et al., 1999 and 2001) have been presented recently, and thus provided a basis for new research approaches.
Current knowledge indicates that in normal hairy skin, physiological angiogenesis occurs associated with the hair cycle. In healthy and mature skin of adult individuals, dermal blood vessels are in a 'quiescent' state which is sustained by a tightly regulated homeostasis of angiogenic factors. Nevertheless, the dermal mature endothelium retains its capacity for brisk initiation of angiogenesis. This so-called 'angiogenic switch' of the dermal vasculature is induced in the hair cycle as well as in tissue repair and various pathological processes (review: Bhushan et al., 2002). In normal and in diseased skin, the angiogenic stimulus seems to originate mainly from the avascular epidermis which is completely dependent on the adjacent dermal capillaries for nutritional supply and vaso-neuro-hormonal co-ordination. Most likely, this accounts to an increasing degree for the high metabolic demands of the modified weight-bearing epidermis of the digital end organ.
According to our working hypothesis, pododermal angiogenesis plays a crucial role in the development and function of the bovine claw as well as in the pathogenesis of laminitis-associated claw diseases and is presumably induced by the pro-angiogenic Vascular Endothelial Growth Factor (VEGF). VEGF may be activated by inhibition of keratinocyte cell adhesion molecules (e.g., cadherins) that in turn is caused by improper or overload-induced pododermal hypoxia or by inflammatory alterations within the claw.
To provide a basis for progressive research on biology and function of the bovine claw, the fundamental role of angiogenic processes in development and functional adaptation of its pododermal vasculature was elucidated in the present study. In order to verify the findings from pododermal micro-corrosion casts ex vivo, the results were compared to an in vitro model of angiogenesis based on cultured bovine microvascular endothelial cells.

Material and methods

Scanning electron microscopy of pododermal micro-corrosion casts:

Micro-corrosion casts of all four digits (main and dew claws) of 30 fore or hind limbs, respectively, of claw-healthy adult cattle, and of 3 fore and hind limbs of adolescent cattle aged 8 to 12 weeks were examined using scanning electron microscopy. Casting procedure was carried out according to Hirschberg et al. (1999). Additionally, casts from 5 pathologically altered adult hind claws displaying symptoms of laminitis-associated diseases (sole haemorrhages, horn discoloration, double sole, heel horn erosion, white-line-disease) were included exemplarily into the examination. All corrosion casts were dissected for scanning electron microscopic examination, taking axial, abaxial, dorsal, and median samples from all regions of the claw (periople, coronet, wall proper, sole and bulb).

Light microscopical examination of pododermal serial sections:

Light microscopy of paraffin-embedded serial sections of all regions of the adult claw was carried out employing routine histological staining besides lectin- and immunohistochemistry.

Cell culture model of angiogenesis in vitro:

An in vitro model of angiogenesis with three-dimensional arrangement of endothelial cells and lumen-formation in capillary-like tubes was established by isolating and culturing bovine microvascular endothelial cells. The different stages of the angiogenic cascade and vascular remodelling were documented by light, scanning and transmission electron microscop.

Results

Comparison of the pododermal angioarchitecture of adult and juvenile claws detected differences in the microvascularisation of the adult and the not yet fully loaded maturing claws. Likewise, microvascular differences between non-loaded dew and weight-bearing main claws of adult claws were observed. The pododermal vascular system showed progressive vascular differentiation as well as alterations in the microvascular patterns. The most prominent differences were detected in the wall proper (lamellae) and the ground surface of the claw (sole, bulb, and terminal papillae of the wall proper).
Particularly in the adolescent, but also in the adult claw, angioadaptation was demonstrated. This angioadaptation was characterised by both sprouting angiogenesis and intussusceptive remodelling of the vasculature. The results obtained from vascular cast morphology were comparable to the respective stages of in vitro angiogenesis and vascular remodelling of cultured microvascular endothelial cells. Evidence of angiogenic processes were also detected in the pathologically altered claws. Immuno-localisation of VEGF within the claw was established.

Discussion

Comparison of the microvascular pattern of claws of adolescent and adult cattle, respectively, allowed us to distinguish for the first time that sprouting angiogenesis and non-sprouting intussusceptive remodelling play a crucial role in maturation and functional adaptation of the bovine claw. Juxtaposing the results of the non-weight-bearing dew claw to those of the loaded main claw indicates that the observed angioadaptation is a visible expression of the increased metabolic demands of the claw caused by the growing body-weight load. In the different pathologically altered claws, increase of the pododermal vascular density via sprouting or intussusceptive neovascularisation seems to be the connectional regenerative or reparative principle, respectively, as well.
To date, the pathogenesis of the laminitis-disease-complex or the so-called laminitis-associated claw diseases remains unclear (Nilsson, 1963; review: Mülling and

Lischer, 2002). Most investigators assume an initial alteration of the pododermal microcirculation resulting in secondary impairment of the horn-producing keratinising epidermal cells. Activated keratinocytes express different keratins, change their cytoskeleton and surface receptors and are hyperproliferative and migratory (review: Freedberg et al., 2001). Differing keratin expression in the germinative and keratinised epidermal layers of the modified skin of healthy and diseased digital end organs has been described. Proliferation and migration of keratinocytes are particularly important for the development and maturation of the papillary body of the digital end organ under the influence of weight-bearing. This process seems to be guided by the subepithelial dermal capillary system situated just beneath the basal membrane, with the capillaries taking on a 'guide rail' function for the dermo-epidermal interface configuration. This emphasises the tight co-ordination of dermal blood vessels and epidermal keratinocytes. Many hoof diseases are characterised by a pathologic progressive subdivision of the papillary body, probably initiated by the same driving forces as in the fetal development and weight-bearing-induced maturation of the dermo-epidermal interface (review: Bragulla and Hirschberg, 2003). Activated keratinocytes express VEGF, the most important angiogenesis-stimulating factor of the cutaneous system, which together with the present results suggests a VEGF-induced regulation of the pododermal angiogenesis in hypoxia or inflammatory events. In the pathogenesis of laminitis and associated diseases in both the equine hoof and the bovine claw, activation of endogenous matrix metalloproteinases (MMPs) has been described and at least in part made responsible for the pathological alterations occurring in these diseases of the digital end organ (Pollitt and Daradka, 1998; Hendry et al., 2003). Activated MMPs cause loosening or break-up, respectively, of the tight dermo-epidermal interface, specifically the basal membrane, which is made responsible for the relevant loss of function of the hoof or claw suspensory apparatus in laminitis. On the other hand, MMPs play a crucial - likewise VEGF-regulated - role in the initial stages of angiogenesis by controlled degradation of the perivascular matrix, thus only enabling and directing the sprouting and migration of endothelial cells (Bhushan et al., 2002). This hirherto neglected correlation between pododermal angiogenesis and development and adaptation of the bovine claw seems to be particularly promising for understanding the physiological as well as the pathologically altered function of the claw. Taking into account the role of pododermal angiogenesis in maturing and pathologically altered claws presented in this study, regulation of pododermal angiogenesis seems to be a new and promising approach to prophylaxis and therapy of claw diseases.

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CO-CULTURE OF EPIDERMAL AND DERMAL BOVINE HOOF CELLS IN A PERFUSION CHAMBER
Development and first experimental experiences

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Introduction

This study reports on the development of a co-culture system of bovine hoof keratinocytes and fibroblasts in a perfusion chamber as well as first experimental experiences. This system was developed to study the mechanisms of dermo-epidermal signalling that control and regulate the proliferation and differentiation of the claw epidermis in vitro. Keratinocyte proliferation and differentiation are controlled by a variety of interacting factors, such as the keratinocyte growth factor (KGF/FGF-7), which is produced by fibroblasts upon stimulation by keratinocyte-derived interleukin-1 (Maas-Szabowski et al, 2000).

The aim of this study was to establish the co-cultivation of keratinocytes and fibroblasts in perfusion chamber systems under defined conditions, creating the platform for our further studies of the dermo epidermal cross-talk in vitro.

Material and Methods

The perfusion chamber PCS3c (Oligene, Berlin; Fig.1) was used to cultivate dermal fibroblasts and epidermal keratinocytes separated by a Millicel® Cell Culture Plate Insert (Millipore, Schwalbach) using identical or different types of cell culture Media. In addition a perfusion chamber developed by Dirk Hoffmann and assembled by a private engineering group was used in combination with S & S membrane filters (Schleicher & Schuell, Dassel).

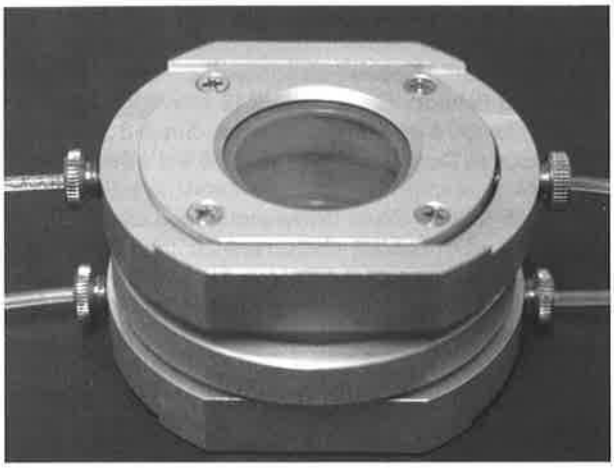

Fig.1: perfusion chamber PCS3c (Oligene, Berlin)

Bovine keratinocytes and fibroblasts were obtained from bovine hooves of slaughtered animals from the local abattoir. For the procedure of isolation of these cells see Nebel and Mülling (2002). The cells were cultivated with Dulbecco´s modified Eagle´s medium (Biochrom, Berlin) supplemented with 10 % fetal bovine serum (Sigma, Taufkirchen). First, fibroblasts were seeded onto the lower side of the Millicell® insert and allowed to grow for 4 days. Then the perfusion chamber was mounted by placing the fibroblast into the chamber and subsequently seeding epidermal keratinocytes onto the upper side of the Millicell® insert. The keratinocytes were allowed to adhere for 1 day. Then the chamber was connected to the tube system with an attached Ismantec 8 channel pump (Isamatec, Wertheim-Mondfeld) and a gas permeable media bag (Oligene, Berlin). We worked with different flow rates ranging from 0.035 ml/min to 0.35 ml/min. The system was run for up to 20 days. During this time it was possible to observe the cultivated cells under the light microscope at any time.

In addition some Millicell® inserts were coated with Matrigel® basement membrane matrix (Becton Dickinson, Heidelberg) using the thin coating method (working instructions of Becton Dickinson) to permit the keratinocytes an improved adherence to the Millicell® inserts. These Millicell® inserts were handled as described above. Using the Matrigel® thick gel method it was possible to grow cells within a three dimensional matrix. Fibroblasts were dispersed in Matrigel® subsequently seeded onto the upper side of Millicell® inserts and grown for 4-5 days under standard cell culture conditions. Afterwards keratinocytes were seeded onto the top of this Matrigel® and allowed to adhere for one day. Than the Millicell® inserts were placed into the perfusion chamber and connected to the fluid flow system. The Millicell® inserts were fixed in 4 % formalin for 24 h and embedded in paraffin. Sections were prepared for haematoxylin and eosin staining and immunohistochemistry.

The perfusion chamber developed by Dirk Hoffmann was handled similarly, the only difference was that the keratinocytes were allowed to adhere for 4 days.

Results

During our first experimental experiences we had technical problems with the PCS3c perfusion chamber and tubing system. Air bubbles were gathering in the upper side of the perfusion chamber and in the tubing system. To resolve this problem we reduced the number of connectors in the tubing system, tilted the perfusion chamber inside the incubator and reduced the flow rate. In addition to the decline of air bubbles in our tubing system the reduced flow rate of 0.035 ml/min diminished the risk of detachment of the cultivated cells from the Millicell® insert.

Generally, the fibroblast showed a better adherence and growth on the Millicell® inserts than the epidermal keratinocytes. Adherence and growth of the keratinocytes was improved by coating the Millicell® inserts with Matrigel®. Furthermore, differentiation and colony formation of the keratinocytes were significantly improved. The use of fibroblasts cultivated in Matrigel® improved the growth and differentiation of keratinocytes but it was difficult to differentiate both cell types microscopically. First experimental experiences over a period from 7 days with the cultivating of epidermal keratinocytes onto S & S membrane filters revealed a slow growth rate without colony formation. Another disadvantage of the newly developed perfusion chamber is that microscopic control of cell growth is not possible.

After several days in culture the cells had grown to confluence. Subsequently, the keratinocytes began to differentiate and built up stratified colonies (Fig.2). Within these colonies the cells showed a characteristic morphology of a stratified squamous epithelium. The epidermis was characterised by demonstration of the expression of markers for early and terminal differentiation such as CK 10, filaggrin and involucrine. In the superficial layers the cells cornified and established a thin horn layer. The in vitro system displayed functional important characteristics. We detected gap junctions on the electron microscopic level and the gap junctional protein Connexin 26 (Cx26) by immunohistochemistry.

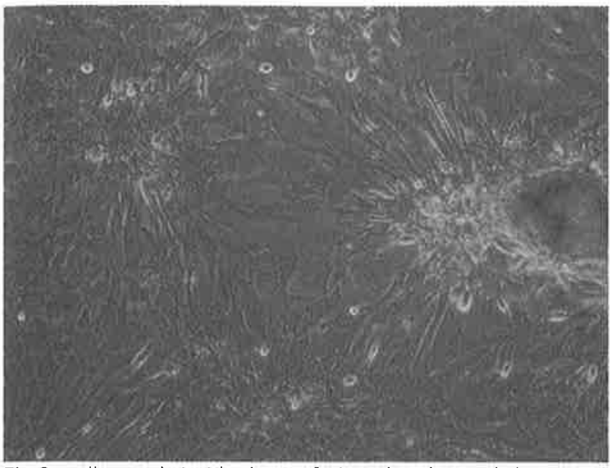
Fig.2: cell growth inside the perfusion chamber with beginning formation of a colony (arrow) of keratinocytes

In the perfusion chamber we were able to generate larger pieces of organotypic tissue. These three-dimensional cultures maintained their organ- specific features over a longer period of time compared to our on plate cultures.

Discussion

The use of a perfusion chamber allows the three dimensional cultures to grow and survive for weeks. Medium supply and gas exchange as the limiting factors in usual two dimensional cell culture systems are available unlimited in the perfusion system. Fluid flow increases the proliferation and differentiation of cultivated cells and permits the generation of three-dimensional cultures (Bancroft et al, 2002). Additional, perfusion chambers systems have the advantage to enable the co-cultivation of fibroblasts and keratinocytes. These cell types were kept separate by Millicell® inserts or S & S membrane filters. Although these membranes separate cells the exchange of molecules like growth factors and growth rate modulating factors is possible through the membrane.. The dermal (mesenchymal) component provides a physiological structural support that through molecular and physical signals influences the morphology, function and proliferative characteristics of the keratinocytes (Merne and Syrjänen, 2003). Eun and Nam (2003) reported when dermal components, such as fibroblasts, are included, the resulting cultures are much more likely to mimic natural skin in terms of function. There is evidence that various subcellular organelles such as lamellar bodies or desmosomes, appear in three-dimensional cultures in a manner similar to that of normal skin. Furthermore, it is possible to perfuse the two different parts of the perfusion chamber with various types cell culture media. These provides the opportunity to add a growth or growth rate modulating factor to the medium for only one cell type and to study the impact of this factor to the other cell type.
In conclusion our in vitro model provides a powerful tool for further investigation of the dermo-epidermal interactions and their role for development of claw diseases. Next experimental steps include analysis of the influences of growth factors like keratinocyte growth factor (KGF/FGF-7) and growth rate modulating factors like interleukin-1 on this in vitro system.

Acknowledgments

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CATTLE LOCOMOTION PATTERNS A HIGH SPEED CINEMATIGRAPHIC STUDY ON THE TREADMILL

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Introduction

Knowledge of the gait, the pressure situation inside the claws during locomotion and the claw's ground contact sequence is essential for claw trimming and prevention of claw diseases in cattle.
Early photographic studies showed locomotion patterns of the limb (MUYBRIDGE, 1898), but not the claw. High

speed cinematography was used in cattle by HERLIN und DREVEMO, 1997 who evaluated limb movements and angular patterns in dairy cows which were kept in different housing systems. Cows on pastures walk between 2 and 12 km per day (3-4km/d) with a maximum speed of 5 km/h (1.5m/s), (ALBRIGHT, 1997; BRADE, 2002).
Aims of this analysis were to investigate the claw's ground contact sequence on the treadmill using high speed cinematography and also whether contact sequences change after functional claw trimming.

Material and Methods

18 heifers (Brown Swiss, mean age 13 months, mean bodyweight 282 kg) came from 4 Swiss farmers where they were kept in loose housing or alpine pastures.
During the study, which was done in 4 groups (two of 5 and two of 4 animals) they were kept in tied stalls. After the studies they were given back to their owners.
Animal's age and body weight allowed to train them to be led on a halter. The pre-training period started one day after arrival and lasted two days.
After walking inside the clinic stable training was extended to the area surrounding the buildings of the Faculty. Thereafter heifers were taken to the treadmill building. To get them used to the new environment (strong lights, treadmill's shape and noise) they were first taken beside the treadmill, but had not to walk on it.
On day three, animals were lead onto the treadmill where they were trained to walk over the treadmill's belt. Later the treadmill was started while heifers were kept on a rope by a person standing beside the treadmill. Animals were slowly adapted to the moving ground. They were adapted to the speed of 1.2 or 1.3 m/s (4.3 or 4.6 km/hour). The treadmill was immediately stopped if animals started panicking or became too nervous.
As soon as the animals were used to the new situation and walked relaxed they were slowly stopped, rewarded with food (positive conditioning) and taken off the treadmill. Treadmill training took place twice in the morning and gait analysis was done in the afternoon of the 3rd day.
The digits were examined with 7-camera positions:(Front legs: two lateral and one front views, Hind legs: two lateral and two oblique views from the front with an angle between 45° and 60°).
The position of the camera and the quality of the film could be controlled on the flat screen of the PC. As soon as the animal reached the speed and showed clear walk, the recording was started, and stopped when four complete motion cycles of the observed limb were shown. Gait sequences (500 Pictures/sec., Solution 320x280 pixel, Shutter 1/1000, Exposure time 1/1000 sec) were recorded for 4 seconds using endless memory.
The treadmill (highspeed treadmill, Mustang 2200 , Graber AG, Fahrwangen, Switzerland) with animal was lighted by 3 Spotlights (220V, 1000W, 300Hz).
The digital camera (Motion Scope PCI 1000S, Redlake Imaging Corporation, 18450 Technology Drive, Suite A, Morgan Hill, CA 95037-5450) with Lens (Cosmicar / Pentax TV-Zoom, 4-48mm, 1:10) was connected to a Desktop-PC and controlled by the manufacture's software with keyboard and mouse. Sequences (220MB, each) were saved as *.avi-file on a external hard disk.
On day four functional claw trimming (TOUSSAINT RAVEN, 1985) was done on all heifers of the corresponding group and on day 5 documentation was repeated accordingly.
Cinematographic studies were evaluated on a different desktop PC by using the specific player program of the camera (MIDAS Player , Redlake Imaging Corporation). Data were evaluated by means of a calculation program and SSPS.

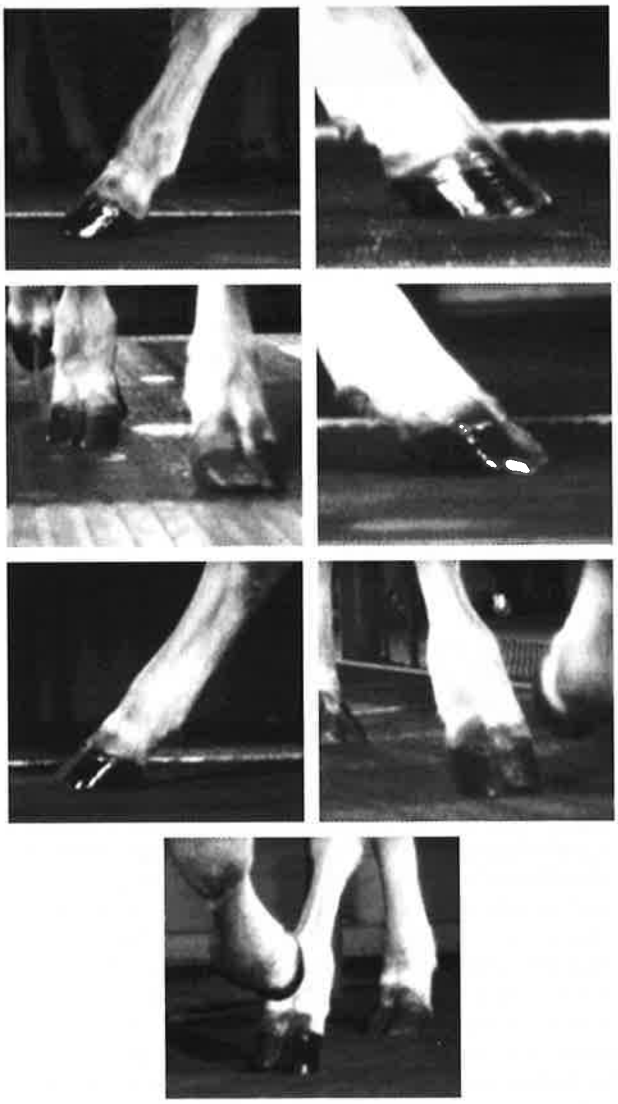

Fig. 1: Images representing the 7 camera positions

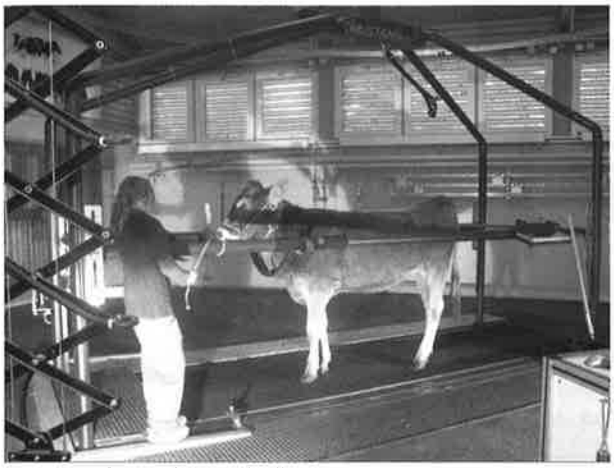

Fig. 2: Heifer on the treadmill

Results

In this study heifers put their hind feet so far underneath the body trunk, that they contacted the ground on a line which corresponded with the median line of the body. Also they put one foot in front of the other, so that the ground contact sequence was not visible from the heifer's rear.

In all heifers, in the hind limbs the lateral claw was always the first one contacting the ground. Even claw trimming did not influence these patterns.

As seen in the hind limbs the ground contact sequence was almost the same in the front limbs but some of the animals showed sequences where both claws contacted the ground at the same time. Nevertheless in the majority also the lateral claw seemed to receive the initial impact force.

