Summary

Navicular disease represents a chronic fore limb lameness in horses. This condition is a painful degenerative disease which may include the navicular bone, the navicular bursa and adjacent surface of the deep digital flexor tendon in one, or more often both fore feet. The disease is considered to be responsible for one third of chronic fore limb lamenesses in all horses.

The disease occurs most frequently in performance horses and is seldom seen in Arabians, ponies and heavy breeds. Navicular disease affects horses between six and nine years of age; however, younger and older horses have also been diagnosed.

Despite the high incidence of the disease and the numerous studies that have focused on it, the disease still remains the cause of much controversy and confusion, in regard to its nomenclature and its aetiology, pathogenesis, radiologic features and treatment. The fact, that no experimental model is able to reproduce navicular disease, and the fact that clinical cases are the only available source of material for research, explain why only so little progress has been made as far as the understanding of the pathology. The two major theories concerning the pathogenesis of navicular disease are circulatory disturbances and static-mechanic overload of the navicular bone. According to the mechanic theory, the pathogenesis of the navicular syndrome is due to a disproportion between the anatomic conformation and the mechanic load. Mechanical factors, such as concussion, compression, friction and tension from ligaments, associated with the size, shape and balance of the foot and distal limb conformation, have an aetiologic role in the syndrome. But there has been little information until now on dimensions of the foot and navicular bone in sound horses, though numerous authors have postulated changes in foot and bone dimensions in case of navicular disease.

The knowledge of the histological architecture of the navicular bone is also an important basis to understand the reason why the fore bone, some breeds and types of horses and some age categories are more susceptible to develop navicular disease. If qualitative variations at the tissue or cellular levels may be easily studied by a classical microscopic examination, the quantitative variations generally escape this kind of research. Stereological methods are precise tools for obtaining quantitative informations on cellular or tissular structures and their modifications in normal or pathologic states.

The aim of this investigation was to define, by three successive levels, the morphological aspects of the navicular bone in sound horses and their variations according to either front or rear limb, morphological type, gender, weight, size and age.

The firts step consisted in studying the measurements of the hoof and navicular bone. The second step was a macroscopic, radiographic and microsopic study of the navicular bone. The third step consisted in a histomorphometrical study of the navicular bone, which permitted to quantify most of the observations made on the sections in the second chapter.

A fourth study is presented in appendix, which consisted in application of the developed techniques to some pathological navicular bones.

Morphometrical study of equine hoof and navicular bone

Hooves and navicular bones issuing from 95 sound horses, classified in 9 morphological types, were studied. Anatomical bases were laid down about morphometry of the hoof and navicular bone and their variations according to either front or hind leg, morphological type, gender, weight, size and age.

Few significant differences were observed between fore and hind feet. Thus, the reason why navicular disease occurs most frequently in the front feet did not depend directly on its

conformation but must rather be related to the weight distribution and the role of the front leg during locomotion.
All the dimensions of the navicular bone (except for the length) were larger in the fore limb. This phenomenon reflected probably an attempt to compensate for the greater forces exerted upon the fore limbs during exercise and at rest.
The hoof and navicular bone of the athletic halfblood were smaller than in the other morphological types and this situation did not improve with increasing age. Shoeing, especially if the horse is shod too precociously, might slow down hoof growth and result into hoof and navicular bone atrophy. Other investigations must determine whether adaptation in bone structure compensate for such unfavourable mechanical conditions.
Some hoof measurements, particularly heel height and sole surface were smaller in the gelding, but few differences were recorded between stallion and mare. Some navicular bone dimensions, particularly articular surface width and length of the bone, were the smaller in the mare, intermediate in the gelding and larger in the stallion.
Though feet conformation varies little with weight, all the hoof and the navicular bone measurements were significantly correlated with body size. In the future, it would be interesting to relate in farriery books standard hoove measurements with heigth rather than with body weight.
All dimensions of the navicular bone decreased with increasing age. This phenomenon is very interesting and could be taken into account when interpreting the shape of the navicular bone in case of navicular disease.

Macroscopic, radiographic and microscopic study of the equine navicular bone

Navicular bones issuing from 95 sound horses, classified in 9 morphological types, were studied. The macroscopical and radiographical characteristics of the navicular bone were defined as well as the variations according to either front or hind leg, morphological type and age.
The microscopical appearance of the navicular bones issuing from 61 sound horses of different breeds and types was defined.
To quantify the structural integrity of the navicular bones, we proposed a grading or scoring system, which permitted to classify the bones in three categories: sound bones, suspicious bones or pathological bones. Three different aspects of the navicular bone were studied, which relate to the three entities proposed by Hertsch (1993) for the navicular syndrome: podotrochl(e)itis/ podotrochl(e)osis or navicular bursitis, podarthritis /podarthrosis and ligament insertions desmopathy. We defined a "bursitis score" which permits to quantify the appearance of the flexor cortex (fibrocartilage, cortical bone), an "arthritis score" which quantifies the modifications in number, localisation and dimension of the canales sesamoidales, a "desmopathy score" which quantifies the appearance of the navicular ligaments and the global shape of the bone and an "architectural score" which quantifies the changes in global bone architecture (cancellous bone, cortico-medular junction, ...).
The bursitis score was calculated by the three techniques: macroscopical, radiographical and microscopical examinations and the results were compared. Conventional radiography gives only little informations about the flexor cortex integrity.
The arthritis, desmopathy and architectural scores were calculated following radiographical and microscopical examinations and the results were compared. The microscopical study of the sections permitted to observe for every horse two distinct zones within the flexor surface cortex that had never been reported in the literature before: an external zone which is mainly composed of poorly remodelled lamellar bone, disposed in a disto-proximal oblique direction, and an

