

Radiographic measurements were taken independently by two lecturers using a manual method. Intraobserver and interobserver repeatability studies were performed to check for agreement in the radiological measurement. The same procedure was made for MRI interpretation. To reduce time spent for radiological measurement a dedicated software (Metron-PX, EponaTech, Preston, CA, USA) could be used (Vargas Rocha et al. 2004, Kummer et al. 2006).

5.4 Limitations of the study

This study has some limitations. First, some radiological parameters, useful in the evaluation of morphometric aspect of the foot, cannot be measured because the retrospective nature of the study. For example, not in all horses a radiopaque marker was placed on lateral and medial aspect of the coronary band.

Another limitation is due to an inherent error of 0,1 mm in the measured parameters of the used software. Therefore the measured of small parameters as DIJH, NPEL and NDEL could be inaccurate. Nevertheless the ratio between DIJH on lateral and medial aspect or NL/NPEL and NL/NDEL were not influenced.

Because of some parameters had a low influence on the presence of lesions, in the further study radiographic measures as NL/NDEL, JT3, HP3P/HP3D and LP3B/MP3B could be excluded from CART analysis. A higher number of samples could be examined in order to have a better statistical significance.

5.5 Conclusions

The results confirm the hypothesis of the study: A relationship between radiographic morphometric evaluation of the equine foot and the presence of bony and teno-desmic alterations was proved.

A complete assessment of morphometric aspect of the foot require at least two radiographic views, the LM and DPa. Parameters can be measured only on good quality radiography. Radiographic signs that had a linear correlation with some structures can reflect the presence of specific pathological alterations. On the basis of measured parameters, CART based on raw data could be used as prediction/diagnostic tool that could aid in the proper management of equine foot in lame and sound horses as well.

CHAPTER 6

Summary

6. Summary

In the evaluation of equine foot radiography clinicians often do not evaluate the morphometric aspect of the foot but focus their attention only on radiographic abnormalities that in most cases reflect cronic pathology. On the basis of biomechanical studies on the forces acting on different structures of the foot, we hypothesized that would be a correlation between foot conformation and incidence/presence of foot lesions.

Seventy-four foot of lame horses were examined: 20 parameters were measured on radiographic views and MRI signal intensity, homogeneity and size of each structure was evaluated. Collected data were used for statistical purpose using simple linear correlation analysis and CART analysis.

Simple linear correlation highlighted the presence of relationship between some morphometric aspects and presence of lesions involving specific structures. Correlation trees explained the partecipation of different radiographic measurements in the development of lesion. CART could be employed during a clinical evaluation of lame horses in order to establish which structure had the major probability to be involved and how to assess proper corrective trimming/shoeing.

In non-lame horses the “CART approach” could have a prognostic value and could help both veterinarians and farriers in the management of foot in order to prevent the development of pathological disorders.

In the current study a relationship between radiographic morphometric aspect of the equine foot and the presence of bony and teno-legamentous was observed.

CHAPTER 7

Acknowledgements

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