Discussion

Although the animals were trained to a very novel situation, it is assessed certain that they exhibit normal physiological locomotion and ground contact patterns while walking on the treadmill.

In general the use of digital high speed cinematography to document the gait in large animals can be assessed as a method with high technical expense, costs but excellent possibilities to observe, save and reproduce analyses.

Conclusion

The study shows that in the hind limbs and mostly also in the front limbs in heifers, the lateral claw recives the first impact force on contacting the ground.

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THE CLAWS OF HEIFERS AND BULLS WITHIN THE FIRST TWO YEARS OF THEIR LIVES - A CONTRIBUTION TO THE DEVELOPMENT OF THE HORN CAPSULA CONSIDERING DIFFERENT BREEDING LINES AND GENDERS

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Introduction

Up to now, the development of the bovine claw is an area of investigation where little is known, despite it being the seat of numerous problems when having reached the state of ma-turity.

Claw measurements as auxiliary traits for selection and for structural claw soundness are common tools described by several authors.

Three years ago, we started this investigation using linear measurement to describe the devel-opment of the horn capsula in new born calves of different genders and breeding lines.

The first bulls and heifers have reached their second year of life and were slaughtered or started the first lactation. This investigation compares the data of the first three months to the data measured after two years of life.

Material and methods

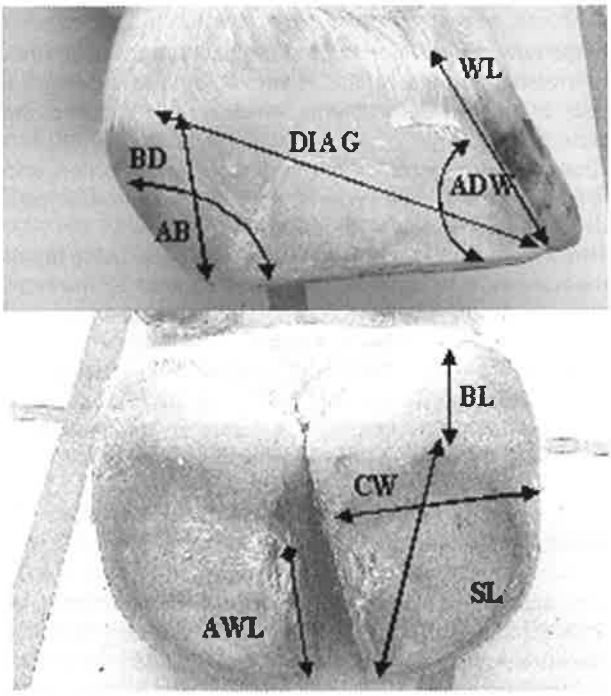
The experiment started at the Experimental Farm of Oberschleißheim at day 4 post partum (p.p.) . Measurements were taken within three weeks interval finishing at an age of three months. Male and female calves of six breeding/crossbreeding lines (genotypes) were

meas-ured under light sedation. These genotypes (gt) were German Fleckvieh (FV), German Hol-steins (GH), F1 crossbred calves of these two breeds (FV-GH or GH-FV) and two back crossed lines DH75 or FV75.
Follow up investigations of bulls were made on the digital organ after slaughter. Investiga-tions in heifers were made before first calving accompanying regular claw trimming.
The parameters studied are shown in Fig.1. All parameters were measured with a caliper and goniometer commonly used in human physiotherapy.
All data have been analysed using a variance analysis by considering the effects gender, posi-tion of the claw, genotype and measurement number.
Measurements started in November 2000. Up to now 60 male and 59 female calves finished the first three months investigation period. In addition, 18 bulls and 23 heifers were included in the study at an age of ~ two years.

Results

All measured parameters changed severely within the interval of investigation. These changes can be seen absolutely, comparing the shape of the horn capsula with three months and the capsula after two years. But there are also changes concerning the position of the claw, gender and genotype.

Wall length has been measured with 4,65 cm at the end of the first three months measuring period. At two years, wall length has reached a mean value of 7,96 cm. Having monitored a severe influence of gender and position of the claw, wall length develops as shown in Fig. 2.



WL - Wall length	Length of the dorsal wall (distal border of the coronary band - toe)
BD - Bulb depth	Height of the bulb, bulb coronet - vertical to the sole
BL - Bulb length	End of the loaded sole - end of the horny bulb
DIAG - Length of the diagonal	Distance toe - bulb coronet
SL - Sole length	Distance toe - end of the loaded sole
AWL - Axial wall length	Toe - axial end of the weight-bearing border before slope
CW - Claw width	Distance between axial and abaxial surface taken at the widest point of the claw
ADW - Angle of the dorsal wall	Angle between dorsal wall and solear surface
AB - Angle of the bulb (AB)	Angle between bulb and solear surface

Fig.1: Parameters of investigation

At three months, wall length does not differ significantly between male and female calves with male calves having slightly longer claws. The position of the claw also has no significant influence on wall length. After 21 months, a clear influence of gender on wall length can be seen with heifers having longer claws than bulls. In bulls, the position of the claw has no sig-nificant influence on wall length with fore medial claws being longer than fore lateral claws. In heifers, fore medial claws are significantly longer than all other claws. In hint claws, there is no clear relationship between inner and outer claws.

Claw width in both measurements is wider in males than in females. Here the difference be-came stronger within the interval of investigation.

Claw angles changed in different ways. Concerning the whole number of measurements, the angle of the dorsal wall shows a loss from 56° to 53°. Concerning both genders, a different way of claw development can be recognized. While bulls show a positive change in the angle

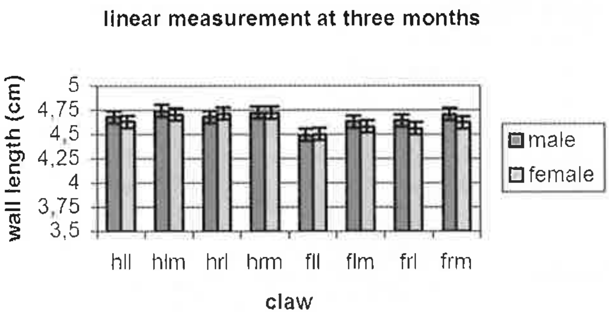
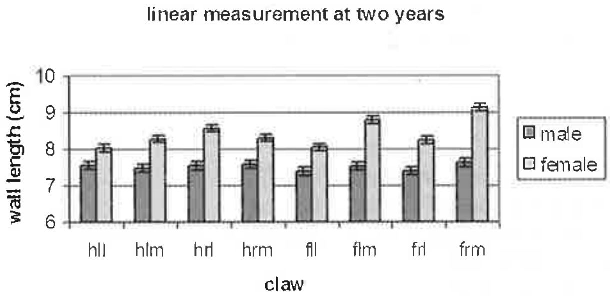


Fig.2: Wall length within the period of investigation



of the dorsal wall from 57° to 58° in hint and from 56° to 59° in fore claws, heifers have a negative development from 56° to 49° in hint and from 56° to 45° in fore claws.

hll - hind left lateral/hind left medial/hrl - hind right lateral/hrm - hind right medial

fll - fore left lateral/flm - fore left medial/frl - fore right lateral/frm -fore right medial

The angle of the bulb in both genders and all pairs of claws shows a loss from about 115°to 109°.

Axial wall length has been introduced as a new parameter into linear measurement consider-ing the strong influence on claw health and being regarded as an elementary factor in claw trimming. In fact, axial wall length is slightly longer in lateral claws hint and fore at the "three months investigation" in both genders. Significantly higher values were reached in hint lat-eral and fore medial claws in both genders at an age of two years.

Comparing different genotypes, significant differences between pure breeds, F1- and back- crossbreds could be found for all parameters. Generally, crossbreds reached higher values than purebreds. This effect differs among genders and genotypes.

Discussion

Linear measurements of the claw allow a clear statement on the size or shape of the claw. Claw development can be described giving clear differences between position of the claw, gender and genotype.
Comparing linear measurements of calves with bulls and heifers clearly shows, that there are changes in size and shape leading to gender x age interactions.
Different measurement parameters allow different interpretations on claw development, per-haps also on claw health being severely influenced by the age, gender or genotype.
So we have to concentrate on a collection of data allowing scientific investigations with re-gard to the mentioned effects.

NATURE OF THE INNERVATION OF DERMAL BLOOD VESSELS IN THE CLAW SUGGESTS A CENTRAL AND LOCAL CO-REGULATION OF MICROCIRCULATION

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Introduction

Innervation of the dermal vascular system plays an important role in the complex regulation of microcirculation in the claw. Beside vasoactive substances in the bloodstream which locally influence the diameter of blood vessels, the central nervous regulation of blood flow provides an adaptation of the blood quantity in various organs depending on the actual need. In the bovine hoof, this central regulation is mediated by sympathetic efferent nerve fibres, which can provide vasodilative or vasoconstrictive neurotransmitters. Moreover, sensory nerve endings emit vasodilative neuropeptides. All together, there is a triple innervation around blood vessels in the hoof.

Material and methods

The lateral claws of the hind limb of cows from a local abattoir were examined. Tissue samples were taken from the different segments of the claw, fixed and processed for immunohistochemistry. Antibodies against tyrosine-hydroxylase (to detect noradrenergic vasoconstrictive nerve fibres), choline acetyltransferase (cholinergic vasodilative fibres), SP and CGRP (vasodilatively acting sensory neuropeptides) were applied.

Results and discussion

Dermal blood vessels in the claw are surrounded by nerve fibres containing different neurotransmitters. The demonstrated occurrence and distribution of these nerve fibres is discussed in relation to the hoof segments and the relevance for claw diseases. The results suggest that the centrally controlled innervation contributes to the regulation of blood flow in dermal blood vessels. Consequently, central/general influences like stress or systemic diseases can alter blood circulation in the claw in addition to local regulating factors. A disturbance of the delicate balance between the three components may influence the microcirculation and thus the nutrition of tissues in the claw.

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THE ROLE OF LESION AND GAIT ANALYSES IN MODELS OF BOVINE LAMENESS

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Abstract

Lameness models were developed employing data collected with a reaction force detection (RFD) system, gait evaluation and lesion diagnosis. The purpose of the study was to generate statistical models that score lameness. Daily reaction forces of cattle freely walking across the RFD system were used to calculate limb movement variables (LMV). Gait and lesions were clinically characterized on a weekly basis. Data were collected over a six-month period from 35 cows, with individual cows monitored from 4 to 20 weeks. Preliminary models were developed using both linear and logistic regression techniques. The independent variables in the models were lesion score, gait score, or a combination of both. The results indicate that both lesion and gate scores were related to LMV; however, variation in LMV was best explained by lesion scores.

Introduction

Lameness is a growing problem in the dairy industry partly because early and accurate diagnosis is hindered by weak correlations between gait abnormalities and presence of lesion (O'Callaghan et al, 2002). Curently dairy lameness detection is insensitive and only 40-45% of the lame cattle may be identified (Wells et al, 1993). Rising costs of bovine lameness and the uncertainties of subjective diagnosis make methods of objective quantification an attractive option.

Objective methodologies employ force plates or load cells to quantify vertical, horizontal, or transverse ground reaction forces (GRF) applied to the limb during the loading, stance, and unloading phases of the stride. We used a single axis load cell system (Rajkondawar et al, 2002) capable of detecting vertical GRF of sound and lame cattle to mathematically model clinical gait scores (GS) to limb movement variables (LMV) and lesion scores (LS) to LMV. LMV are derived from GRF components. Results show lesion-based models more accurately determined lameness status than gait-based models.

Materials and Methods

Gaits of mature, lactating, and dry Holstein cattle were scored after observation of weight bearing symmetry, body posture, length of stride, changes in anterior and posterior swing phases of the stride, arc of the stride, flight of the foot through the arc, symmetry between arcs portended by the left and right feet, foot and limb placement during weight bearing, symmetry of foot flight, foot placement during weight bearing, reluctance to move, body posture, and the presence of supporting or swinging leg lameness. LS were assigned upon inspection of the claw, inter-digital regions, and the upper limb. Pain localization was examined by hoof tester. Signatures of GRF of hind and fore limbs were recorded to calculate six LMV (Table 1) which were equated to GS and LS by logistic regression. Models were developed for LMV recorded from 1-3 days (1D, 2D, and 3D models) prior to veterinarian examination.

Results

The lameness models are of the form

$$LI = 3 - \frac{e^{\alpha_1 + f(\mathrm{LMV})}}{1 + e^{\alpha_1 + f(\mathrm{LMV})}} - \frac{e^{\alpha_2 + f(\mathrm{LMV})}}{1 + e^{\alpha_2 + f(\mathrm{LMV})}}$$

where LI is the

Table1. The limb movement variables (LVM) used in the lameness model

Table 1. The limb movement variables (LMV) used in the lameness models.

LMV	Units	Description
PGRF	no dimension	Peak ground reaction force of a limb normalized by animal's weight
AGRF	no dimension	Average ground reaction force of a limb normalized by animal's weight
ST	s	Stance time - duration of a limb contact with the floor
I	s	Impulse - integral of the GRF with respect to time
GRF_{ω}	1/s	The area under the Fourier transformed curve of a GRF
$GRF\omega_{\omega}$	$1/s^2$	The area under the Fourier transformed curve of the product (GRF*ω)

Table1. The limb movement variables (LVM) used in the lameness model

Model	f(LMV)
1D	$\beta_1{*}PGRF_{-1D}+\beta_2{*}AGRF_{-1D}+\beta_3{*}I_{-1D}+\beta_4{*}ST_{-1D}+\beta_5{*}(GRF_{\omega-1D}+\beta_6{*}(GRF\omega_{\omega-1D}$
2D	$\beta_1{*}PGRF_{-1D}+\beta_2{*}AGRF_{-1D}+\beta_3{*}I_{-1D}+(\beta_4{*}ST)_{-1D}+\beta_5{*}(GRF_{\omega})_{-1D}+\beta_6{*}(GRF\omega_{\omega})_{-1D}+$ $\beta_7{*}PGRF_{-2D}+\beta_8{*}AGRF_{-2D}+\beta_9{*}I_{-2D}+\beta_{10}{*}ST_{-2D}+\beta_{11}{*}(GRF_{\omega})_{-2D}+\beta_{12}{*}(GRF\omega_{\omega})_{-2D}$
3D	$\beta_1{*}PGRF_{-1D}+\beta_2{*}AGRF_{-1D}+\beta_3{*}I_{-1D}+\beta_4{*}ST_{-1D}+\beta_5{*}(GRF_{\omega})_{-1D}+\beta_6{*}(GRF\omega_{\omega})_{-1D}+$ $\beta_7{*}PGRF_{-2D}+\beta_8{*}AGRF_{-2D}+\beta_9{*}I_{-2D}+\beta_{10}{*}ST_{-2D}+\beta_{11}{*}(GRF_{\omega})_{-2D}+\beta_{12}{*}(GRF\omega_{\omega})_{-2D}+$ $\beta_{13}{*}PGRF_{-3D}+\beta_{14}{*}AGRF_{-3D}+\beta_{15}{*}I_{-3D}+\beta_{16}{*}ST_{-3D}+\beta_{17}{*}(GRF_{\omega})_{-3D}+\beta_{18}{*}(GRF\omega_{\omega})_{-3D}$

The values of the alpha and beta coefficients for the 1D, 2D and 3D gait and lesion based models are listed in Table 3. Table 4 lists the sum of squared errors (E) and ROC values, and Table 5 lists the cutoff values and % true positives, % true negatives, % false positive, and % false negative for the 1D, 2D, and 3D gait and lesion lameness models. E is evaluated as $\sum_N (GS-LI)^2$ and $\sum_N (LS-LI)^2$ for the

gait and lesion based models, respectively. The cutoff values in Table 5 distinguish sound from lame cattle and were derived to achieve equal sensitivity and selectivity.

Compared to chance estimates of lameness (ROC of 0.5) the 1D, and 2D gait based models performed adequately (ROC = 0.72 and 0.75, respectively), whereas the 3D gait based model performed poorly (ROC = 0.61). The 1D, 2D, and 3D lesion based models performed well (ROC = 0.81, 0.85, and 0.83) with relatively less error than gait based models. Percent true positive was higher while percent false negative was lower in the lesion based compared to the gait based models. Thus, models equating LMV to LS more accurately predicted lameness than models equating LMV to GS.

Discussion

The mathematical characterization of the relationship between LS and LMV reflect hind limb lameness more accurately than GS and LMV. These findings are surprising considering LMV input was derived from relatively few components of the vertical GRF curves. In horses, multiple LMV components and bilateral symmetry from the horizontal and vertical axes improve detection of lameness (Dow et al 1991, Clayton et al, 2000). Our results suggest vertical GRF input may be sufficient for modeling bovine lameness. The differences may rise because the majority of bovine lameness is restricted to lesion(s) of the interdigital region and/or lateral claw of the hind limb.

Differences in accuracy, sensitivity and specificity between the two models may reflect difficulties in consistently establishing the "true state" of gait and lesion through clinical gait and

Table 3. Coefficients of gait and lesion based models

Model		α_1	α_2	β_1	β_2	β_3	β_4	β_5	β_6	β_7	β_8	β_9	β_{10}	β_{11}	β_{12}	β_{13}	β_{14}	β_{15}	β_{16}	β_{17}	β_{18}
Gait	1D	-2.22	-0.76	1.45	-1.72	4.43	-0.87	7.53	-0.37												
	2D	-4.61	-1.52	-1.02	-1.71	4.28	-0.82	7.32	-0.42	2.85	8.71	-1.39	0.75	-3.1	0.26						
	3D	-6.11	-2.87	-0.71	-2.93	3.45	-0.70	6.88	-0.47	1.00	8.50	-2.76	1.00	-2.53	0.20	15.13	-12.37	3.90	-0.76	3.79	-0.42
Lesion	1D	-3.55	-0.86	-1.61	-0.54	3.70	-0.67	13.36	-0.71												
	2D	-5.91	-2.99	-2.26	-0.01	3.25	-0.59	9.42	-0.50	2.15	8.96	1.45	-0.06	-1.42	0.08						
	3D	-8.54	-5.42	1.92	-2.14	2.63	-0.52	5.85	-0.44	1.26	9.48	2.21	-0.32	-4.23	0.17	11.24	5.02	-1.73	0.25	-3.57	-0.06

Table 4. Errors and ROC values of gait and lesion based models

Model	N	Gait			Lesion		
		E	E/N	ROC	E	E/N	ROC
1D	114	30.03	0.26	0.72	16.40	0.14	0.81
2D	113	26.31	0.23	0.75	14.51	0.13	0.85
3D	110	33.48	0.30	0.61	17.65	0.16	0.83

Table 5. Cutoff, true positive, true negative, false positive, and false negative for gait and lesion based models.

Model	Model base	Cutoff	%TP	%TN	%FP	FN
1D	Gait	1.45	52	15	7	26
2D		1.46	52	14	7	27
3D		NA	NA	NA	NA	NA
1D	Lesion	1.69	62	11	4	23
2D		1.68	64	13	3	20
3D		1.63	66	13	3	18

lesion diagnoses. Lesion diagnosis, though objective, suffers from problems in assigning pain to causality of lameness. Clinical gait analysis suffers problems with reproducibility, sensitivity, and specificity due to subjectivity in observer diagnosis. Differences in the nature of the variables and the continuous versus discrete measures of variables sensed by the RFD and the veterinarian, further compound errors in the modeling process. In spite of these problems, the lesion-based diagnosis produced a more accurate model than gait diagnosis in lameness classification.

The findings suggest bovine lameness may be amenable to practical methods of automated, objective detection. Future testing and model refinement could generate an objective, standardized diagnostic system to accurately assess the incidence, prevalence and impact of lameness.

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CT AND MRI SCANNING OF THE BOVINE HOOF FOR IMPROVED EDUCATION AND TRAINING IN FUNCTIONAL ANATOMY

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Introduction

There is a discrepancy between the increasing accumulation of knowledge about biology and diseases of the bovine hoof on one side and the actual level of knowledge of veterinarians on the other side (Greenough, 2002). This is distressing because a good standard of knowledge is a prerequisite for successful prevention of lameness.

We certainly have a strong need for improvements in education and training of Anatomy, Physiology and Pathology of the bovine hoof. The prerequisite is that we incorporate the acquired knowledge into the curricula. Another aspect is good pictorial material that illustrates particularly complex three dimensional anatomical situations. Appreciation of three dimensionality frequently is the key for functional understanding. New imaging techniques such as CT and MRI are far too expensive as diagnostic tools for cattle and are not applicable under field conditions. However, they can be employed for research and these are powerful tools for teaching functional Anatomy in a illustrative way.

There are a number of training programmes available already among them the excellent multimedial training programme recently presented by Zengerling et al. (2002). In comparison with these programmes our idea is to generate picture material and make it available for all educators interested in incorporating it in their own teaching concepts, programmes and presentations according to the specific requirements within their teaching environment. In other words people can select the material that is appropriate for visualisation of what they want to explain and that fits into their already existing concepts.

In this paper we focus on the use of CT and MRI images in combination with gross and microscopic anatomical pictures as teaching material which can be used for training and education of students, veterinarians and hoof trimmers.

Material and Methods

CT and MRI imaging and computer aided reconstruction were employed to generate individual and serial pictures as well as three-dimensional reconstructions of structural elements of the claw in their physiological spatial relationship and functional entity.

The distal limbs of eight slaughtered cows with sound claws were obtained from a local abattoir. For Computer Tomography of fresh and frozen digits we used two different scanners. First a Philips TOMOSCAN M 1-line CT scanner with 2 sec. rotation per scan and a minimal scan thickness of 2 mm. Series of scans were prepared in sagittal and transverse orientation. In addition selected series of scans were prepared with a General Electric LIGHTSPEED 16-line CT scanner with 0.5 sec. rotation time and a minimal scan thickness of 0.625 mm. With the light speed scanner we prepared two set of 390 continuous scans each at thickness of 0.6 mm.

MRI scans in sagittal and transverse orientation of four claws were prepared with a MRI scanner Siemens SYMPHONY 1.5 Tesla using the Syng Software. The datasets from the MRI scanner were used for three dimensional reconstruction using the General Electric Advantage Windows- 3D software on a General Electric 3D workstation.

All images were saved as DICOM standard files. For viewing images and selecting optimal windows and levels for structures of different density we used the AccuLite software Vers. 3.116 (AccuImage, Diagnostics software corporation) running on a PC under MS Windows® XP.

Results

In the CT images the structural elements of the hoof unit were all depicted in a good quality. Adaptation of Windows and levels was easy and reliable with the AccuLite software. Visualisation of all structures was possible at good quality. Of particular interest were the illustration of the pedal bone and its position within the horn capsule. The position of the pedal bone was well shown in sagittal and transverse series. In addition the dermal and fat tissue elements of the suspensory apparatus and the supportive cushion were visible with a good resolution. These functionally important soft tissue elements were displayed in high quality in the MRI scans. The spatial arrangement of fat cushions and tendons including their attachments to the bone were visible in relation to each other and to the horn shoe. Joints and synovial bursae were well demonstrated in the CT and MRI scans.