internal zone which is mainly composed of secondary bone, with a latero-medial direction for Haversian canals.
Navicular bone morphology can vary considerably with member (fore or rear), morphological type and age of the horse. When we have to evaluate for example a radiography of the navicular bone, great care must be taken before declaring bone pathological: it's important to compare with normal datas coming from similar type of horses within the same range of age.
Numerous anomalies were observed in fore navicular bones; macroscopic ones as congestive zones, synovial fossae at the level of the sagittal ridge, ...; radiographic ones as bone shape modifications, alterations of the bone architecture, changes in number, shape and localisation of the canales sesamoidales, ...); and microscopic ones as fibrocartilage degenerescence, changes in bone shape, bone architecture, ... The quality of the fore navicular bones don't seem to be as good as that of the rear bones.
We observed that the different morphological types of horses don't display the same kind of bones anomalies. Light horses and ponies showed more frequently macroscopic, radiographic and microscopic alterations within the flexor surface cortex as well as modifications in bone architecture. Heavy horses showed very frequently modifications of the global shape of the bone. In heavy horses and ponies, its a commun finding to observe modifications in the number, shape and localisation of the canales sesamoidales.
Thus, light horses and ponies seemed to be more prone to develop navicular bursitis and modifications of the bone architecture whereas heavy horses show a greater propension to develop podarthritis or the ligaments insertions desmopathy.
Numerous radiographical and microscopical anomalies were observed for the geldings navicular bones whereas it was the contrary for the mare, which showed fewer bones anomalies and rarely modifications of the number, shape and localisation of the canales sesamoidales.
Mares could thus possess high quality navicular bones.
The calculated scores also varied with the weight of the horse as low weight horses showed more frequently modifications of the navicular bone architecture whereas high weight horses mainly showed modifications of the global shape of the bone and alterations in number, shape and localisation of the canales sesamoidales.
Most of the related macroscopic, radiographic or microscopic anomalies reported for the navicular bones in this study showed an increasing frequency with age. The navicular bone architecture greatly change with increasing age, a phenomenon that needs a quantification.

Histomorphometric study of the equine navicular bone

Navicular bones collected from the four limbs of 61 sound horses were studied and the anatomic bases were described for histomorphometry of the navicular bones.
Fore navicular bones possessed less cortical bone at the level of the articular surface, as well as at the level of the flexor surface and proximal border, but larger amounts of cancellous bone. Articular and flexor surface cortical bone showed a larger porosity in the fore navicular bones and a larger amount of mineralized cartilage. The mineralized portion for distal impar- and collateral sesamoidean ligaments were also larger for the fore navicular bones. Bone architecture is discussed with regard to the mechanic load, encountered by the bone during locomotion.
Light horses and ponies possessed larger amounts of cancellous bone and fewer cortical bone in their navicular bone, whereas draft horses and heavy ponies showed marked thickening of navicular cortical bone with minimum intracortical porosity, and a decreased amount of cancellous bone marrow spaces associated with an increase of trabecular bone volume and thus seemed to possess denser and stronger bones than the lighter animals.
Flexor cortex external zone tended to be smaller for the heavy ponies than for the light ponies whereas it was the contrary for horses, with the largest amount of external zone registered for

draft horses. This phenomenon could be related either to a different hoof conformation and thus different strains within ligaments and bone, either to differences in bone remodelling activity.
By comparing the sedentary to the athletic halfbred, we have observed that exercise had increased the cortical bone volume at the expense of the cancellous bone volume which could be the result of reduced resorption and increased formation at the corticoendosteal junction. Cancellous bone was reduced for the athletic horses but the amount of trabeculae and their specific surface were larger than for the sedentary halfbred. Increased bone formation and reduced resorption could also account for these differences. But the final bone architecture in athletic horses could however be less suited to resist high compression loads induced by the deep digital flexor tendon and could lead in some cases to a pathological state.
We observed a reduced amount of cortical bone for the gelding, with an increased porosity both for cortical and cancellous bone. We thought that the deficiency in male hormones induced by castration could lead to a greater squeletal fragility.
We were very suprised to observe for the mare a larger cortical bone volume and reduced amounts of cancellous bone within the navicular bone, which is exactly the opposite of the datas found in the literature. Generaly, other authors reported a larger volume of cancellous bone for the females. But mechanical strains within the navicular bones are enormous, and females possess smalller navicular bones than stallions. Mares realise exercise of the same high intensity as males and compensate for the smaller bone measurements by increasing the bone strenght.
Navicular bone architecture greatly changed with an increasing weigth of the horse. High weight horses showed an increase of the cortical bone volume, with a smaller porosity and a reduced amount of cancellous bone.
Navicular bone architecture is not the same in young and old horses, nor in sedentary and athletic horses.
In most horses, the cortical bone volume diminished with increasing age whereas cancellous bone volume increased. This phenomenon could result from the subendosteal tunneling of the inner part of the cortex and conversion to a trabecular-like structure. Trabecular bone volume diminished with increasing age and the trabecular network also modified with an increased size of marrow cavities and discontinuity of the bone structure.
For athletic horses, cortical bone volume rather increased with age whereas cancellous bone volume decreased! The favourable effects of exercise on bone mass is thus maintained even in old horses and could compensate for the decrease in bone dimensions we observed previously. A sporting activity permitted to prevent the navicular bone architecture degradation in old horses.