The sets of 0.6 mm scans through the whole digit provided excellent information in very fine details within their spatial arrangement inside the claw. Even smaller dermal blood vessels were visible. It was even possible to differentiate the dermis in some regions. Demonstration of the MRI image series in cine mode provided a fast and illustrative overview on the spatial arrangement and interrelationship of structures within the claw capsule.

A computer aided three-dimensional reconstruction of different tissue elements based on the differences in density was performed. Reconstruction of the bony elements of the digit was successful and provided a three dimensional picture with high resolution of details (figure 3). This reconstruction is available as a series of pictures but also as a digital video for observation from different viewpoints. The reconstruction of the dermis was difficult and only partly successful. In some regions we obtained reconstruction in good quality whereas in others reconstruction failed. All the imaging material generated during our investigations can easily be incorporated into common software such as Powerpoint®.

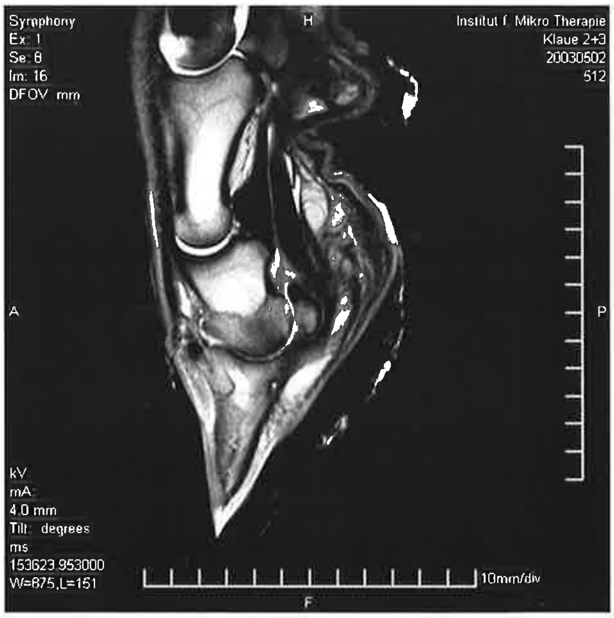

Figure 1. Sagittal MRI scan of the digit showing the hard and soft tissue elements within the claw

Figure 2. Transverse CT scan of the claw highlighting the fat cushions and interjacent collagen systems in their spatial relation to the distal phalanx

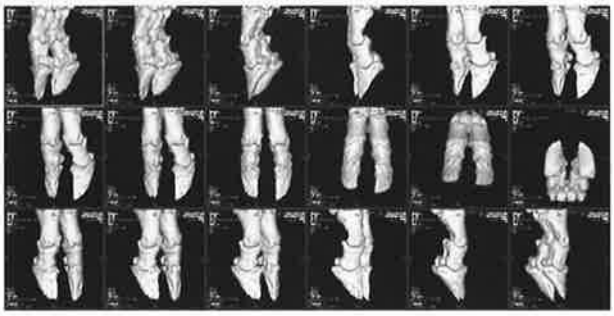

Figure 3. Three-dimensional reconstruction of the skeleton of the digit from MRI scan series. Selection of images from a larger series of pictures. These images can be viewed from any position or watched as a real time movie

Discussion

This report provides an insight in CT and a MRI imaging of the claw. The pictures clearly demonstrate the potential of these imaging techniques as demonstrative teaching material which can easily be incorporated into existing teaching concepts.
The images obtained help to improve three-dimensional appreciation of the complex inner structures of the claw and thus improve understanding of the function of the claw. The advantage of the image series is that they provide anatomical information about the different elements of the hoof in their functional entity. The images as well as the reconstructions can be used in a flexible way in presentations, posters and teaching programmes.
The three-dimensional reconstruction of the skeleton of the digit can be used as valuable teaching material facilitating the important step of creating three-dimensional understanding. For demonstration of dermal structures however reconstruction remained unsatisfactory. Reconstruction succeeded in some areas but failed in others. With ongoing technical progress it will undoubtedly be possible to create reconstructions of soft tissue elements with similar density possible in near future.
For successful education in the prevention of lameness we need good teaching concepts and programmes at different levels of knowledge. An essential component is good and attractive picture material illustrating the complex morphological, physiological and pathophysiological situations. Our idea is to provide CT and MRI images to people interested in using them within their own teaching concepts.
CT and MRI imaging of claws affected with the most common lesions is underway. With these investigations we hope to gain additional information and insight in the nature of common claw lesions and to provide further contribution to education.

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MATRIX OVERLOADED - STRUCTURAL ALTERATIONS OF CLAW CONNECTIVE TISSUE AND THEIR FUNCTIONAL IMPLICATIONS

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Introduction

Collagen fibres of the connective tissue are the crucial structural and functional components of the suspensory apparatus of the third phalanx in the claw. The outstanding structural and functional role of the suspending structures in healthy and diseased claws has clearly been demonstrated (Lischer et al., 2002, Maierl et al., 2002, Tarlton and Webster, 2002, Westerfeld and Mülling, 2000). The sinkage of the pedal bone in subclinical laminitis is responsible for the secondary damage of claw tissue and a variety of laminitis associated lesions. Alterations of the suspensory apparatus or more precisely alterations of the formed extracellular matrix in the connective tissue, the collagen fibres, have been made responsible for this dislocation (Ossent and Lischer, 2000; Mülling and Lischer, 2002; Tarlton et al., 2000).

The effects of MMP-2 and MMP-9 on dermo-epidermal explants have been investigated and described by Hendry et al. (2003) and a proteolytic enzyme, "hoofase", was discovered by Tarlton and Webster (2002).
Changes in the collagen network are an integral part of tendon pathology (Birch et al., 1998) and partial removal of collagen may predispose to tendon rupture (Riley et al., 2002). An elongation or an increasing elasticity of the collagen system has been postulated to be responsible for the sinkage of the third phalanx during laminitis in cattle. However, the actual causes for the connective tissue alterations as well as their pathomorphology are not known yet. Matrixmetalloproteinases (MMPs) seem to be involved in tissue damage leading to sinking pedal bones. Assuming an outstanding role of MMPs there is still the necessity to understand the nature of tissue lesions related to MMP effects and their functional implications. This is of particular interest because there is no evidence for a disruption of connective tissue leading to tissue separation during sub clinical laminitis (Lischer et al., 2002; Ossent and Lischer, 2000).
This study aims to examine and demonstrate the effects of activated MMPs on collagen fibres and the subsequent degradation of collagen from the bovine hoof by activated MMPs in vitro and to discuss possible functional implications within the bovine hoof in vivo.

Material and Methods

Sound claws of hindlimbs from 4 adult Holstein Friesian cows, 2 - 4 years old were obtained from a local abattoir. Claws were cleaned and prepared for sampling under sterile conditions. Tissue was taken from band saw sections. Collagen lattices from the dermis of the bulb and sole and dermo-epidermal explants were prepared. Explants and lattices were cultured under standard conditions and exposed to different concentrations of activated MMP-2 and MMP-9 (Chemicon International) for different duration. Samples were fixed before incubation and at hourly intervals over a period of 6 hours and subsequent after 12 and 24 hours. All samples were routinely prepared for scanning (SEM) and transmission (TEM) electron microscopy. Structural alterations were examined by SEM and TEM examination. In addition MMP-2 and MMP-9 were demonstrated by immunohistochemistry using monoclonal antibodies against MMP-2 and MMP-9 (Dunn Labortechnik).

Results

Exposure of dermal collagen fibre to MMP-2 and MMP-9 led to a time dependent removal of mature collagen from the dermal network (fig. 1) in the explants and dermal lattices. The subsequent collagen break down was revealed by electron microscopy. Under the influence of MMPs a time dependent progressive structural disintegration was detectable in the collagen lattices and with time delay in the dermo-epidermal explants as well. Collagen degradation resulted in a dermo-epidermal separation in vitro (fig. 2). Transmission electron microscopy showed the ultrastructural alterations occurring at the level of individual collagen micro fibrils. Initial damage is reflected by a loss of their characteristic periodicity in the TEM. With ongoing enzymatic influence deterioration and decomposition occur which are detectable under the TEM and confirmed and illustrated in their three-dimensionality by SEM. Finally complete sections of the fibrils disappear. Scanning electron microscopy basically confirmed the TEM findings and illustrated the distribution of the alterations within the dermal fibre network in the explants. By immunohistochemistry we detected a low level of MMP-2 and MMP-9 in the dermal collagen network in all control explants before incubation. After incubation the MMPs were detectable in situ and a more or less uniform distribution in the tissue was demonstrated.

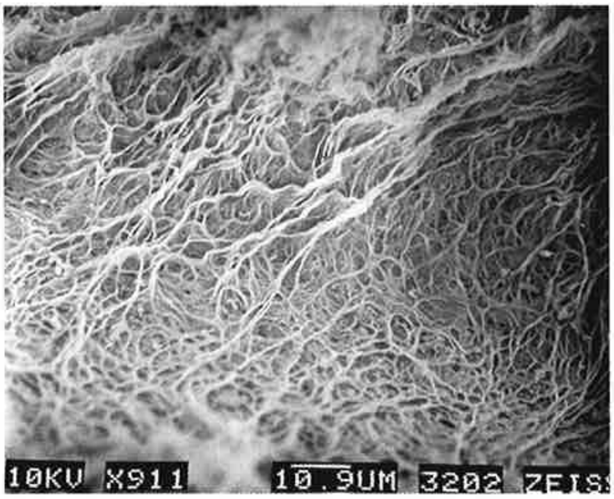

Figure 1. SEM micrograph of dermal collagen network in the sole


Figure 2. SEM micrograph showing in vitro separation of epidermal cells (arrows) from the underlying collagen network

Discussion

In many pathological conditions there is an imbalance between the synthesis and degradation of the matrix leading to collagen network degradation. The important role of MMPs is generally accepted and there is a lot of evidence for a central role of MMPs in the alterations of hoof tissue during the pathogenesis of laminitis (Tarlton et al., 2000). An initial denaturation of collagen by damage due to mechanical load (overloading failure) as described for tendons (Birch et al., 1998) is likely for the laminitic claw as well.
Our morphological examination was an attempt to provide explanations for the effects of MMPs that have already been demonstrated in claw tissue (Hendry et al., 2003). The structural alterations demonstrated here are in accordance with collagen removal in human and equine tendons (Birch et al., 1998; Riley et al., 2002). Exposure of dermal collagen to activated MMP-2 and MMP-9 leads to a removal of collagen from the dermal network and subsequent disintegration of the system as revealed by electron microscopy.
In order to explain the obvious sinking of the pedal bone during laminitis increased elasticity, elongation or instability in the connective tissue fibres have been postulated. The unanswered question is what kind of structural damage of the dermal matrix actually causes the weakening of the suspensory apparatus?
From the structural alterations due to the effects of activated MMPS one can conclude that depending on the degree of alterations we will find either elongation or instability. Damage of a limited number of collagen fibres leads to microrupture and slight increase in length of a small fibre bundle. The overall elongation and instability will depend on the number of fibres affected. Obviously there is no rupture of the collagen system in the suspensory apparatus during laminitis (Ossent and Lischer, 2000). This suggests that either the alterations in vivo are different from our in vitro findings or the removal of collagen is terminated or controlled by bioactive molecules under in vivo conditions. Another possibility is a limited mechanical load of the collagen network in the claw compared to tendons. For tendons it has been reported that the interaction of overload and MMP effect leads to rupture of the tendon. An increased elasticity of the suspensory apparatus can not be deduced from the structural alterations caused by MMPs. Collagen fibres have a very limited elasticity of about 1-3 %, which is not changed by the observed MMP related collagen degradation.
Looking at our results the question arises what happens if collagen fibres of the suspensory apparatus in the claw become damaged in the way we demonstrated in vitro? In other words what are the possible functional implications of our in vitro findings for the hoof unit in vivo?
Our findings suggest that an increased instability of the collagen fibres and consequently the suspensory apparatus occur in case of MMP activation in the hoof. Degradation of a certain number of collagen microfibrils within the collagen fibres of the suspensory apparatus can prepare the pathway for mechanical induced microruptures which have been described for stressed tendons. If the damaged matrix is loaded elongation is the consequence leading to a sinking pedal bone in the hoof without actual separation within the connective tissue. Maybe the biomechanical load of the suspending collagen systems in the claw is not high enough or the collagen damage not severe enough to cause fibre rupture and separation. In a next step the results obtained so far will be tested in an isolated limb model under conditions closer to the in vivo situation.
In summary the structural alterations of collagen systems described here in vitro provide explanation for a potential progressive collagen fibre elongation and biomechanical weakening which occur during laminitis in vivo. Overload of the structural damaged matrix causes the sinking of the pedal bone. To what extend other factors influencing collagen integrity interact with MMP effects will be the task of future in vitro experiments.

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ON THE MECHANICAL BEHAVIOR OF BOVINE HOOF HORN

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Abstract

The mechanical behavior of bovine hoof horn was evaluated using a newly developed process that utilizes micro-tensile specimens. The purpose of the study was to quantify variations in the mechanical properties of hoof horn between specific regions of the sole and to validate new methods for studying the potential influence of environmental and physiological factors on mechanical properties of the bovine claw. Tensile specimens comprised of Zones 4 and 6 of the sole, as well and the wall and white line were excised from both the medial and lateral claws of the hooves from mature Holstein cows. After extraction the specimens were either fully dehydrated (0% moisture) or saturated (100% moisture) and then subjected to uniaxial tension to failure. It was found that both the elastic modulus and proportional limit strength of the hoof horn were unique within the individual regions evaluated. Preliminary findings indicate that the sole in Region 6 exhibits the lowest elastic modulus and strength. However, the influence of moisture on the mechanical properties was far greater than regional variations.

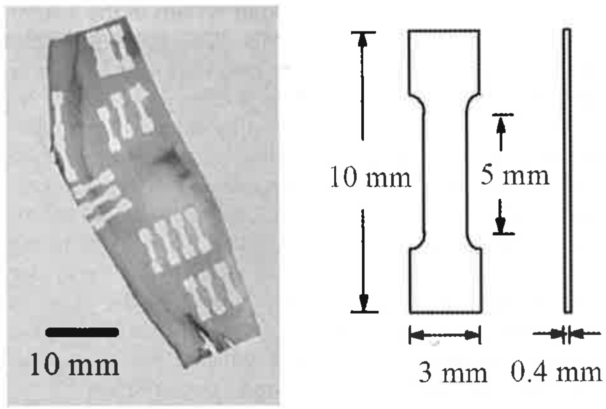
Introduction

Lameness is a multifaceted problem with many interrelated causal factors. In general, lameness in bovines manifests itself in the soft tissue or horn of the hoof, or both [Toussaint-Raven, E., 1985]. Of particular interest are nutritional and environmental factors that alter the structural integrity of hoof horn. These alterations can directly result in lameness or can cause changes that increase the potential for opportunistic infections. An understanding of the biomechanical properties of hoof structures and associated changes due to infectious, metabolic, nutritional and environmental insults is necessary to fully understand the pathogenesis of claw lesions. Previous evaluations of healthy bovine horn found that the hardness of the wall was greater than the sole and that both were harder than the heel [Hoblet, 2000]. It has been demonstrated that the mechanical properties of horn tissue are influenced by nutrition [e.g. Offer et al., 1997] and moisture [e.g. Reilly et al., 2002]. Yet, a complete understanding of the mechanical behavior of hoof horn does not exist.

Materials and Methods

The hooves of two Holstein and two Black Angus cows have been examined. The front and rear hooves of each animal were obtained within 12 hours of slaughter and a thorough clinical examination was conducted by an experienced veterinarian. All four hooves of the animals were diagnosed as sound. The lateral and medial claws of each hoof were separated and the sole of each claw was trimmed to provide a uniform flat reference plane. Incremental slices were then excised from the existing surface proximally until reaching the dermal-epidermal junction.

Conventional dogbone tensile specimens were prepared from the uniform slices of hoof horn using specially prepared dies. Individual specimens were stamped from the serial sections at the locations of interest (Fig. 1). The specimens were then stored in a dry or wet environment at 2°C for a period of 48 hours. The "dry" specimens were stored in air and the "wet" specimens were submerged in distilled water. Though the moisture content was not quantified, the wet storage conditions promoted saturation (~100% relative moisture content) and the "dry" specimens were considerede to be near dehydration (~0% moisture).



a) horn slice with specimens removed

b) dimensions of the stamped specimens

Figure 1 Stamping tensile specimens from thin slices of bovine hoof horn.

The tensile specimens were removed from storage and prepared to enable application of a non-contact optical method for strain measurements. Briefly, a peripheral coating of black enamel spray paint was applied to one side of each specimen. The process resulted in a very high contrast speckle pattern on the specimen's surface, which appeared as a series of black dots on a matte white background. After the surface preparation each specimen was mounted within a special universal testing center. The in-plane displacement field resulting from tensile loading of the specimens was monitored using Digital Image Correlation (DIC). Through a comparison of digital images of the specimens taken before and during the tensile loading the in-plane displacements were quantified in terms of the change in location of the speckles. Additional details regarding the application of DIC to soft and hard tissues can be found elsewhere [Zhang and Arola, 2003]. The stress-strain response for each specimen was established from the load and displacement measurements and enabled determination of the elastic modulus (E) and proportional limit stress (o). An average E and o were determined for the front and rear hooves of each animal, and for all four hooves combined.

Results and Discussion

Results from the tensile tests indicated that the stiffness and strength of the bovine hoof horn decreased significantly with moisture. The average elastic modulus of the front and rear hoof horn from the Holstein cows is shown in Figure 2. Both the stiffness and strength of the hoof horn decreased by nearly a factor of 20 with hydration. No significant differences in E or o were evident between the front and hind hooves or medial and lateral claws for any of the animals examined. The average (standard deviation) elastic modulus of the hoof horn of all animals (both breeds) in the "dry" and "wet" conditions was found to be 3020 (580) MPa and 106 (34) MPa,

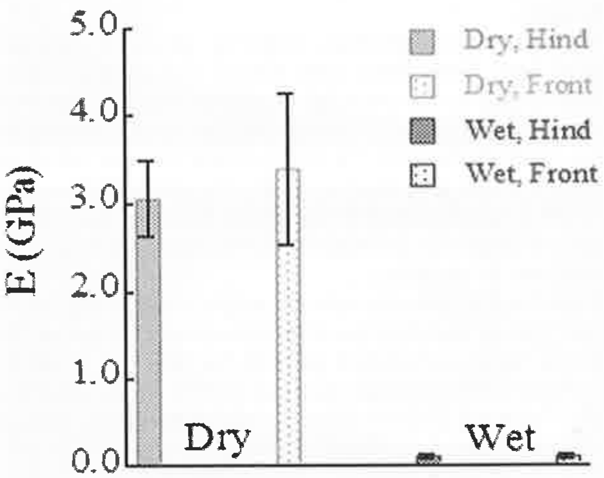


Figure 2 Elastic Modulus of wet and dry Holstein hoof horn (Region 4 horn).

respectively. The average Oo in the dry and wet conditions was 30.4 (6.0) MPa and 1.7 (0.5) MPa, respectively. Based on the significant reduction in strength and stiffness with moisture, dairy management practices promoting high moisture content of hoof horn may increase the likelihood of hoof ailments attributed to mechanical loads.

Interestingly, the stiffness and strength of dry hoof horn decreased with proximity to the dermal-epidermal junction. This is consistent with results of investigations on equine horn [Kasapi and Gosline, 1999] where the stiffness in horn tissue decreased with proximity to the underlying dermal-epidermal junction. The proportional limit stress (o) of the "dry" horn decreased with proximity to the dermis as well. Horn properties were also found to be unique within different regions of the sole. A comparison of the elastic modulus for the dehydrated horn in terms of zones of the sole is shown in Figure 3. Zone 6 exhibited the lowest strength and stiffness of the hoof horn examined.

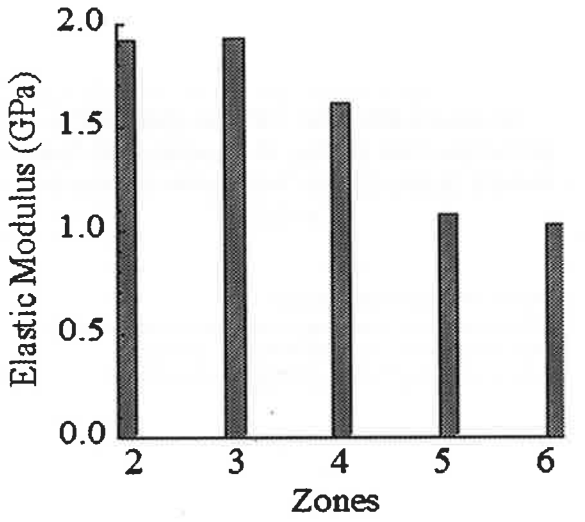


Figure 3 The elastic modulus of hoof horn from different regions of the hoof.

Aside from horn sample size, there are distinct limitations to the preliminary study. The evaluation was limited to uniaxial tension experiments with specimens excised with an orientation perpendicular to the keratin tubules. In addition, although the properties were established from more than 100 specimens, the study was comprised of only 4 animals with unknown age and diet. A complete evaluation of the biomechanics of hoof horn should be conducted with many more animals and examine horn properties in tension and compression. Nevertheless, results from the preliminary study distinguished that moisture has a significant influence on the mechanical behavior of hoof horn and that horn properties are unique within the different regions of the sole.

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3D-MEASUREMENT OF THE DISTANCE BETWEEN THE DISTAL PHALANX AND THE INNER SURFACE OF THE CLAW HORN IN CATTLE

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Introduction

The distal phalanx in cattle is attached to the claw horn in a twofold way: on the one hand it is suspended by the wall segment of the dermis with its typical lammellar structure (Westerfeld et al., 2000). On the other hand it is supported in the palmar/plantar region by the bulb with its especially thick subcutaneous tissue (Räber, 2000; Räber et al., 2002). Especially in dairy cows the tissues comprising this cushion undergo some significant changes with increasing age: it could be observed that there is a loss of fatty tissue on the one hand associated with an increase of collagen (Lischer et al., 2000). This leads to a more "sclerotic" structure of the bulb rendering it less compliant. Furthermore the suspensory apparatus has been described to slacken in the periparturient period (Tarlton et al., 2002). If this is combined with a weakening of the abaxial suspension in the wall segment there is the possibility of a rotation of the third phalanx (Ossent et al., 2000). This leads to an altered distribution of pressure and mechanically influences the dermal blood supply. In the worst case these changes may lead to sole ulcer.

In order to verify these observations it is desirable to have a method to measure the minimal distance of the surface of the distal phalanx and the inner surface of the horn capsule and its changes under load.

It has been the objective of this study to develop a method to determine the bone-horn-distance threedimensionally in bovine claws.

Material and Methods

For this purpose the right front and the left hindclaws were taken from 7 beef bulls (German Simmentals, average body weight 580 kg ± 25 kg) from the local abbattoir. In all feet the claws were trimmed by functional claw trimming in order to provide a physiological ground surface. There the claws were scanned in an unloaded state in a computed tomograph (Somatom AR-S, Siemens, Erlangen, Germany) of the Radiologic Section of the Veterinary Surgical Clinics (for technical details see table 1). After this procedure the feet were positioned in a material testing machine and were loaded with the physiological weight at normal stance. The load applied to each of the specimens was calculated from the body weight according to the distribution of 55%:45% body weight between front legs and hind legs respectively. The position and the load were fixed and the whole specimen was scanned a second time in the loaded state.
The distal phalanx and the inner surface of the horn capsule were reconstructed in both datasets (unloaded / loaded) on the basis of two different thresholds: claw horn could be differentiated by an upper threshold of 145 Hounsfield Units (HU), while bone was reconstructed with a threshold of 300 HU. Objects were computed by the "marching-cube-algorithm". The minimal distance between the surface points of both objects were measured by the "nearest-neighbour-algorithm". The values were colour coded and projected onto the surface of the coffin bone. Thus it was possible to create a corresponding pair of each distal phalanx.

Results

No significant differences could be observed between front and hind claws and lateral and medial claws respectively. In the unloaded state there was a distance of 5-6 mm (fig. 1/left) in the dorsal and abaxial aspect of the distal phalanx. On the axial surface distance values of up to 4-5 mm could be found. On the solear surface (fig. 2/left) a clear increase of the values from the distal tip (3 mm) of the coffin bone towards the flexor tubercle (7-8 mm) can be observed.

When loaded statically with the weight a single leg has to bear during standing there are almost no changes in the dorsal, axial and abaxial parts of the claw (fig. 1/right). Generally the distances increase slightly which indicates that the distal phalanx slightly sinks towards the ground surface of the claw. Distance changes in the solear surface of the coffin bone vary topographically (fig. 2/right): in the distal area close to the tip almost no changes can be observed. But the closer the respective surface point lies to the flexor tubercle the grester are the differences between unloaded and loaded state. Maximal differences are 3 mm.

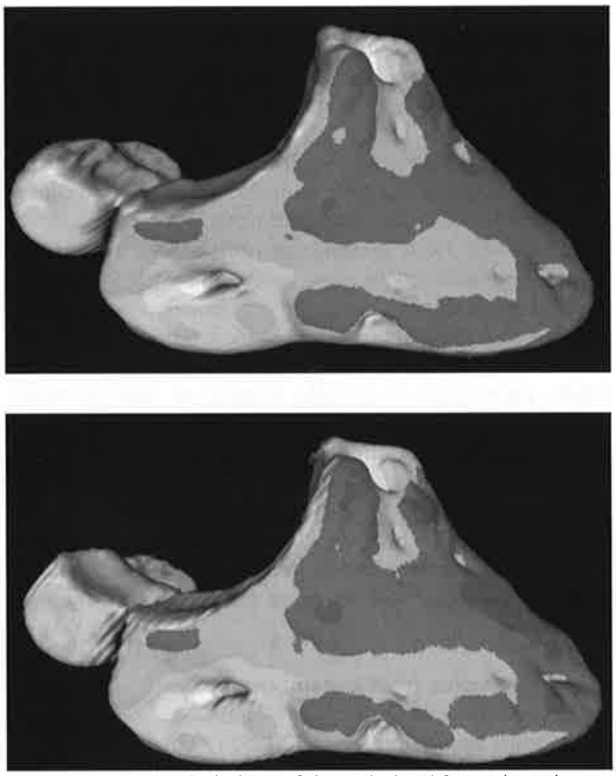

Fig. 1: Lateral distal phalanx of the right hind foot (abaxial view) in the unloaded state (left) and loaded with 130 kg (right). There are only slight differences between the two loading conditions.

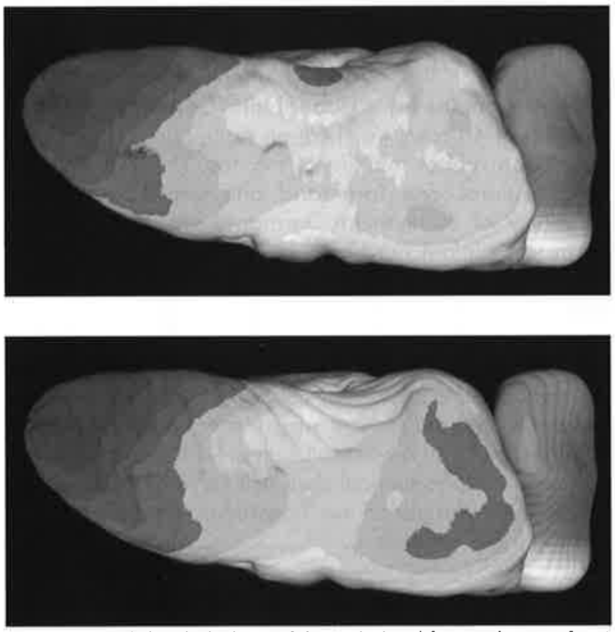

Fig. 2: Lateral distal phalanx of the right hind foot (solear surface) in the unloaded state (left) and loaded with 130 kg (right). There are differences up to 3 mm between the two loading conditions.

Table 1: Technical data of computed tomographic datasets

Type of computer tomograph	Siemens Somatom AR-S
Acceleration voltage [kV]	110
Tube current	105
Exposure [mAs]	315
Reconstruction Kernel	AH71
Slice thickness [mm]	1
Pixel Matrix	512 x 512
Pixelspacing [mm/Pixel]	0,2-0,35

Discussion

With this method it is possible for the first time to have a look into the claw and observe the changes during loading. Measured values represent the distance between the surface of the bone and the first solid part of the horn in the respective segment. This means that the horn lamellae are not considered due to the relatively low spatial resolution of the CT-dataset and the partial volume effect resulting from this. The measured values however permit determination of the changes in the position of the distal phalanx relative to the claw capsule. Thus it is possible to detect areas with especially high changes when loaded.
From the biomechanical point of view these findings prove that there is a tilting movement of the distal phalanx when loaded. This necessarily involves a corresponding deformation of the dorsal part of the coronary horn. If this movement and the aforementioned changes in bone-horn-distance are considered it becomes obvious that especially the region of transition between proximal soft bulb to the distal hard bulb experiences heavy compressive stress.
In order to see whether a loosening of the suspensory apparatus as postulated for older dairy cows leads to a reduced bone-horn-distance with a higher risk of sole ulcers it will be interesting to compare nulliparous heifers with age-matched primiparous heifers and older cows with a higher number of lactations.

Acknowledgement

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MORPHOMETRICAL ANALYSIS OF THE MICROSTRUCTURE OF HOOF HORN AND ITS INTERACTION WITH FLOORING SYSTEMS

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Introduction

The quality of hoof horn and its interaction with the housing system are important factors for claw health. Poor horn quality is responsible for or associated with many claw lesions which cause pain, reduce milk yield and ultimately lead to slaughter. Horn quality is determined by the horn cells, the intercellular cement and the hoof horn architecture, i.e. horn tubules, their structure and arrangement. Literature quotes 16,4 ± 1,9 tubules/mm^2 as standard value for sole horn of good quality (Dietz & Prietz, 1981) Recently, soft and elastic flooring has been reported to have a positive effect on the microstructure of hoof horn (Benz, 2002).
Our major aim was to perform morphometrical analysis of horn microstructure on a large number of samples from animals kept on concrete in common housing systems and thus to determine genetic influence on hoof horn quality as a basis for breeding selection. Additionally, we wanted to look for further evidence for the interaction between horn architecture and properties of the flooring system. Moreover, we wanted to discuss the consequences for quality of hoof horn structure and function of the hoof unit. Finally we wanted to discuss the results of our analysis with main focus on the differences between literature and obtained data.

Material and methods

We carried out morphometrical analysis of the horn tubule parameters in a large number of horn samples, from one term (Hohenheim and Alnarp) or up to three sampling dates (Luxemburg). The results should give an insight into the influence of different flooring systems and demonstrate continuity of horn quality in claws kept on steady floor.
We obtained horn samples from dairy cows from three different trials. All samples were prepared and analysed identically.

a. Horn samples from Luxembourg:

In cooperation with Luxembourg Herdbook samples were taken from approximately 1000 dairy cows in 11 farms (size between 50 and 200 cows) over 3 sampling dates, about 6 months between each date. Husbandary conditions varied between farms with or without pasture. Since the samples were taken from horn grown during indoor season when nearly all cows' were kept on slatted floor, the influence of pasture can' be ignored.

b. Horn samples from Hohenheim/Germany:

A group of 40 cows was kept on slatted floor and subsequently on rubber mats for 4 months. The trial included two locations, one farm and one test station at the University of Hohenheim/Germany. After each period (farm/test station) horn samples were taken to measure the influence of the flooring systems on horn microstructure.

c. Horn samples from Alnarp/Sweden

We performed a pilot study using horn samples from 22 cows of 4 different groups. All animals were kept on slatted floor, partly in a feedstall with or without scraper. The obtained morphometrical data will serve as basic values for future investigation on horn/floor interactions concerning these animals.

All horn samples (a-c) were glued onto wooden blocks and after desiccation the unfixed, non dehydrated material was cut with a Polycut S-microtome (Leica). The sections were stained with the PAS-reaction according to McManus. Light microscopical examination was done with a Zeiss Axioskope with an attached digital camera (Progress 3012), connected to personal computer. Data were analysed with the Lucia® 32 G Nikon® software and the obtained data were exported into EXCEL® (Microsoft.) Statistical analysis was performed with SPSS® (SPSS Inc.).
We measured area, minimal and maximal diameter of

both medulla and cortex of the horn tubules. The statistical analysis included: tubules per visual field (visual field = 0,46mm^2), area per visual field, total medulla area, total cortex area and the limiting values of diameters.

Results

a. Analysis of the horn samples of cows from 3 farms taken at 2 sampling dates showed continuity of tubule-parameters between both dates: the number of horn tubules per visual field differed just a little between the terms, all farms showed an average number ranging from 13,36 to 14,79 tubules per visual field. Morphometrical and data analysis revealed a characteristic pattern for tubule number per area for the individual farms. Tubule numbers remained almost constant over the 2 sampling dates evaluated until now (Fig. 1). Many pathological alterations (31 samples =6,25%) could be observed as shown in Fig. 3. 256 of 561(=45.63%) of the samples could not be used due to bad sample size and/or quality.

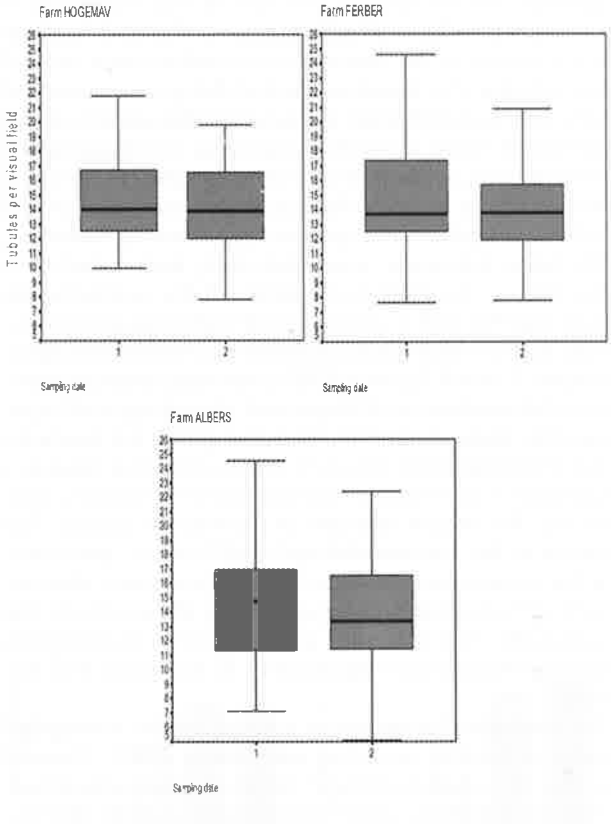

Fig. 1: Average number of tubules between sampling dates, comparison between farms

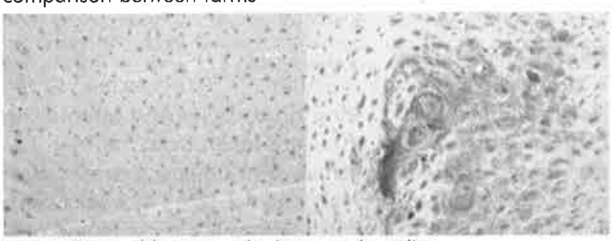

Fig. 2: Normal horn, marked as good quality

Fig. 3:Pathologic variation, marked as poor quality

b. Keeping the animals on soft-elastic rubber mats significantly improved the horn microstructure. Light-microscopic investigations of this horn showed positive changes in the horn cell architecture on the yielding slatted floor (Benz, 2002).

Horn from the hard flooring system showed 44, horn of the same animals kept on rubber floor showed 46 tubules per field of view. Maximal diameter of hard-floor horn is 55μm and 45μm in animals kept on rubber floor

c. We found no significant differences in morphology or dimension of the tubules in the four groups. Neither the thickness of horn tubules nor the proportion of medulla/cortex area showed significant differences.

Discussion

The intention of our morphometrical analysis was to demonstrate the continuity of horn quality with a steady flooring system over a long period of time. Also the correlation between the used flooring system and horn structure of the bovine claw was determined.

Horn quality is defined by the following factors: number of tubules per area, diameter of horn tubules, ratio of medulla and cortex and discrimination of horn tubules and intertubular horn. The resistance of claw horn is determined by the above parameters. Higher resistance is enhanced by a large number of horn tubules, small diameter, small ratio of medulla/cortex and precise differentiation from tubules to intertubular horn (Fürst, 1992; Dietz and Prietz, 1981). The role of pigmentation is controversial (Mülling, 1993).

The horn of a healthy claw shows small horn tubules with narrow medulla area and intact intercellular substance (Fig. 2). Solid horn of good quality shows higher resistance against negative environmental influences. In contrast, dysfunctional hoof horn is in contrast susceptible to these effects (Muelling and Budras, 1998)

The condition of the bovine claw is affected by the flooring system, especially by its hardness; therefore functional implications of claw horn of inferior quality are, among others, lower resistance against bacteria invasion, instable horn microstructure and environmental influences.

The Luxembourg data shows continuity of horn quality between the examined sampling dates. Compared to the values quoted in literature, there are about twice as many tubules per mm^2 in sole horn. In pathologically altered samples, tubule size ranged between 5 and 33 tubules per visual field (between 11 and 74 per mm^2), showing that high tubular variance is characteristic for pathologic horn. Even an influence of season is possible. Until summer 2004 all samples will be prepared and morphometrically analysed. This study is the first to evaluate such a great number of animals which must be considered when discussing the obtained data in comparison to the values quoted in literature.

Hohenheim data proved the interaction between flooring and horn quality, claw health was significantly improved by elastic slatted floors compared to the usual slatted floors (Benz, 2002). The average number of tubules per field of view exceeded the values quoted in literature sim-

ilar to Luxembourg data.
As a result of the small amount of animals in the four groups Alnarp data did not show significant differences in horn architecture. Because all cows were kept on slatted floor, animals on floors of similar type obviously show comparable horn structure. The influence of the scraper on horn architecture can be neglected. Further examinations with a larger number of animals kept on different floors (slatted floor, mastic asphalt, rubber floor) will be performed in the next months.
These results lead to a first conclusion that horn quality differences of individuals are smaller than differences in horn quality related to housing systems.
In the last two years soft rubber mats were launched to improve the housing systems for cows, not only to get higher milk yield and a more profitable situation but also to achieve advanced animal welfare. True to the motto: prevention is better than cure!

Acknowledgements

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BIOCHEMICAL AND BIOPHYSICAL CHANGES TO THE CONNECTIVE TISSUES OF THE BOVINE HOOF AROUND PARTURITION

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Introduction

The most common cause of lameness in dairy cattle involves claw horn lesions (CHL), the majority occurring after calving. CHL present initially as haemorrhages of the sole and white line, and may progress to solar ulceration and separation of the white line1. Ossent and Lischer have described the progressive pathology of CHL2, however the underlying mechanisms of tissue damage are not known. The aim of this study was to investigate the biomechanical, biochemical and biophysical changes in the supportive connective tissue around first calving. The hypothesis is that the primary cause of CHL may be a reduction in the supportive capacity of the connective tissue in the hoof wall. This would permit the third phalanx to drop, transmitting greater forces to the sole, resulting in the pathology described by Ossent and Lisher2, and the clinical presentation described above.
We have previously presented data demonstrating a decrease in the supportive capacity of the connective tissues together with a widening and distorting of the laminae, and elevated tissue remodelling (matrix metalloproteinase-2 (MMP-2), and 52kDa hoofase) prior to maximum biomechanical changes and clinical signs of lameness3,4. Here we report further changes in the biochemical and biophysical nature of these connective tissues.
Collagen is an important component of the corium, conferring the tensile strength of connective tissues. The nature of the post-translational modifications, particularly the cross-links in collagen, are an important determinant of the level of supportive capacity of the corium. The cross-links may vary with age, hormonal environment, and the mechanical requirements of the tissue and disease.
The biophysical properties of a tissue can be investigated using differential scanning calorimetry (DSC). Thermal energy absorbed as collagen denatures generates a thermogram (figure 1), which is analysed to provide information on collagen stability, composition and environment.

Materials and Methods

Hoof segments, comprising horn, bone and interposing connective tissue (corium), were taken from the hind lateral claws of maiden heifers and heifers 2 weeks precalving (C-2), and 4 (C+4) and 12 (C+12) weeks postcalving. After biomechanical testing (data presented previously3), the corium was removed and pulverised under liquid nitrogen. An aliquot was reduced with sodium borohydride, acid hydrolysed, and the collagen content determined from hydroxyproline quantified using an autoanalyser5. Lysine hydroxylation and levels of immature and mature collagen cross-links were determined by amino acid analysis of the acid hydrolysate5. Sulphated proteoglycan content was determined from an enzyme digest by colorimetry3. Biophysical properties were investigated using DSC on an aliquot of native tissue5. Data was analysed using one-way ANOVAs, after checking for normality.

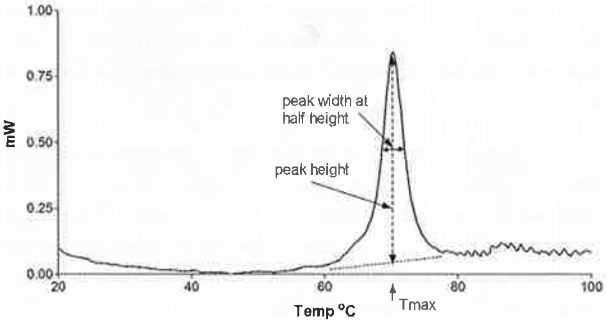

Figure 1: A typical thermogram of bovine hoof corium.

Hydroxylation of the lysine residues in collagen was greater in the calved heifers ($p<0.001$; figure 2a), with increased immature (DHLNL:LHNL, $p<0.001$; figure 2b) and mature (HL-Pyr:L-Pyr, $p<0.05$) collagen cross-link ratios. There were no significant changes in the overall total levels of either mature or immature cross-links, nor in the collagen or proteoglycan contents of the connective tissue between maiden and calving heifers.

The thermal (biophysical) properties of the connective tissue also changed with calving, with a significant decrease in the denaturation temperature, Tmax ($p<0.01$; figure 3a), and change in the thermogram peak height and width at C+12 (figure 3b). There was no change in the enthalpy.

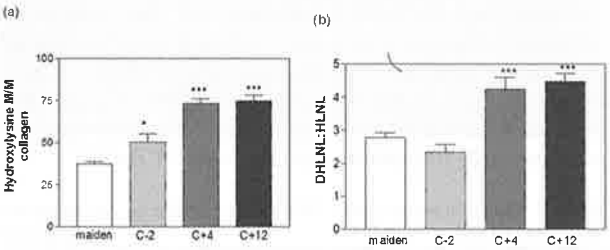

Figure 2: Altered collagen post-translational modifications of hoof corium around calving; (a) The level of lysine hydroxylation increases immediately prior to calving, reaching a maximum at C+12; (b)The immature cross-link ratio, DHLNL:HLNL increases after calving. (* $P<0.05$; *** $P<0.001$; compared to maidens).

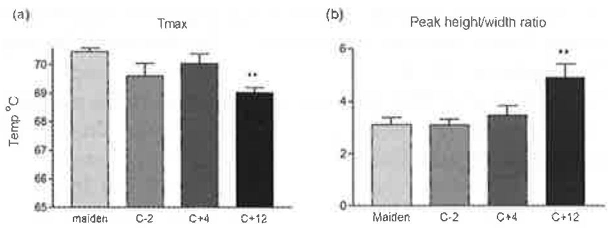

Figure 3: DSC results. (a) The temperature of denaturation (Tmax) decreases after calving; (b) The shape of the denaturation peak changes after calving. (** $P<0.01$, compared to maidens).

Discussion

The elevated collagen lysyl hydroxylation and the consequent increase in the collagen cross-link ratios demonstrated in this study are changes associated with tissue repair and remodelling. An elevated level of tissue turnover and repair around parturition was also first suggested by the increase in proteolytic activity we previously reported4. These biochemical changes begin to occur at least 2 weeks before calving, increasing to a maximum at C+12, in a similar manner as the biomechanical changes3, but prior to the clinical signs. In further support of these findings, the changes in the physical properties also suggest that the collagen of the corium is less stable in calving heifers compared to maidens. The temperature of denaturation (Tmax) is significantly decreased at C+12, whilst the shape of the denaturation peak is also altered, suggesting a fundamental change in the nature of the collagen. The differences in the post-translational modifications of the collagen described above would contribute to these changes in the thermal properties of the corium demonstrated by the DSC.

Prior to calving we have demonstrated changes in the biochemical nature of the hoof connective tissue, which progress after calving, culminating in the maximum changes in biochemical, biophysical histological and biomechanical properties at C+12. Together, data from this study and our previous investigations support the hypothesis that primary causal events associated with calving weaken the supportive structures of the hoof, leading to increased susceptibility to CHL and lameness. We are currently investigating in further detail the initiating factors involved in these processes, and the importance of the hormones associated with partuition.

Acknowledgments

We are grateful to the BBSRC for funding this work.

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THE USE OF RADIOGRAPHY TO ASSESS HOOF DEVELOPMENT IN PREGNANT AND LACTATING HEIFERS

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Introduction

Measurement of hoof horn confirmation can identify significant external changes in the hoof, however internal changes cannot be detected. This study used radiography as an additional means of measuring internal changes affecting hoof horn development and foot conformation in the hoof of the growing dairy heifer

Materials adn methods

The study followed a two by three factorial design with heifers randomly assigned to one of two housing systems and one of three formalin treatments.

Housing treatment 1	Straw yard. No access to concrete.
Housing treatment 2	Straw yard. Concrete feed passage.
Formalin treatment A	Fortnightly footbaths with 5% formaldehyde.
Formalin treatment B	Three monthly painting with 40% formaldehyde.
Formalin treatment C	No foot bathing.

Fifty-two heifers included in the study had radiographs taken of the distal phalynx of the lateral claw of the right hind limb. Radiographs were taken within one month prior to parturition and within one month after parturition.

Radiographs were taken using a Portable Diagnostic X-ray unit (SMR Medical Imaging PX-15HF). Single emulsion mammography film (Kodak Min-RG film) was held in a flexible plastic cassette in the inter-digital cleft by means of an adjustable metal frame. The frame was constructed in such a way that when it was fitted to a WOPA leg-lifting box, the mounted x-ray machine was at a fixed distance and constant angle from the claw. Exposure of 72 kV, 20mAS and a film focal distance of 800mm were maintained for each radiograph. The film was developed in an automated x-ray-processing unit (Optimax compact automatic tabletop processor 117x-1-0000).

Radiograph of the right hind lateral claw distal phalanx included the distal inter-phalangeal joint, the cranial tip and the flexor process of sole of the distal phalanx. A line was drawn on the radiograph, (illuminated by a viewing box) joining the flexor process and the cranial tip of the distal phalynx. A second line was drawn joining the cranial and caudal aspects of the plantar surface of the claw capsule.

The thickness of the sole at the flexor process (measurement 1) and the cranial tip of the distal phalynx (measurement 2) were measured (accuracy 1 mm). The angle of convergence of the two lines was also measured (measurement 3). This was undertaken using a geometric protractor (accuracy 0.5 degrees).

Results

The values for Measures 1, 2 and 3 are shown in Table 1. Paired t-tests were performed on individuals where a measurement (radiographs) was made both before and after calving. Results showed that there were no significant differences between sole thickness measurements and distal phalynx angles (measurements 1-3) before and after calving for any of the housing and formalin treatment groups.

Univariate analysis looked for association between each of the predictor variables (individual housing and formalin treatment groups) with the output variables (sole thickness and distal phalynx angle) using one-way ANOVA in SPSS. This was undertaken for animals before calving and after calving, and for all data combined. No significant differences were found between any of the housing and formalin treatment groups for any of the outcomes.

Housing and formalin treatment and the interaction between housing and formalin treatment were considered as potential predictors for multivariable analysis. A generalised linear model was created in SPSS, using these predictors, but none were significantly able to predict the outcome (sole thickness - measurements 1 and 2).

Table 1 Sole thickness (mm, (SEM)) and angle of convergence (degrees, (SEM))

	Straw yard, no concrete			Straw yard, concrete feed passage			Overall housing		
	Measure 1 (mm)	Measure 2 (mm)	Measure 3 (degrees)	Measure 1 (mm)	Measure 2 (mm)	Measure 3 (degrees)	Measure 1 (mm)	Measure 2 (mm)	Measure 3 (degrees)
Formalin foot-bath	17.jan (0.9)	13.jun (1.1)	3.jul (0.4)	18.jul (0.8)	15.0 (0.8)	4.jun (0.3)	17.sep (0.8)	14.mar (0.7)	4.feb (0.2)
Formalin painting	17.mar (0.6)	13.jun (0.6)	3.jun (0.5)	15.sep (0.4)	12.maj (0.5)	3.jun (0.4)	16.jun (0.4)	13.jan (0.4)	3.jun (0.3)
No formalin	16.avg (0.7)	12.jun (0.6)	4.jul (0.5)	18.jun (0.6)	14.0 (0.5)	4.jun (0.4)	17.jul (0.5)	13.mar (0.4)	4.jun (0.3)
Overall foot treatment	17.jan (0.4)	13.feb (0.4)	4.jan (0.3)	17.maj (0.4)	13.jun (0.3)	4.feb (0.2)			

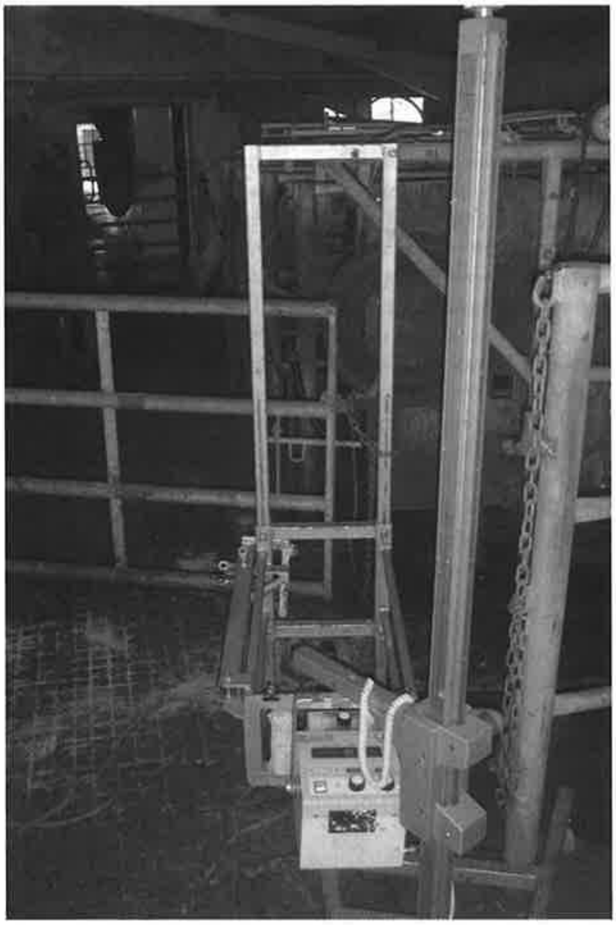

Figure 1: Radiographs were taken using a flexible custom made frame that attached to a Wopa crush

Figure 2: Hoof was fixed in position using ropes

DISCUSSION

This study found no difference in the thickness of sole or angle of the distal phalynx between different housing groups. The housing design in this trial, where heifers have the ability to lie on deep straw at all times, did not affect the radiological appearance of the foot. Heifers having access to a concrete strip from where they stand to feed did not show significant radiographic changes in sole thickness and distal phalynx angle to the sole. A concrete feeding passage (that allows a reduction in faecal contamination of a bedded area of a straw yard system) does not seem to be disadvantageous in terms of changes in foot structure in the dairy heifer.

This study found no difference in the thickness of sole or angle of the distal phalynx between the different treatment groups. These measurements may be more related to the development of non-infectious claw disease (such as solar haemorrhage and ulceration), than infectious foot disease. Footbaths and topical foot treatments are commonly used to treat and help prevent infectious conditions affecting the bovine foot and researchers have found their use reduces interdigital disease (Blowey, 1992). The different treatments used in this study however had no effect on the thickness of sole or angle of the distal phalynx.

It is known that development of non-infectious claw diseases result from a complex interaction of host and environment factors (Arkins, 1981). This study found no changes in sole thickness and distal phalynx angle following exposure to the different housing and footbathing treatments outlined. Therefore development of non-infectious claw lesions, associated with different housing and footbathing treatments similar to those investigated, may be unrelated to the indices of sole thickness and distal phalynx angle, or occur as a more complex interaction of host, environment and management factors.

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SOLE LENGTH, SOLE WIDTH, BULB HEIGHT, BULB WIDTH AND SOLE SURFACE AREA IN CATTLE BEFORE AND AFTER FUNCTIONAL TRIM-MING.

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Introduction

Series of claw measurements have been undertaken previously (1, 2) and have provided substantial information about claw trimming and about the possible biomechanics of claw diseases. It was shown that the lateral claws were bigger than the medial ones regarding many measures including sole length and width. Ossent described a simple method to remove the horn shoe to examine the corium (3).

Material and Methods

In this study, 80 digit specimens, 40 from finisher bulls, 20 from young cows and 20 from older cows, were used. The measurements - sole length, sole width, bulb length and and heigth and width, sole surface area - were taken at a defined sole thickness (5 mm at the tip, 8 mm at the heel). The ratio of the dorsal wall length and the bulb length was calculated.
After that, the lateral claw was adjusted to the medial claw ("functional trimming") and the measure-ments repeated in the lateral claws.
In all claws, the horn shoe was removed and the meas-urements taken again, if good border lines of the meas-ures could be recognized ("corium values").
Statistical analysis was done with the paired t-test ($p < 0.01$) and ANOVA. Correlations were calcu-lated with Pearson's correlation coefficient.

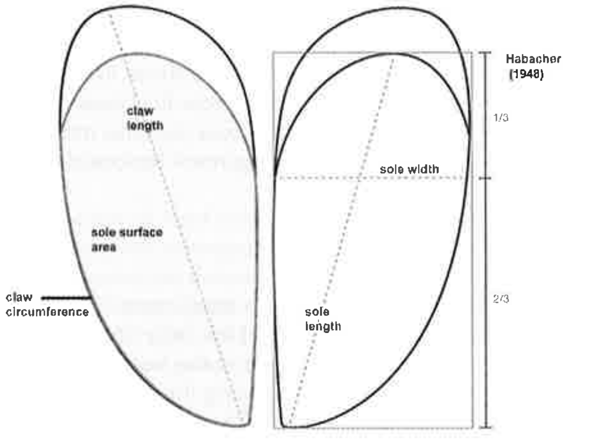

Fig. 1 Claw measures taken at the sole (Habacher's rectangle inserted)(4).

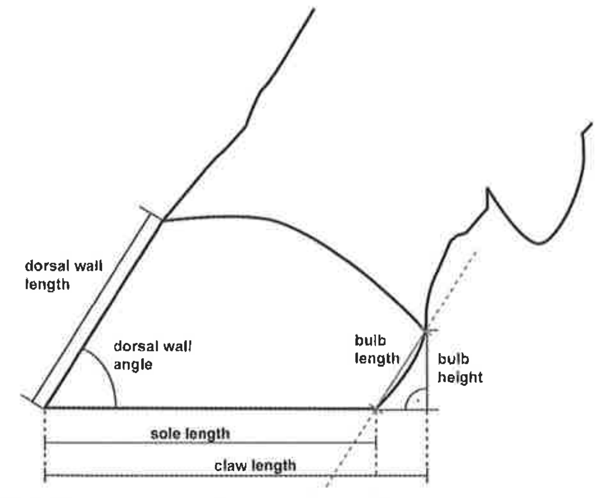

Fig 2 Claw measures taken at the wall and sole, seen from abaxial

Results

The dorsal wall lengths increased with age. They were not statistically different in the lateral and me-dial claws. After functional trimming, the lateral claws had shorter dorsal walls than the medial ones in all groups. The values were significantly less than that of the medial claws in the young bulls and young cows. The corium values were similar in the lateral and in the medial claws.
The dorsal wall angle was highest in the bulls. Functional trimming increased the angle of the lateral claws in the bulls, but decreased it in the cows.
The bulb was significantly higher in the lateral claws. There was a significant negative correlation of the bulb height and the age for the medial claws ($r = -.339$).
The bulb width was biggest in the young bulls. There was a tendency for the bulb width of the medial claws to decrease with age ($r = -0.264$, $p < 0,05$).
Bulb height and width were also bigger in the lateral cori-um values.
The lateral claws had significantly longer soles than the medial. The length increased also significantly with age. After functional trimming, the sole length of the lateral claw had further increased. Also, the sole of the lateral claws was significantly wider than the medial in all groups.
The lateral claws had a significant larger sole surface area in all animals. Functional trimming in-creased these values for the lateral claws.
At the defined sole thickness, the ratio of the dorsal wall length to the bulb length was nearly 2 : 1 only in the bulls. For the cows, a ratio of 2,2 : 1 was calculated.

Discussion

Functional trimming decreases the dorsal wall length and the bulb height in the lateral claws, but in-creases the sole length, width and the sole surface area. Since the bulb height of the medial claws gets smaller with the age, as shown by this study, it may not be wise to reduce the bulb height of the lateral claw to that of the medial. This will create a bulb region that is too low and therefore may be prone to claw lesions like heel horn erosion and digital dermatitis.
The lateral claw should therefore only be trimmed to the height of the medial claw when the medial claw has a sufficient bulb height. Causes of the decrease of the bulb height of the medial claw may be underuse of the medi-al bulb because the lateral bulb is bigger.

Conclusion

The adjustment of the lateral claw to the sole heigth of the medial claw brings a sinificant decrease of the bulb height and enlarges the sole measures significantly.

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PIGMENTATION, IMPRESSION HARDNESS AND THE PRESENCE OF MELANOCYTES IN BOVINE CLAW TISSUE

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Introduction

Lameness and the formation of lesions in the hooves of cattle are well known to be associated with the quality of horn at individual sites within the claw. Good quality horn is characterised by the presence of cornified epidermal cells containing a well synthesised cytoskeleton and effective intercellular adhesion, which contribute to physical properties, and effectiveness of function. Among the compositional properties of bovine claw is the variable presence of pigmentation in the horn of the wall. Pigmentation in other integumental tissues, such as skin and hair follicle, is produced by melanocytes, which transfer pigment-containing- and synthesising-melanosome organelles to adjacent keratinocytes. Their major synthetic products are eumelanin and pheomelanin, which are considered to confer photo-protective properties on tissues particularly in response to ultra-violet radiation. The effects of the presence of deposited pigments and melanosomes on cytoskeleton and other structures in keratinocytes are not known. Anecdotal evidence has suggested that pigmented wall horn is associated with a greater resistance to lesion formation, although results published in the literature (e.g. Vermunt & Greenough, 1995) are not consistent. The aims of the present study were to investigate, in claw horn varying in pigmentation, physical properties of hardness and dry matter and histological properties of dermal and epidermal tissues.

Materials and methods

Right hind medial and lateral claws were collected from female crossbred cattle from a commercial abattoir and transported to the laboratory on ice and then graded on a colour scale. Those with very dark brown or black claw wall horn were classed as pigmented and the others were non-pigmented. Impression hardness was measured immediately using a duropenetrometer (Durotech) on the coronary wall horn at 0.5 cm intervals from the lower perioplic horn line to the distal edge, under the distal edge and on the sole and heel at consistent locations. Cryostat sections (10 μm) of tissue dermis and epidermis were prepared from the coronary and mid-wall regions and stained (Fontana-Masson, DuVal et al., 2002) to detect the presence of deposited pigment and melanocytes.

Results

Values for impression hardness for both pigmented and non-pigmented claw wall horn increased progressively from the uppermost coronary horn (UCH) site to a 2 cm lower site (Figure 1). Non-pigmented horn showed, on average, significantly greater values for hardness in measurements taken from the UCH to the 4.5 cm lower site with no differences recorded thereafter. There were also non-significant trends for greater values for hardness for non-pigmented horn at individual sites; under the distal edge, sole and heel horn compared with pigmented wall horn. Significant effects were not due to differences in water retention in horn since there were no differences in values for dry matters of a range of horn samples tested (Figure 2). Histological examination of pigmented claws showed clear evidence of the presence of pigmented cells in epidermis of coronary region soft tissue (Plate 1), but not dermis or in laminar sections (Plate 2). Pigmentation was concentrated particularly along the basement membrane at the uppermost region of intertubular horn. There was no evidence of pigmentation in epidermis from claws with non-pigmented wall horn (Plate 3).

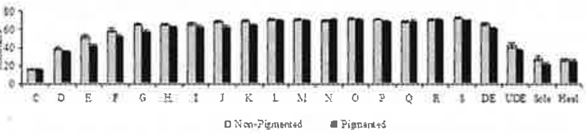

Figure 1. Hardness measurements. Results are shown as mean ± SEM for n=11 animals (DE = distal edge: UDE = under the distal edge).

Table 1. Pooled mean values (± SEM) for hardness of the claw regions shown in Figure 1.

Region	Non-pigmented	Pigmented	Significance
C-G	46.5 ± 1.84	40.3 ± 1.61	P<0.05
H-L	68.5 ± 0.52	64.8 ± 0.67	P<0.001
M-UDE	66.4 ± 0.91	65.1 ± 0.98	n.s.
Sole & Heel	27.6 ± 1.37	23.6 ± 1.52	n.s.

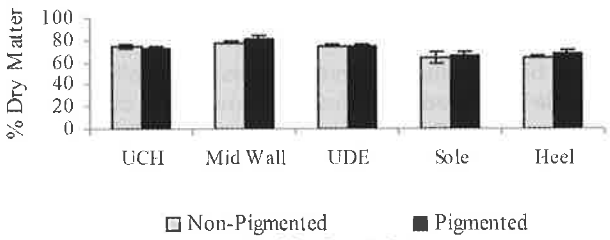

Figure 2. Dry matter as a % of fresh weight in horn samples from claws with pigmented or non-pigmented wall horn. Results are shown as mean ± SEM for n=5 animals (UCH = uppermost coronary horn, UDE = under the distal edge).

Plate1

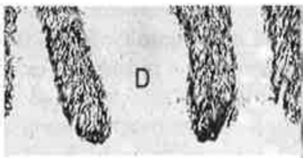

Plate2

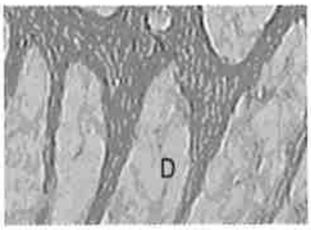

Plate 3

Plate 1. Coronary region of a pigmented claw: positive staining for melanocytes in the epidermis, x400

Plate 2. Mid-laminar region of a pigmented claw: no staining for melanocytes, x100

Plate 3. Coronary region of a non-pigmented claw: no staining for melanocytes, x400

(D = dermis)

Discussion

The results indicate the increase in impression hardness arising from differentiation and expression of wall horn gene products in coronary epidermal cells, which occurred at a maximum up to 2 cm below the uppermost measurement for coronary horn. There was clear evidence that the increase in hardness developed more slowly in pigmented than non-pigmented horn. This is an interesting observation with currently unknown origin. It is however, tempting to speculate that the presence of melanosomes and pigment granules may influence terminal events in the interaction between cytoskeletal intermediate filaments and associated proteins. Histological examination confirmed the absence of pigment in dermal tissues and showing evidence of melanosome-produced pigmentation in soft tissue epidermis of claws with pigmented wall horn. The concentration of melanocytes along the basement membrane of the upper interpapilliary area of the coronary region epidermis suggests a particular contribution to pigmentation in intertubular horn. Further studies could usefully investigate ultrastructure and gene expression in animals expressing pigmented and non-pigmented genotypes to determine the basis for the differences in the physical properties measured.

Acknowledgements

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BASIC STEPS OF A FINITE ELEMENT MODEL OF THE BOVINE CLAW

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This work was done as part of the scientific EU - project "A multidisciplinary approach to the reduction in lameness and the improvement in dairy cow welfare in the European Union" Working titel: LAME COW

Introduction

Claw soundness as a central factor in bovine industry is assessed in studies dealing with claw horn mechanical properties and the biomechanics of the bovine claw, and in research concerning diseases of the bovine foot and their correlation to housing, feeding, conformation and use of the animals. We want to present a sophisticated solution of a finite element model for combining mechanical research and basic material findings in order to gain more information about possible stress and strain in the claw capsule with the aim to better understanding of disorders of the bovine claw.

Materials and Methods

Post mortem samples of physiological bovine claws from mature Fleckvieh cows were collected from abattoirs throughout Austria. A total of 2150 animals were screened and twenty sound hind feet making up 40 separate claws were chosen for the physiological claw model. Utmost care was taken in ensuring the dry matter content remaining constant with samples being carefully packaged and deep frozen and repackaged between procedures. Test pieces were cut from the claw using a band saw. Four pieces approximately 2 cm in width were taken from the side of the claw, two to three pieces from the sole and two pieces from the axial wall. The horn capsule of these claws was then separated from the distal phalanx by hand. Further material testing was performed at the Austrian Research Institute for Chemistry and Technology. A total of 338 test pieces underwent finer milling, the elastic modulus of these prepared samples was determined according to DIN EN 53 457 and ÖNORM EN ISO 868 using the material testing maschine Zwick 1747. Following modulus testing the samples` dry matters were determined by weighing samples before and after 48 hours of drying at a temperature of 110°C. Image digitalisation of the physiological form of a selected bovine claw was done by Westcam, Innsbruck, Austria and FE modeling was performed using the software IDEAS, Structural Dynamic Research Corporation, USA and the formerly obtained material data with the elastic moduls ranging between 700 N/mm^2 at the toe and only mean 200 N/mm^2 at the sole. The FE model was placed on a flat and hard surface, produced as a platform underlying the claw, no boundary conditions were necessary. Model loading was performed by defining a total load of 1500 N, distributed as pulling force in the lower third of the inside of the abaxial claw wall. The axial wall and the sole were not loaded.

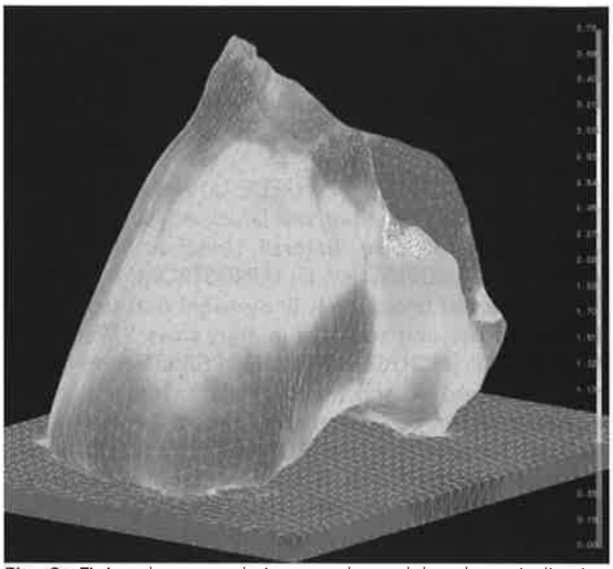

Fig. 2: Finite element solution, mesh model, colours indicating material stresses.

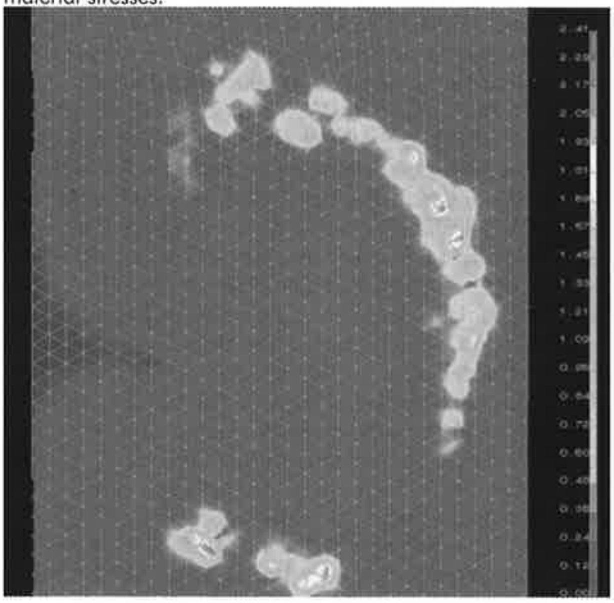

Fig. 3: Material stress in the platform supporting the claw.

Results and discussion

Fig. 1: Solid model of a bovine hind claw.

The FE model of the bovine claw shows very little deformation. The axial wall moves slightly outward and downward into the interdigital space, so does the rest of the proximal wall, but to an even lesser extent. Material stress shows maximum values in the proximal axial wall, higher stresses are found in the dorsal wall. The support platform shows a stress distribution roughly assembling the distal rim of the claw wall.

Deformation of the FE claw model is very little compared to the equine FE hoof model. Reason therefore is found in the comparably small load for one claw, estimated as the half of 3000 N of one hind foot at the bovine`s walk. Also the combination of the medial and lateral claw with their connecting and supporting ligaments meeting in the interdigital space takes over a big part of shock absorption. Compared to the equine hoof, the bovine claw and its biomechanics take over only a small part of the total limbs` shock absorption capacity.

Stress distribution in the support platform may seem logic in the first place, but comparing the results to the referred literature, validation of the bovine FE model is very close at hand. Further research with pathological FE claw models is under progression and will give even more valuable information.

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EXAMINATIONS OF THE DIGIT OF SLAUGHTERED BULLS IN COMPARISON TO THEIR DEVELOPMENT IN THE FIRST THREE MONTH USING DUAL ENERGY X-RAY APSORPBTIOMETRY (DXA)

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Introduction

Development of the bovine claw is still an area of investigation where more information is needed to get a clearer picture of the numerous problems when it has reaches maturity. One tool to measure claw development is dual energy x-rax absorptiometry (DXA).

Three years ago, we started this investigation using DXA to describe the development of the horn capsul in new born calves of different sexes and breeding lines. In addition, the whole body or body regions were analysed for the amount of fat tissue, lean tissue, bone mineral content and bone mineral density. Thus, measurements of skeleton growth and bone density of the claw region in hind and fore claws have been done.

The first 18 bulls originating from this previous study have finished their second year and went to the slaughterhouse. This analysis compares the data of the first three months to the data measured after two years of life.

Material and methods

First investigations began at day 4 post partum (p.p.) and were performed at the Experimental Farm of Oberschleißheim within a three weeks interval finishing three months later. Male and female calves of four breeding/crossbreeding lines were scanned under light sedation. These breeding lines were German Fleckvieh (FV), German Holsteins (GH), F1 crossbred calves of these two breeds (FV-GH with Fleckvieh Sire or GH-FV with German Holstein Sire).

X-ray scans were analysed by the help of the LUNAR DPX-IQ software. A region of interest was defined to analyse the data from the tip of the claw up to the fetlock joint.

Follow up investigations were made on the digital organ of bulls after slaughtering.

All data have been analysed using a variance analysis by considering the effects sex, position of the claw, breeding line and measurement number.

The study started in November 2000. Up to now, we finished the "first three months investi-gations" in 60 male calves, while 18 bulls finished the study at an age of two years.

Results

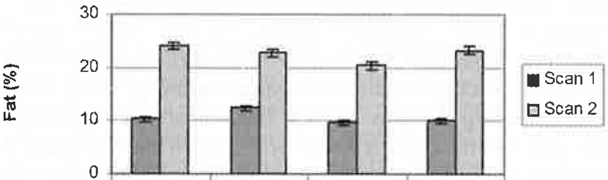
Considering the interaction effect of claw and number of measurement, bone mineral content (BMC) and bone mineral density (BMD) are similar in all four pairs of claws at an age of three months (BMC- ca. 15,5g / BMD - ca.0,6 g/cm^2) and at an age of two years (BMC - ca.106g / BMD - ca. 1,94g/cm^2). There is no significant difference between fore and hind, medial and lateral claws. Bone mineral density is more than three time as high at two years of age as it was at three months.

Significant differences appear by combining the effects breeding line and number of meas-urement. Crossbreds reach higher values of BMC and BMD than the original breeds. These differences are statistically significant as demonstrated in table 1 for bone mineral content at both points of time.

Tab.1: Bone Mineral Content (BMC) in different breeding lines Least Square Mean ± Standard Error of Estimation*) *Least Square Means with different letters are significantly different (p 0.05)

Breeding line	Measurement with three months	Measurement with two years	Breeding line
German Holstein (GH)	13,04 ± 0,81 ^{a}	95,60 ± 1,47 ^{a}	German Holstein (GH)
German Fleckvieh (FV)	14,86 ± 0,68 ^{b}	106,31 ± 1,47 ^{b}	German Fleckvieh (FV)
GH x FV	15,42 ± 0,67 ^{b}	109,53 ± 0,96 ^{b}	FV x GH
FV x GH	16,60 ± 0,70 ^{b}	114,40 ± 1,13 ^{c}	GH X FV

The percentage of fat tissue is also influenced by the genetic origin, as shown in Fig.1. Pure German Fleckvieh reaches the highest percentage in scan 1 (three months), pure German Hol-stein bulls have the highest percentage in the "two years" scan.



	German Holstein	German Fleckvieh	GH X FV	FV X GH
Scan 1	10,3	12,42	9,71	9,98
Scan 2	24,06	22,82	20,42	23,26

Fig.1: Percentage of fat tissue in the region of interest depending on scan number and breeding line.

Discussion

In addition to bone mineral measurements, DXA provides data on the "soft tissue" composi-tion of the digital organ. This investigation shows that there is in fact no significant difference between fore and hind, medial and lateral claws in the amount of mineralized or not mineralized tis-sue.

It can also be seen that the effect of breeding line influences the development of the digital organ.

Up to now, no clear information is available concerning the relations between claw develop-ment and claw health. DXA can provide data on the "inner" development of the digital organ creating a basis for further research concerning diseases of the claw.

CLAW TRIMMING TECHNIQUES , RESEARCH AND PRACTICE

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Introduction:

Lameness is an increasing problem in Modern Dairy Husbandry. Many aspects in the husbandry have changed. Housing is a major change and with the housing the total management changed. From day and night grazing cows are kept inside the whole year round. Zero grazing or Summer feeding has become a popular feeding system. When cows are grazing in summer, the large groups of cows are causing gateway trouble. Through breeding a double purpose cow becomes a single purpose cow. Milk yields are creeping up and nutrition changes. The negative energy balance becomes bigger and last longer. Labour is getting more expensive, mechanization and automation replace labour, therefore more cows are kept with fewer people.
Lameness is an increased problem, but not the only problem. Fertility and mastitis are often an even bigger problem. How big is the connection or interaction between those problems on the farm or are they NOT connected? Can only hoof trimming solve the problem of lameness? With research causes of diseases should be found, in practice trials solutions should be found to deal with the changes in (Dairy) animal husbandry. Education is important to teach managers best practice.

Research:

Research in lameness is a necessity we can not do with out. What is important to investigate. Research is based on lameness often on farms with large problems. Farms without lameness problems are often not in the picture. Lameness is a multi factorial problem. High yielding cows and low costs in housing, nutrition etc., low input high output farming.
Breeding is another item of interest. Increasing the milk yield is the first item farmers are interested in. They all say that conformation is important to them, but are they really trying to improve! Is the capacity of the cows in balance with the genetic potential milk production. Grassland management is the second important if not the most important item for health on the farms. Quality of grass silage or even fresh grass is depending on the variety of grass in the field, type of soil and climate. Silage storage, cutting stage for silage or zero grazing etc. are important to look at. Feeding Maize (corn), feeding concentrate or straights, block feeding or TMR (total mixed ration). Nutrition is known as being a very big item in Laminitis, but is still not controlled by nutrition. Research in this field is indispensable. Housing conditions are an item, "COW COMFORT", again we have to look at the differences in climate. The majority of cows are kept in cubicle housing. Design of the cubicles have to change to provide the cow more comfort. Flooring is important for the cows to walk on, cleaning the floors for hygiene matters. Concrete (slatted), slippery, uneven etc flooring can cause mechanical damage to the feet and legs. Calf rearing and young stock rearing is of great importance and certainly not the last in line on the farm. Development of capacity in cows lies in this period. The youth has the future.

Practice:

In practice there are some good tools developed to assist the farmer or specialist on the farm to check on functioning of the cows the so called "Cow Signals". Body condition score (BCS), Faecal score, Locomotion score, Foot score or Claw score are all aids to spot problems in an early stage. Hoof trimming is an aspect widely accepted as a tool to prevent lameness and in case of lameness to cure the lameness. When is the best time to trim cows routinely, is it in a certain season or at a certain lactation stage? Is preventative trimming a must or should cows only be trimmed in case of lameness. Is the trimming best done by the specialized hoof trimmer or veterinarian or even by the farmer or herdsman?
In the Netherlands cows are trimmed routinely since the late seventies early eighties to the hoof trimming technique of Mr. E. Toussaint Raven, the also called "Dutch Method". The goal for routine trimming is to trim back overgrowth and unbalanced weight bearing. Long claws are hindering the cow to walk natural on hard surfaces, the gait of the cows is short and stiff. When concrete is slippery the same effect is seen on the gait. Innovation of concrete floors is necessary, like rubber coating, automatic scrapers, roughening the floors etc.
Unbalanced weight bearing causes overload of a claw per foot and sole ulcers, wall ulcers appear. By routine trimming the goal is to restore the balance in the claws. The stability in the claws is restored by trying to trim the soles flat to create a walking surface on the claws. This allows the cow to stand up straight on her claws. Inclining soles on a hard surface increases the chance on typical sole ulcers.
Routine trimming is meant to prevent lameness, but in overdoing the trimming it can cause lameness too. Important in routine trimming is to look at conditions on the farm to decide the necessary trimming to be done.
In case of lameness curative trimming is necessary. In the curative trimming it is important to transfer the weight bearing from the painful claw to the healthy claw. This can often be done by trimming the painful claw lower (in

this case the sole thinner than normal) than the healthy claw. In case of too little height difference a block can raise the healthy claw.
New research with pressure plates has as well emphasized (Dr. W. Kehler, University Hanover, Germany) as contradict (PhD P. P. J. van der Tol, University of Utrecht, the Netherlands) this theory of weight bearing. Another discussion is going on about the weight bearing if it should be most/ only on the weight bearing border or on the weight bearing border and the sole.

At last regular hoof trimming is part of the hoof care, the major hoof care should be done by the farmer/ manager. Lameness is linked to the total management of (dairy) cows and is a multi factorial problem. Lameness is not only a financial loss, but more so a welfare issue.

PC-SUPPORTED DOCUMENTATION OF CLAW DISEASES AS THE BASIS FOR HERD MANAGEMENT

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Introduction

Claw health has a strong influence on longevity and therefore, on the profitability of the dairy cow. Besides mastitis and reproductive failure, lameness is one of the most important culling reasons in dairy herds. However, often dairy farmers and their consultants lack reliable data from which the causes of claw diseases could be derived. This would be a prerequisite to establish therapeutic and prophylactic measures to improve claw health. To cope with this problem, the Association for Claw Trimming and Hygiene (German Agriculture Society; DLG) the members of which include dairy farmers, hoof trimmers, veterinarians, consultants and scientists, joined forces with the Teaching and Research Facility for Animal Husbandry Echem (LVA Echem), the Cooperative of Claw Trimmers Saxony and VIT PC-Software Paretz Co. to create a concept for a computer supported documentation and analysis system. This system collects and evaluates claw trimming data. It also processes data of individual animals and their environment. Data of claw trimming together with data of herd management allow the description of the farm situation in relation to the incidence of claw diseases and their causes.
The systematic recording of claw diseases permits recommendations to improve claw health. A nomenclature of claw diseases determined by the experts from the DLG forms the basis for data collection with the intention to standardize terms nationwide.

Material and methods

During regular claw trimming on selected dairy farms (Figure 3: 326 cows), data are recorded by trained professional claw trimmers (Cooperative of Claw Trimmers Saxony). This project is a joint effort of the LVA Echem, DLG and the University Göttingen. Since the detail of the required information varies, documentation consists of several data forms. There is one simple form (claw disease, treatment methods; Figure 1) as well as other forms for more detailed information (horn quality, limb position etc.). When all of the data have been entered into the computer, the new PC program will evaluate the data for the claw trimmer and then send the information to the DLG for the preparation of a national/regional claw report. The overview "Claw Project" (Figure 2) illustrates how the software works. Because of the ADIS/ADET format, documented data can be used by several herd health computer programs.

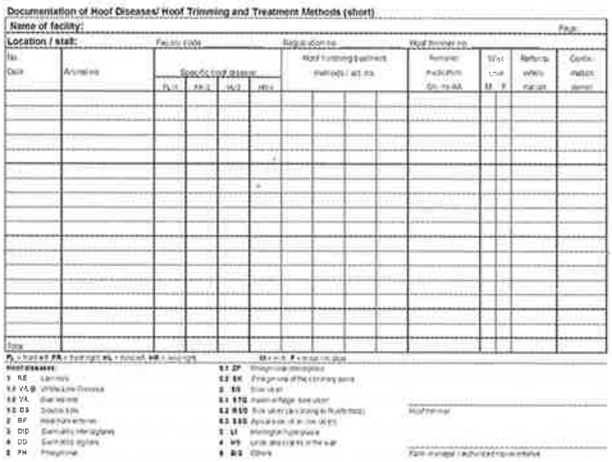

Figure 1

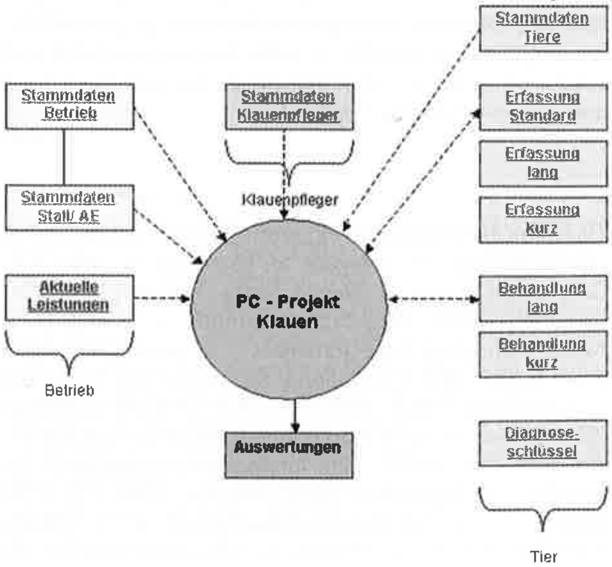

Figure 2

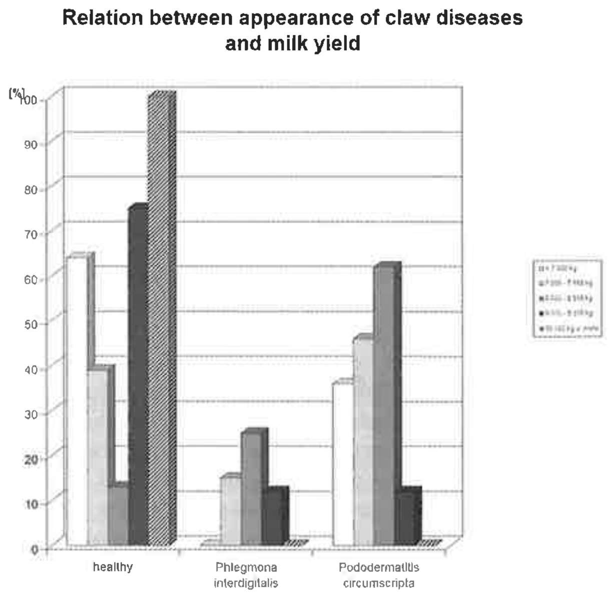

Figure 3

Discussion

Vermunt and Greenough1 state an annual incidence of 10% lame cows in an individual herd as the maximum at which the resulting costs are still acceptable. However, they point out that in the future, a 5% incidence of a certain disease could already mean financial loss. Often the animal holder does not adequately know the incidence of diseases2,3. In Germany (4.4 Mio dairy cows) the culling rate due to lameness is about 10 %. The opportunity to establish a uniform data base throughout Germany in the near future to serve as a basis for diagnosis, nomenclature4 and documentation acknowledges the increased relevance of claw diseases as a very important economic factor. The data gathered can be used to precisely find a cause, and particularly to implement preventive measures. With the computer supported monitoring of lameness and claw diseases in association with the monitoring of individual risk factors (e.g. milk yield, stage of lactation, age etc.) and management factors (e.g. animal husbandry) it is now possible to study the characteristics and predisposing factors of lameness in the individual herd and regional/national herd 5,6,7.

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FIELD USE OF HERD LAMENESS DATA ANALYSIS

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Introduction

In this paper the use of a worksheet, in which individual and lameness data are collected and used to create graphs and reports, is illustrated.

Materials and methods

The used spreadsheet is based on MS Excel 2000 ©, it has been used for the:

1) Collection of lameness records from 1/1 to 31/12 of each year.
2) Processing of data, i.e. transformation of records in information, with calculation, for each quarter and at the end of the year, of the incidence and the number of lameness cases, on the mean number of cows present in the period, and subsequent creation of reports and graphs.

1) Collection of lameness records (individual data)
Records are collected both during routine trimming sessions and emergency calls. All feet are always trimmed as a rule. Data can be recorded directly on the PC or can be first written on a corresponding paper form to be filed into the spreadsheet later on.

1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22
dat e	her d id	Eu id	lact. n°	calv ing dat e	day s fro m calv	gro up	nl c	l chr lam	sa lam	Fri	Fro	Fli	Flo	Rri	Rro	Rli	Rlo	bloc k	ter-apy	nex t visit	not es

Date of intervention (1), cow's herd id (2) and cow's group (3), e.g. dry group, are recorded before trimming. EU ID of the cow (4), date of calving (5) and parity (6), are imported from the herd database if present. The spreadsheet calculates days from calving at the date of trimming (6). The squares from 8 to 22 are filled with observations during the cow's exam. Chronic (9) and subacute forms (10) of laminitis are recorded, as dichotomous data, if the lesions are present in claws of at least two limbs. When both kinds of alterations are present in the same patient both squares are filled in. Subclinical laminitis is not recorded because too common in the area where we work. Squares from 11 to 18 refer to the eight claws and are filled in with alphanumeric codes which describe the lesions and are of immediate comprehension by the herdsman. Alphanumeric codes provide recording opportunities for: a) Lesions of the skin and interdigital soft tissues: Digital Dermatitis (code DD) and Interdigital Phlegmon (code IP). b) Lesions of the limb: e.g. wounds, gonitis, etc. (code L and the diagnosis is written in "(22) notes"). c) Lesions of the horny capsule: ulcer (code U) and abscess (code A). These lesions are also coded according to a five zone location scheme in the claw, to their severity (presence of necrosis), stage (if chronic) and whether or not present in a corkscrew claw (e.g. code for a sole abscess , AS, toe abscess AT, if in a corkscrew claw ASCC, ATCC). d) subclinical lesions and claw deformities: e.g. white line separation (code WLS), corkscrew claw (code CC). Squares from 19 to 22 contain information about the number of orthopaedic soles eventually applied (19), additional treatments (20) (e.g. systemic administration of an antibiotic), eventual scheduled control visit (21) and other observations (22).

At the end of the cow's trimming the square 8 is filled in with the result of the cow's exam: code L if lame (new case), code NL if not lame, code C if control.

The clinical evaluation of lameness is done in three subsequent steps: gait observation before trimming, presence of one or more painful lesions in the claws and gait observation after trimming. Evidence of a painful lesion during trimming is used as the gold standard for the diagnosis of supporting lameness. If no painful claw lesions are found in a lame cow, the upper part of the limb is examined. A new case of lameness (code L) is recorded on first examination of a lame, if the same cow is examined due to lameness in a different limb or if the same limb shows signs of lameness at least 28 days after a previous recording (Greenough et Al., 1997). The spreadsheet allows recording of individual data by cow's id thus showing her records of any selected period.

2) processing of data (herd data)

The spreadsheet is set up in order to process only new cases of lameness. Reports and graphs are created and show:

a) Incidence and case number: total, per lactation number (1,2,3+) and per stage of lactation (in six different periods of days from calving: 0-30 , 31-60 , 61-120 , 121-210 , >211; Dry period).

b) Incidence and case number per type of disease: total, per lactation number (1,2,3+) and per stage of lactation. Diseases are divided in four gross classes: "Lame horn", which includes all the cows that have one or more lesions of the horny shoe (ulcer, abscess); "Lame dermatitis", where all the cows which have one or more Digital Dermatitis lesions are recorded; "Lame phlegmon", that groups all the cows with one or more Interdigital Phlegmon lesions and "Lame leg" where all the cows with swinging limb lameness are grouped.

If a cow has at the same time more than one disease attributed to a different class (e.g. sole ulcer and digital dermatitis), a new lameness case will be recorded for each disease type (lame horn and lame dermatitis). This means that the sum of the incidence and number of cases for the single type of disease will become greater than the figure expressing total lameness. This method of recording has been adopted in order to preserve the highest amount of information in the dataset and to monitor the evolution of each single gross class of disease during time; at the same time we must consider that if a cow is not lame because of one type of disease she would still be because of the other one. Data are processed quarterly and annually for the average number of the total of cows which are present in the period and divided among lactations 1,2, 3+. These numbers are provided by dairyman's associations database at quarterly intervals. This is an absolute epidemiological bias because the population at risk is not estimated correctly. On the other hand, in the field of lameness, it is not clear how the population at risk should be estimated.

c) digital lesions: a lame cow can have at the same time more than one lesion, (e.g. two sole ulcers or two digital dermatitises). The number of lesions can be clearly greater than the number of lameness cases. The report produces the total number of painful lesions: ulcers, abscesses, digital dermatitis and interdigital phegmon lesions and calculates various indices that are useful for the fine tuning of the analysis e.g. the mean number of lesions for each lame cow divided per type of disease, the distribution of the lesions between fore and hind feet and, for ulcers and abscesses only, the distribution of those lesions between inner and outer claws.

d) corkscrew deformities, the spreadsheet produces data about: 1) the number of corkscrew claws trimmed in lame and not lame cows and the % of corkscrew claws on the total number of trimmed claws. 2) the distribution of corkscrew claws between fore and hind feet, 3) the distribution of corkscrew claws between inner and outer claws of front and rear feet; 4) the number of ulcers and abscesses found in corkscrew claws and 5) their % found in corkscrew claws among all ulcers and abscesses.

Results

To illustrate the use of this spreadsheet the evolution of the lameness problem in a herd of about 200 head will be briefly described. Year 2001: 200 cows present, 68 in lactation n°1, 52 in lactation n° 2, 80 in lactation n° 3+. Average milk production: 10.576 kg 2x. Slatted floor, cubicles with old uncomfortable mattresses and low neck rail (90 cm), ventilation only in the feeding area. Routine trimming at drying off. 150 new lameness cases, incidence 75%, prevalent type of disease "lame horn", 124 cases and 62% incidence (tab n° 1). Among lame horn 82 cases out of 124 were in lactation 3+, (66,1%) (tab n°2) and 54 cases of 124, (43,5%) occurred during the 3rd quarter (summer). The analysis of lame horn cases per stage of lactation showed a different distribution per parity: in lactation # 3+ a higher number of "lame horn" cases occurred short after calving. The analysis showed thus a severe herd lame horn lameness problem, prevalent in lactation 3+ and during the third quarter. Recommendations were: a second routine trimming session for cows in lactation # 3+, from 60 to 90 days after calving, improvement of cubicle comfort, summer ventilation of cubicles and evaporative cooling of the barn, check ration's balance and management. Cow comfort recommendations were implemented only during 2003.

TYPE OF DISEASE	case number	Incidence %
"lame horn"	124	62,0
"lame dermatitis"	20	10,0
"lame phlegmon"	4	2,0
"lame leg"	4	2,0

Table 1

TYPE OF DISEASE	Lact. 1	Lact. 2	Lact . 3+
lame horn	16	26	82
lame dermatitis	5	8	7
lame phlegmon	1	1	2
lame leg	1	2	1

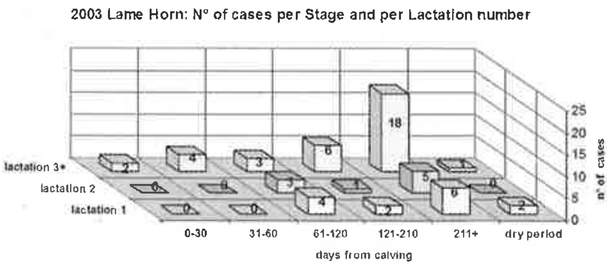
Table 2 number per lactation number

Year 2003 results (the first nine months data of 2003 versus the first nine months data of 2001): (tab. 3) more than 40% reduction of incidence of lame horn cases, 32 less lame horn cases during summer (- 59,3%), 30 less lame horn cases among lactation # 3+ (- 46,9%), 13 less lame horn cases among lactation #2 (-59,1%).

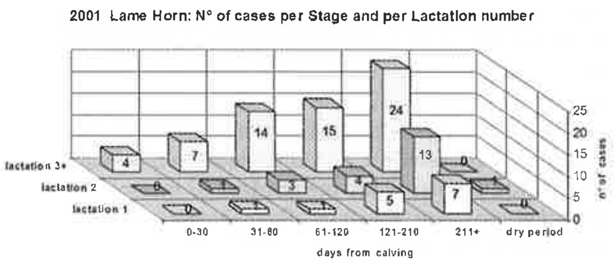
Table 3: data of first nine months from 2001 to 2003

Year	2001	2002	2003	2003 vs 2001	
cows lame n°	125	108	71	-54	-43,2%
Incidence %	62,4	53,1	35,8	-26,6	-42,6%
lame horn n°	100	90	57	-43	-43,0%
lame horn Incidence%	49,9	44,3	28,8	-21,1	-42,4%

No improvement in lactation #1, probably because no routine trimming was performed until drying off. Graphs n°3 and n°4 show the more favourable distribution of lame horn cases in lactation # 3+, divided per production stage, in the first nine months of 2003 versus the same period of 2001, the probable effect of added routine trimming from 60 to 90 days after calving which was introduced only for this class of cows from 2002. Lesion analysis on corkscrew claws shows 6% on total claws trimmed, 18,8% of all ucers and 39,1% of all abscesses occurring in these claws.



Graph 3: 2001



Graph 4: 2003

Discussion

Lameness problems are different in every herd and the current example has shown its own "truth" with the help of lameness data analysis. Herd data processing allows as to identify the severity of a lameness problem, the prevalent types of disease, their distribution by lactations and its stage and the seasonal effects on lameness, so suggesting the eventual presence of risk factors. Finally it can provide a periodic herd lameness analysis comprising possible estimation of economic losses, definition of preset targets, necessary recommendations to the herdsman, and monitoring the effects of the implemented measures. Lameness in cattle appears to be highly dependent on many different factors whose single role is difficult to interpret, further statistical analysis could be of great significance, once an agreed definition of population at risk and of new cases could be obtained in the peculiar field of cattle lameness.

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EFFECTS OF FUNCTIONAL CLAW TRIMMING ON PRESSURE DISTRIBUTION UNDER HIND CLAWS OF GERMAN HOLSTEIN COWS

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Introduction

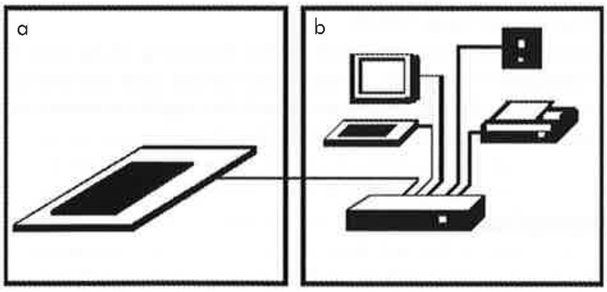
The objective of this study was to investigate the effects of Functional Claw Trimming (FCT) on the load distribution under the weight-bearing surface of the hind claws of Holstein dairy cows over a period of six month after claw trimming.

Material and Methods

The study was carried out with 21 zero grazing cows selected out of a herd of about 90 cows. Animals were housed during the whole study in a free-stall with slatted floor and cubicles covered by rubber mats. The average milk yield of the herd was 8,900 kg. The cows were fed gras and corn silage ad libidum and concentrate depending on milk production.

The animals selected for the study belonged to the herd for more than one year. The lactation numbers and the days in milk of the cows differed markedly. The cows were not lame and showed neither a sole ulcer at the typical site nor a visible damaged corium at any other site. At the beginning of the study the inner hind claws of the animals had no alteration beside a slight red discoloration to be able to bear a potential overload. The horny shoes of the hind limbs were not trimmed or cut in any way during at least the last six months.

The plate (20 cm x 35 cm) consists of four sensors (compacitors) per cm2. One hind foot of a cow was placed on the plate for each measurement.

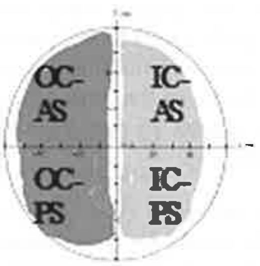


The portable personal computer for registration and analysis of the data.

The punctual pressure distribution under the claws was recorded with an electronic measuring device. The assessment of data is based on changes of capacitive resistances due to vertical pressure by the placed hind foot that compresses the dielectric of the compacitors..

Accordingly, the device consists of a plate (20 cm x 35 cm) containing four sensors (compacitors) per cm2 and a portable personal computer for registration and analysis of the data. The change of the capacity of a single compacitor that corresponds to the local pressure is transduced to a registered corresponding value.

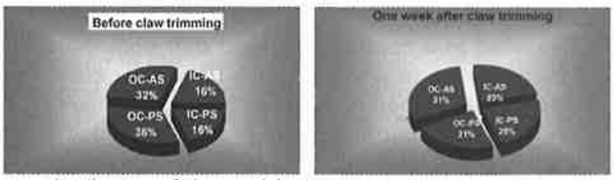
The measurements were carried out once before and thirteen times after the cows had been trimmed. For each measurement, the total weight-bearing area, the relative weight-bearing area of each claw, the relative pressure load of each hind claw and the centre of gravity of the total weight-bearing surface was determined. For further analysis the weight-bearing surface of each claw was split into an apical (fore) and a pulvinal (hind) segment.



The four investigated segments of the hind claws: pulvinal segment of the outer claw (O-PS), apical segment of the outer claw (OC-AS), pulvinal segment of the inner claw (IC-PS), apical segment of the inner claw (IC-AS).

Results

Before FCT ratio of outer and inner weight-bearing surface area was on average 63 % to 37 %. After FCT the surface area was significantly increased for 14 weeks. The maximum increase of total ground surface area was found two weeks after FCT (+12.9 % on average). In spite of this increase and regardless of the time period passed since FCT the ratio of outer and inner ground surface persisted approximately 60 % to 40 %.



The distribution of the total limb weight load (TLWL) under the pulvinal segment (PS) and the apical segment (AS) of the outer (OC) and the inner claws (IC) of the hind limbs before FCT and one week after FCT.

Before FCT the outer claws of the hind limbs bore on average 68 % and the inner claws on average 32 % of the total limb weight load (TLWL) with the pulvinal segment of the outer hind-claws exhibiting on average 36 % of TLWL. FCT had an obvious impact on relative weight load. Thus, the mean load distribution between the claws during the first six weeks after trimming was almost equal (50 % : 50 %). Under the outer claw the mean maximum pressure load showed a decrease of 9.6 N/ cm2 and a mean max-

imum increase in pressure load of 9 N/ cm2 under the inner claw. Trimming initially led to a 24 % decrease in pressure load for the outer claw (reduction of 16 % of TLWL to 52 % of TLWL) and a 50 % increase of pressure load for the inner claw (enhancement of 16 % of TLWL to 48 % of TLWL), compared to the pre-trimming status. The pressure load under the pulvinal segment of the outer claw was reduced by 42 % of the pre-trimming load (reduction of 15 % of TLWL to 21 % of TLWL). The burden of the corresponding apical segment of the outer claw remained constant 30 % of the TLWL throughout the observed period (before and after FCT). Six weeks after FCT had been carried out the pressure under the pulvinal segment started to increase progressively.
Claw trimming resulted in a considerable load shift from the outer pulvinal segment to whole neighbouring inner claw. The additional weight load (15 % of the TLWL) of the inner claw was split between the inner pulvinal segment (+ 9 %) and the inner apical segment (+ 6 %).

Before FCT the centre of gravity was located within the outer weight-bearing surface, slightly apical to the site of the typical sole ulcer. After claw trimming the mean centre of load was shifted towards the tip of the limb with a maximum of 8 mm and simultaneously 25 mm towards the region of the interdigital space.

Investigations on a basis of the individual cow revealed that good individual results could not always be achieved especially not in cows with an absolute body weight far above 600 kg.

26 weeks after FCT there were no significant differences compared to the measurements before trimming. But about half of the animals reached already 4 months after FCT a status comparable with the pre-trimming status.

Discussion

The decrease in the load of the outer claw was mainly due to a load reduction of the outer pulvinal segment. This is the desired effect for this area with the most serious claw diseases.
FCT resulted in a considerable load shift from the outer pulvinal segment to whole neighbouring inner claw. The additional weight load of the inner pulvinal segment (+ 9 %) and the inner apical segment (+ 6 %) exceeded at no time 25 % of the total limb load for both segments of the inner claw. As a previous study revealed that the inner structures of the outer und the inner claw do not differ (SOHRT, J. T. 1999, Thesis Tierärztl. Hochsch Hannover), there is no risk of an overburdening of parts of the inner claw.
An inner claw which is trimmed high in the bulb (a principle of FCT) is able to take over the load of the pulvinal segment of the outer claw on its whole weight-bearing surface: a considerable part of the shifted load is taken over by the apical segment of the inner claw
The comparison of the dynamics of load distribution for different cows indicated that those cows with a mean body weight above 650 kg were faced with a critical overburden of the outer claw two month earlier than cows of the other classes. This difference turned out to be significant only for some measurements. Thus further investigations with a higher number of animals in each group are necessary to examine this aspect.
Under common dairy production conditions, where the cows are kept in free stall barns without pasture throughout the year it is advisable to perform claw trimming at least twice per year. If claw diseases are a major problem the interval between two trimmings should be reduced to 4 month.

DIFFERENCE IN LENGTH OF THE METACARPAL AND METATARSAL CONDYLES IN CALVES AND THE CORRELATION TO CLAW SIZE

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Introduction

The lateral claw of a hind limb is affected by sole ulcers and laminitis much more frequently and more severely than other claws (Smits, Frankena et al. 1992; Kehler and Sohrt 2000). Although this fact is probably known for more than a century, the causes are not completely understood. Mechanical (Rusterholz 1920) or dynamic (Toussaint Raven 1985) overload of the lateral claw has been proposed. Recently, Paulus and Nuss found that the lateral claw reaches further distal than the medial claw. They concluded that there might be a difference in the length between the medial and lateral digit (Paulus and Nuss 2002). Because it had been shown, however, that the length of the digital bones was not different (Ranft 1936), they hy-pothesized that possibly the lateral metatarsal condyle might be longer than the medial (Paulus and Nuss 2002).
Consequently, the objective of the following study was to investigate the length of the meta-carpal and metatarsal condyles in calves and to correlate the results to measurements of the claw size.

Material and methods

The front and hind feet of 42 calves (mean age 21 days, median 7 days) of different breed and sex, which died or were killed of causes unrelated to the study, were collect-

ed at the facilities of the Department of Food Animals, Zürich. The metacarpal and metatarsal bones were isolated and cut with a saw in a transverse direction so two halves were obtained. To determine the bone length, 14 variables were measured on the cut surface of the dorsal halves (Fig. 1). Additionally, 5 measures of the claws - the dorsal wall length, the claw length, the sole with on two distinct points and the bulb height - were taken (Fig 1).
The measurements were done directly with craft instruments (precision 0.1 mm). Then the bone measurements were repeated with the computer software Metron PX® from standard-ised digital photographs. Calculations and statistical analysis were done with StatView® us-ing the paired t-test ($p < 0.01$), multiple regression analysis and Spearman`s correlation coef-ficient.

Results

Manual and digital measurements were not statistically different.
The metatarsal bones were consistently 2 cm longer than the metacarpal bones, as measured by the L2- and L2'-distances (Fig 1).

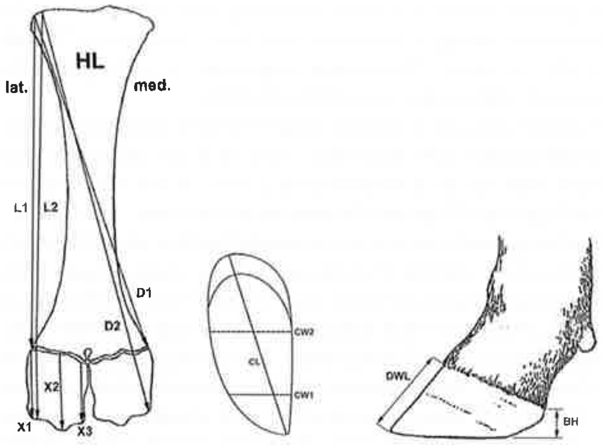

Fig. 1 Measurements of the bones and the claws (scheme); L1 to X3: 7 measurements of the lateral side; not shown: 7 measurements of the medial part (L1' to X3').

The lateral condyles of the metatarsal bones were significantly longer than the medial ones, expressed by the differences between the measured variables ($p < 0.01$ for L2 : L2', X1 : X1', X2 : X2', X3 : X3') (see Fig. 2). In the metacarpal bones, the lateral condyle was also significantly longer than the medial, expressed by the differences between X1 and X1', X2 and X2' and X3 and X3'.

a) Measures taken on the cut surface of a left metatarsal bone, shown on the lateral part. L1 = distance from the lateral end of the MT to the lateral border of the physis; L2 = distance from the lateral end of the MT to the abaxial border of the lateral condyle; D1 = distance from the lateral end of the MT to the medi al border of the physis; D2 = distance from the lat eral end of the MT to the abaxial border of the medi al condyle; X1 = distance from the lateral border of the physis to the abaxial end of the lateral con-dyle; X2 = distance from the physis to the distal end of the condylar ridge; X3 = distance from the axial aspect of the physis to the axial end of the lateral condyle. The relevant measures were taken at the me-dial part accordingly (L1' to X3').
b) Measures of the claw, solear view. CL = claw length; CW1 = claw width at the end of the axial wall; CW2 = claw width at the widest part of the claw.
c) Measures of the claw, side view. DWL = dorsal wall length; BH = bulb height.

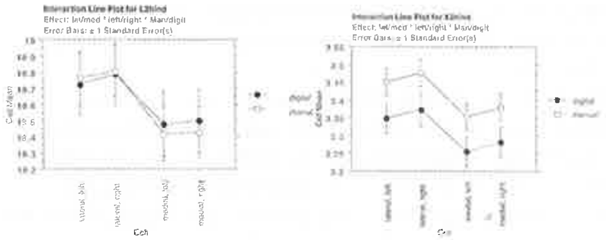

Fig. 2 Differences of mean measures between the medial and lateral condyles of the metatarsal bones of 42 calves.

a) Difference of L2 (lateral side) and L2' (medial side) of the metatarsus: lateral part significantly ($p < 0.01$) longer than the medial part.
b) Difference of X2 (lateral condyle) and X2' (medial condyle) in the metatarsus: distance from the physis to the lateral condylar ridge significantly ($p < 0.01$) longer than to the medial.

Discussion

The measurements of this study confirm that there is a considerable difference of the meta-carpal and metatarsal bones regarding length, as described earlier (Petersen 1921). In the calves of our study, the difference was almost exactly 2 cm. Additionally, it is shown by our study that there is a significant difference in the length of the medial and lateral condyle in both the metatarsus and metacarpus. The lateral condyles are longer than the medial ones.
According to our results, the lateral claw of hind limbs is bigger in calves, expressed by claw length and claw width. However, claws of calves are small and differences in claw size are subtle. It also has to be born in mind that it is difficult to obtain concise values when biologi-cal tissues are measured that can be compressed and therefore may vary in size.
Positive correlations between claw size and length of the condyles were found. The longer lateral condyle corresponded to larger lateral claws.

Conclusion

There is a significant and constant difference in length of the metatarsal condyles in calves. A positive correlation between the length of the condyles and the claw length and width exists in the hind limbs.

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MEASUREMENT OF THE TEMPERATURE DEVELOPMENT ON THE CORIUM OF BOVINE CLAWS DURING CLAW TRIMMING USING VARIOUS GRINDING DISCS

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Introduction

Many claw trimmers use motorized disk cutters for functional claw trimming in cows. Many different disks are available for paring off the bovine sole horn: disks with steel blades, disks with a variable amount and various particle sizes of granulated scales of hard metal (carbide cutting alloy), abrasive and sanding disks. These disks are fitted on angle grinders performing up to 10,000 revolutions per minute or a circular speed of 60 m/s for disks with 11.5 cm diameter.
In literature on claw trimming techniques excessive thermogenesis is always mentioned, with a thermic insult of the corium as a possible result of the use of motorized disk cutters (1-11). The occurrence of such high temperatures having a pathological effect on the corium was thought to depend on the surface of the disks - finely grained, coarsely grained or fitted with steel blades - and on the duration pressure of these rotating disks against the sole horn. These possible negative effects have been mentioned in all the textbooks about claw trimming, published in the last years (1-11). Nevertheless we could find no scientific report about this assumed thermic insult.
Thus, the object of this study was to assess and to measure the possible temperature increase on the corium of the sole in claws during correct and incorrect claw trimming using grinding disks with various abrasive and cutting properties.

Material & Methods

The study was carried out on bovine feet from the slaughterhouse. For this experimental study, 4 different disks were tested (Fig. 1): aluminium disks fitted with steel blades (DL-disk, 10.0 cm, Demotec, Germany), disks with a 50% and 70% amount of fitted hard metal granulate (12.5 cm, Harnischmacher, Germany) and an abrasive disk with fine particles of silica granulate (11.5 cm, semiflexible plastics, Cecrops, Spain).
A correct functional claw trimming was carried out with each disk using a standard sole horn thickness of 5 mm in the toe area. There were 4 groups, in each group 10 pairs of claws were correctly trimmed.
Furthermore, an incorrect claw trimming was intentionally performed with each disk; and in each claws the sole horn was cut to a thickness of 2 mm in the toe area. In each group 10 pairs of claws were trimmed.
The claw specimens were prepared before claw trimming following a standard protocol: on the deep frozen claw specimens the tip of each claw (lateral and medial claw) was cut using a hoof pincer in such a way, that the solar corium could be already seen. Using the corium layer as a landmark, the sole thickness that should be left in place - 5 mm or 2 mm - was marked with a colour pen on the cut surface. Two 3 mm diameter holes were drilled through the abaxial wall into the subsolear corium layer: the first hole was located 2.5 cm plantar to the claw tip, the second hole 5 cm plantar to the tip. The bovine feet specimens were then warmed up to 35° C in a waterbath group by group, the digits were fixed on a table, the thermocouples were introduced into the drill holes and fixed with a head-conducing paste. A third thermocouple was used for measuring the room temperature. The thermocouples (type k with a range to 400°C) were connected via a PCMCIA-card (National Instruments NI-1400) to a laptop. Data acquisition, signal conditioning and storing was done under program control (Lab View, National Instruments).
Measurements were taken during the entire claw trimming procedure and for a further two minutes in order to measure the protracted temperature increase caused by the insulation property of the horn tissue after the claw trimming had been finished.

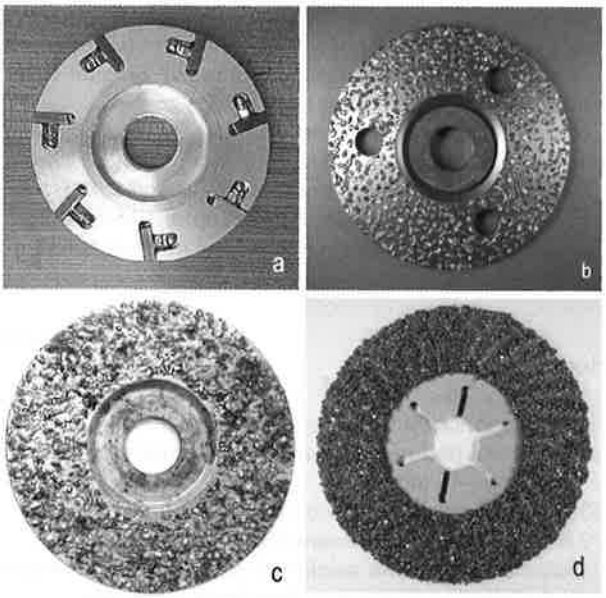

Fig. 1 a, b, c, d: The disks used for this study; (a): aluminium disk with steel blades; (b): disk with a 50% and (c) disk with a 70% amount of fitted hard metal granulate; (d): abrasive disk with fine particles of silicium granulate.

Results

The data of the measurements showed that there was no temperature increase (median: 0.05-0.16°C, SD: 0.14) in the group where the aluminium-disk with steel blades (DL-disk, Demotec) was used, and only a minimal temperature increase in the corium in the 2 groups with correctly trimmed claws where disks with a 50% (median: 0.06-0.26, SD: 0.31) and a 70% (median: 0.13-0.25, SD: 1.48) amount of fitted hard metal granulate were used, and moderate (median: 0.28-0.74; SD: 1.41) temperature increase in the group with correctly trimmed claws where the abrasive disk was applied.
In the groups with incorrect claw trimming we found a very slight temperature increase (median: 0.03-0.57; SD: 1.55) in the group where the aluminium-disk with steel blades (DL-disk, Demotec) was applied, the other groups also showed a slight increase (50% granulate: median: 0.09-1.57; SD: 3.61; and 70% granulate: median: 0.04-1.50; SD: 3.37). The highest temperature increase was in the group with incorrect claw trimming where the abrasive semiflexible plastics disk was used (median: 0.38-2.46; SD: 2.44).
There was no statistically significant difference in temperature increase between the different disks. A statistical difference in heat production was shown between a correct functional claw trimming and incorrect claw trimming.

Discussion

The results of this experimental study indicate that thermogenesis due to mechanical claw trimming using these modern disks can be neglected if correct functional claw trimming is performed with a minimum sole thickness at the toe of 5 mm using modern standard disks.

In claws with incorrect claw trimming carried out producing a sole thickness of 2 mm, only in 5 of 80 values was a temperature increase between 6.0 to 10.6° C observed. All the other measurements in these groups with incorrect claw trimming revealed also only a very slight increase (0-4.3° C), therefore deleterious thermic effects to the corium are also unlikely. An exception was the group of incorrect claw trimming where the abrasive semiflexible plastics disk was applied.
It is known that the sole horn is a very good thermal insulator. These insulation properties of sole horn had been tested in a preliminary experiment comparing the heat conductivity of various metals with bovine sole horn specimens (11).
We can conclude that deleterious effects in claws which will be incorrectly trimmed result from the loss of mechanical stability of the claw caused by excessive thinning of the sole or excessive abrasion (grinding) of the weightbearing margin and distal wall edge. This loss of mechanical claw stability leads to contusion of the corium, to breaking of the thin sole horn or breaking within the white line between the sole and wall and to a subsequent infection of the corium. But, in these cases the development of the infection is favoured by the mechanical damage to the corium and not by an excessive thermogenesis caused by disks. This pathogenesis in the claws of bovine patients where the sole was excessively thinned and the weightbearing margin and distal wall edge was excessively abrased by incorrect claw trimming has been described (12, 13).

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MAGIC FORMULA OF HEEL-LESS TECHNIQUE

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Introduction

Miserable are cows suffering from sole ulcers and white line disease. Since my apprenticeship, I've been hoping and trying to cure these lesions swiftly by trimming claws. In this paper, as a professional hoof-trimmer of my quarter century experiences, I would like to present a charming formula for lameness cows.

Learning about laminitis in horses brings the important role of the deep digital flexor tendon to my attention. In cattle as even-toe ungulates, there are two claws in one leg, the deep digital flexor tendon splits above the fetlock joints and each branch then proceeds to the tubercle of the distal phalanx. It tenses when the foot bears weight. Many troubled feet have a height difference between inner and outer claw and sole ulcer occurs at the typical site of sole-heel junction. Here I have my Heel Depression Theory.

Materials and Methods

Heel depression theory (Heel-less Theory)

The deep digital flexor tendon prevents the distal phalanx from tending to tip forward and upward together with the ligament of the distal sesamoid bone. When there is a heel height difference between claws, the deep digital flexor tendon of the higher claw cannot stretch as much as the lower one. The looseness of the deep digital flexor tendon lets the pedal bone sink into the corium.

Consequently, the posterior part of the solar corium would get direct pressure from the distal phalanx resulting in contusion of the dermis of the typical site (Fig.1). Trimming claws equal height, the deep digital flexor tendon would restore its function to pull up the distal phalanx (Fig2).

Heel-less Technique

(1) Maintenance trimming with the Dutch Method to make the lateral and medial claws in the same height correctly.

(2) Making the toe-triangle on the affected claw (Fig.3) The toe triangle is the apical part of the sole that is from the end of the axial wall to the end of the toe. It is the effective bearing surface for a lame cow

(3) Paring down the posterior two-thirds of the sole as thin as possible until the elasticity is palpable. The transition border from the toe-triangle to the thinned sole should have an abrupt step. The sharp transition can help the cow to stand on the toe triangle and the thinned sole would not transmit the percussion to the lesion from the toe-triangle, which provides good rest for the affected corium. The body weight is supported at the toe-triangle and there would be no weight bearing on the heel of the affected claw (Fig.4).

From July to September 2003, 3,171 Holstein cows were trimmed on 14 dairy farms.

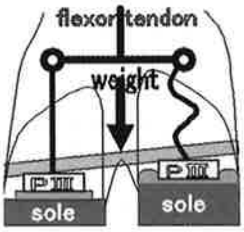


Fig. 1

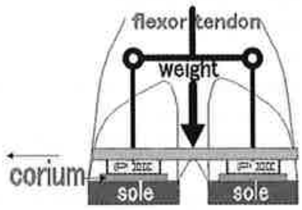


Fig. 2

Fig. 3

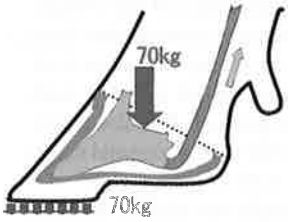


Fig. 4

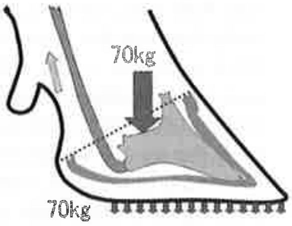
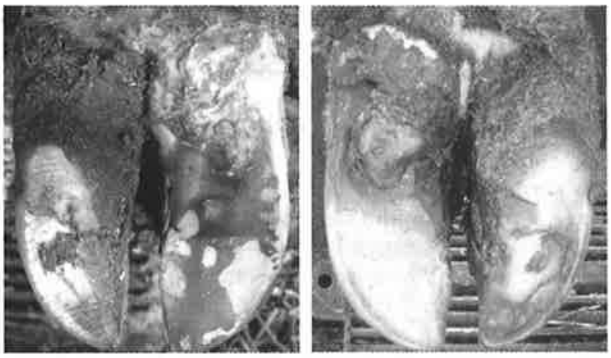


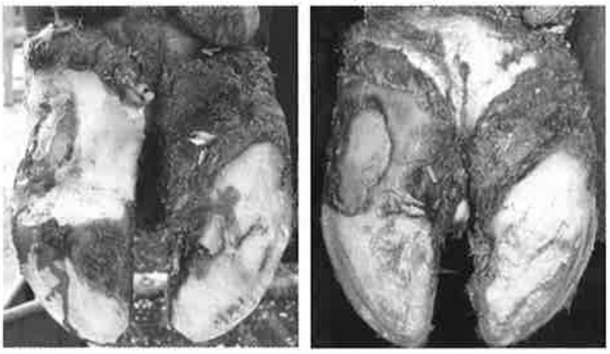
Fig. 5

Results

Out of 3,171 Holstein cows trimmed, two major digital lesions were found as follows: sole ulcers194 cows [6.1 %] (241 feet) and white line disease 114 cows [3.6 %] (123 feet). With the Heel-less Technique, I treated 84% of sole ulcers (202 feet) and 72% of white line disease (88 feet). In addition, as a preventive trimming, I trimmed 97 feet with the Heel-less Technique when yellowish discoloration was observed in the sole and/or white line. Out of all the heel-less trimming applied, fore feet accounted for 20% (78 feet, medial claws 71feet, lateral claws 7feet), and hind feet accounted for 80% (309 feet, medial claws 15feet, lateral claws 294feet). 14 feet needed wooden blocks in my estimation.

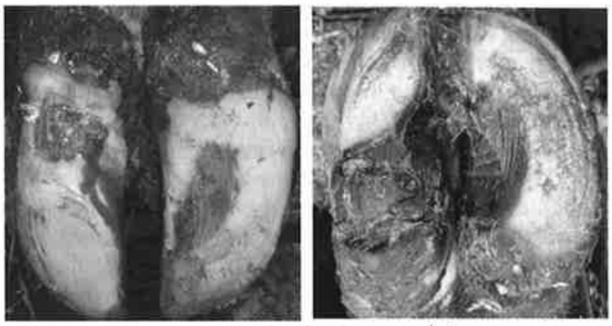


Picture 1 hind left (4 weeks)

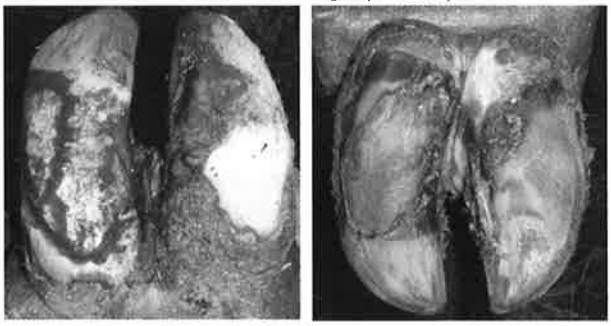


Picture 2 hind left (8 weeks)

Picture 1 shows the toe triangle bears weight as much as the medial claw. The stain of the sole shows there is no weight bearing area on the heel. Picture 2 is a white line disease claw. The bulb of the affected claw was swollen because the pedal bone squeezed the digital cushion out. Eight weeks later it could restore the shape of the bulb. The Heel-less Technique took away compression from the digital cushion and maintained the figure of the claws.

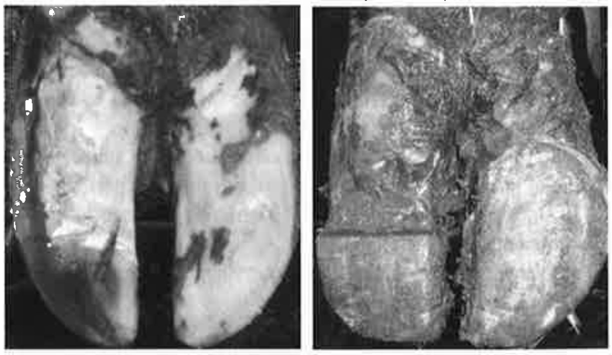


Picture 3 hind right (5 weeks)



Picture 4 fore right (4 weeks)

Picture 5 hind left (5 weeks)



Picture 6 hind left (3 weeks)

Picture 5; Heel-less Technique was not effective when the height difference between the toe triangle and the heel was not sufficient. (e.g. a severely worn out heel or sinkage of the pedal bone) Picture 6; Two blocks were used to make the height difference. It worked well.

Discussion

The Heel-less Technique works well on sole ulcers and white line disease. I'd like to point out three advantages of the Heel-less Technique in therapeutic trimming. First, it can kill pain when a cow stands or even walks. She changes her gait from stepping on the heel first to toe first. The Heel-less Technique provides an alternative way to walk. When a cow feels pain, she walks in a way of toe-first-touching. In the recovery stage she may walk in a way of heel-first-touching. Secondly, thinned sole/heel will reduce the internal pressure and break the force spreading through hard solar horn from toe-triangle. The third advantage is the restoration of the deformed claw shapes. The correct balance between the medial and the lateral claw is restored after several weeks applying the Heel-less Technique. Sometimes the Heel-less Technique didn't work well. It may be difficult to stand with the toe triangle when she's got a weak and swollen pastern. In case of a severely worn heel or sinking of the pedal bone, the toe triangle could not be left high enough or when the toe triangle is not strong enough, applying blocks is recommended.

ANATOMIC DETERMINATION OF THE SOLE THICKNESS IN UNTRIMMED CATTLE

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Abstract

Cattle hoof trimming is an important factor to restore normal function of the hoof and preventing one of the most important economical losses in dairy industry. In functional hoof trimming medial digit of the hindlimb and lateral digit of the forelimb consider as normal digit and recommended to be the first digits to be trimmed, and continue the trimming by pairing contra digits for determination of the toe length.
With regard to some possible variations in growth and wearing of the hoof horn in bovine digits, current study performed to measure sole thickness and it's variation between lateral and medial untrimmed digits.
Three hundred hooves collected from slaughtered cattle were divided, according to the breed into three groups , The most important factor in different groups were body size or body weight of the animals, as cattle in group A were adult registered Holstein that weight more than 550 Kg, Cattle in Group B were Adult Cross Breed weighting less than 550 Kg and more than 400 Kg and finally animals in Group C were adult Native breed that weight less than 400 Kg.None of the cattle under study trimmed routinely. Sole thickness was measured at the most distal end of the sensitive tissue after performing a midsaggital section in medial and lateral digits of fore and hindlimbs.
Sole thickness of forelimb lateral digits recorded as 10.6 ± 4.97, 9.92 ± 5.1, 8.21 ± 5.73 mm in groups A,B and C respectively that were less than thickness of contra medial digits (11.6 ± 4.9, 11.4 ± 5.96, 8.88 ± 5.14 mm). In contrast thickness of the hindlimb lateral digits recorded as11.5 ± 6.65, 10.9 ± 4.98, 7.28 ± 2.65 mm in groups A, B and C respectively that were more than thickness of contra medial digits(11 ± 6.58, 10.1 ± 4.44, 7.08 ± 2.42 mm).
With regard to the results although non of the differences were significant ($P<0.05$), It seems that concerning of the lateral and medial digit in hind and forelimb respectively as the most normal digit and performing functional hoof trimming may result to overtrimming of the opposite digits.

Introduction

Lameness, a multifactorial disease, is no doubt one of the biggest problems dairy producers are facing today. Currently there are many elements contributing to lameness on modern dairy operations, concrete, standing time, cow comfort, walking distance, nutrition, hygiene, and claw trimming (Shearer and Van Amstel,2001). Horny covering of the hooves protects distal parts of the limbs and enables cattle to bear weight and movements. The claw horn and it's supporting structures are a modified skin and also consist of a cellular epidermis and an underlying dermis. The dermis or corium is tough and resilient, provides nutrients to the epidermis and cushions bones and joints against mechanical injuries (Magsa and Kempson, 2002). The dermis presents several segments that correspond to the parts of the hoof. The horn of the wall is produced over the coronary dermis and slides distally over and between the laminae of the dermis over which sufficient horn is produced to maintain adhesion. The horn of the other parts of the hoof grows away from the dermis at a rate of 5 mm per month, which makes dairy producers to trim the claw (Dyce, 1995). Anatomic studies have shown that there are three critical structural units in the claw. These are the connective tissue system in the suspensory and the supportive apparatus, the vascular system and the differentiating epidermal cells (Mulling, 2002). At the toe, the pedal bone is tightly adherent to the corium and therefore to the horn but, caudaly it is separated digital cushion (Blowey, 1998).
In order to save normal function of the hooves regular hoof trimming is essential, but as mentioned before " If there is no lameness problem, trimming can produce it"(Toussaint Raven, 1989). As one of the primary purposes of the claw horn capsule is to protect the corium, when excess claw horn has been removed and the sole is no longer able to properly support the cow's body weight, the underlying corium subject to damage from bruising (Shearer, 2002 and Mulling, 2002). In functional hoof trimming medial digit of the hindlimb and lateral digit of the forelimb consider as normal digit and recommended to be the first digits to be trimmed, and continue the trimming by pairing contra digits for determination of the toe length. With regard to some possible variations in growth and wearing of the hoof horn in bovine digits, current study performed to measure sole thickness and it's variation between lateral and medial untrimmed digits.

Materials and Methods

Three hundred hooves collected from slaughtered cattle were divided, according to the breed into three groups , The most important factor in different groups were body size or body weight of the animals, as cattle in group A were adult registered Holstein that weight more than 550 Kg, Cattle in Group B were Adult Cross Breed weighting less than 550 Kg and more than 400 Kg and finally animals in Group C were adult Native breed that weight less than 400 Kg. None of the cattle under study trimmed routinely. Sole thickness was measured at the most distal end of the sensitive tissue after performing a midsaggital section in medial and lateral digits of fore and hindlimb.

Data compared by t-test and values under 0.05 considered as significant.

Results

Sole thickness of forelimb lateral digits recorded as 10.6 ± 4.97 , 9.92 ± 5.1, 8.21 ± 5.73 mm in groups A, B and C respectively that were less than thickness of contra medial digits (11.6 ± 4.9, 11.4 ± 5.96, 8.88 ± 5.14 mm). In contrast thickness of the hindlimb lateral digits recorded as 11.5 ± 6.65, 10.9 ± 4.98, 7.28 ± 2.65 mm in groups A, B and C respectively that were more than thickness of contra medial digits(11 ± 6.58, 10.1 ± 4.44, 7.08 ± 2.42 mm)(Table I).The difference between lateral and contramedial digits were not significant ($P<0.05$).

Table 1: Distribution of sole thickness in different groups under study

FORELIMB						HINDLIMB					
A mm		B mm		C mm		A mm		B mm		C mm	
LATERAL	MEDIAL	LATERAL	MEDIAL	LATERAL	MEDIAL	LATERAL	MEDIAL	LATERAL	MEDIAL	LATERAL	MEDIAL
10.6± 4.97	11.6± 4.9	9.92± 5.1	11.4± 5.96	8.21± 5.73	8.88± 5.14	11.5± 6.65	11±6. 58	10.9± 4.98	10.1± 4.44	7.28± 2.65	7.68± 2.42
NS		NS		NS		NS		NS		NS	

Discussion

As one of the primary purposes of the claw horn capsule is to protect the corium, when excess claw horn has been removed , the sole is no longer able to properly support the cow's body weight, and the underlying corium subject to damage from bruising (Shearer, 2002 and Mulling, 2002).

In functional hoof trimming the most important determinant is toe length and if the toe is cut shorter, then the sole will automatically be trimmed thinner (Blowey, 2002) that can result to hemorrhage of the sole (Paulus and Nuss, 2002). It has been mentioned that medial hind claw and lateral fore claw represents the normal claw, and has to be used as a model for more abnormal lateral and medial claw respectively (Shearer, 2002). Thickness of the sole in medial digit of the forlimb and lateral digits of the hindlimb in different breeds is slightly more than corresponding digit, but the difference were not significant($P<0.05$). With regard to the 5-7mm estimation of proper sole thickness for protection of the sensitive inner parts (Van Amstel et al,2002) It seems that just a small diameter of the sole (table I) could be trimmed during hoof trimming. Proper sole maintenance would be the result of correct estimation of the toe length in performing the first cut of hoof trimming. In according to the results, concerning medial and lateral digits in fore and hindlimb as normal digits is really important in maintaining the sole thickness and overtimming would be the result in case of missing the above mentioned fact. Body weight could be a key in estimation the sole thickness and also toe length in performing the first cut of hoof trimming.

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RESULTS FROM CLAW TRIMMING AND ELECTRONIC RECORDING BY ONE PERSON

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Introduction

During three years of claw trimming 19797 examinations were made of the hind feet of cattle on 99 farms located mainly in North Germany. The recordings were stored electronically. Further data about the animals including the cow's identity, breed and yield characteristics (downloaded from the internet) and some farm information were also recorded. Detailed information about the recording system is presented in another paper in these proceedings (Pijl, 2004).

Usually the registered farms are visited twice a year and the complete herd (all animals of 24 months and older) is trimmed. There are 35-500 animals on each farm, mostly Holstein x Friesian (HF) or cross-bred HF. The animals mainly graze on pasture in the summer and are kept in cubicle stalls in the winter. The main feed is silage.

The trimming and the diagnoses were done by one person (RP). This paper presents some preliminary findings on the types and distributions of lesions. For rotation, laminitis and digital dermatitis some further details of the influence of parity and calendar month and the occurrence of other lesions have been presented.

Results

There were 51% of right hind legs and 49% of left hind legs with at least one lesion. Laminitis was the most common lesion diagnosed (30%), followed by interdigital dermatitis, rotation and digital dermatitis. Sole ulcers were quite rare, possibly because most of these animals undergo prophylactic trimming once or twice a year (Figure 1).

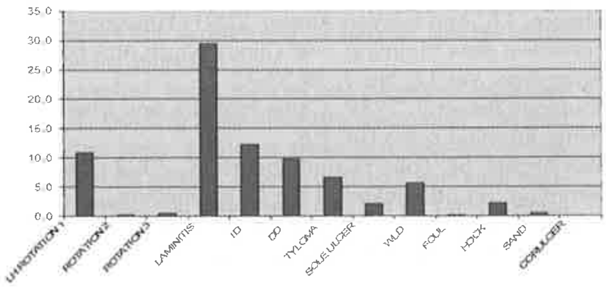

Figure 1. The prevalence of lesions on the left hind foot

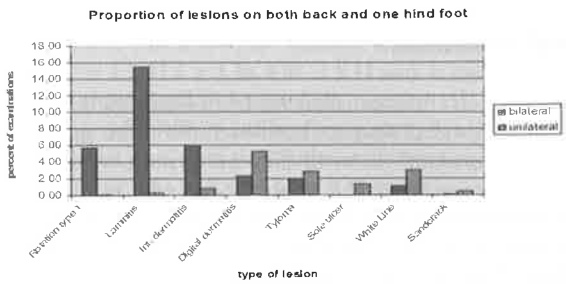

Figure 2. The distribution of abnormalities by unilateral or bilateral occurrence

Laminitis and rotation were predominantly diagnosed bilaterally whilst the rest of the diagnoses were more likely to be unilateral (Figure 2). However the overall prevalence of lesions between left and right hind feet was very similar. The left hind foot only was therefore used for further analysis.

Rotation of the medial claw

In rotation of the medial claw of the hind leg (Figure 3) the position of the medial hind claw against the lateral hind claw changes (Pijl, 1998, 2000). In most cases the toe tip of the medial claw moves in front of the toe tip of the lateral claw. At the same time the dorsal walls are not level. There were 1976 cases with rotation, and 1716 other diagnoses were made (Table 2). This means that in 87% of cases a combination of rotation and one other abnormality occurred.

Figure 3. Rotation of the medial claw.

Table 1. Number of examinations and the percentage which show rotation and simultaneously another abnormality

Lesion	Number	Percent
Laminitis	755	35.25
Interdigital Dermatitis	350	16.34
Digital Dermatitis	390	18.21
Tyloma	88	4.11
Sole ulcer	21	0.98
White line disease	57	2.66
Swollen hock	55	2.57

Table 2. Number and percentage of rotation in different lactations

no. lactations	no. rotations	total no. examined	% Rotations
0	1	2	50.00
1	791	3816	20.73
2	645	4756	13.56
3	305	3499	8.72
4	145	2606	5.56
5	46	1653	2.78
6	23	1038	2.22
7	12	560	2.14
8	7	256	2.73
9	1	138	0.72

With increasing age the prevalence of rotation decreases. This may be because '"functional claw trimming" has a positive influence on the cows on these farms.

Another explanation for this phenomenon may be that animals with rotation are sooner sold than others.

Laminitis

There were 5830 cases of laminitis; in Table 3 the other lesions also recorded at the same time are listed. On 81% of occasions animals with laminitis also had one or more other abnormalities simultaneously.

Table 3. Number and percent of lesions associated with laminitis.

Type of lesion	Number affected	Percent affected
Rotation 1	755	12.95
White Line	614	10.53
Tyloma	725	12.44
Sole ulcer	290	4.97
Digital Dermatitis	707	12.13
Inter. Dermatitis	1364	23.40
Thick hock	258	4.43

Digital dermatitis

Figure 4 illustrates the pattern of digital dermatitis by time of year. This indicates that there are peaks of DD in the winter and spring months with a few peaks at other times of year. This is similar to that published in 1994 (Pijl). This may occur because of how the cows are housed or fed.

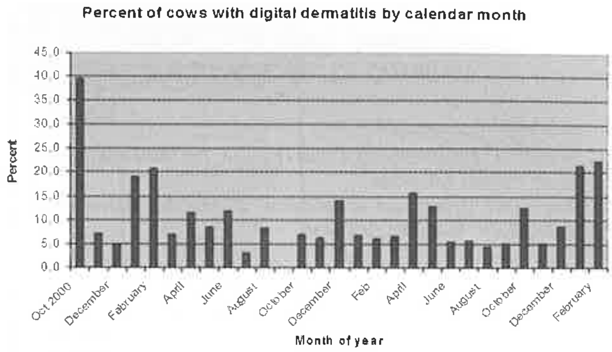

Figure 4 Prevalence of digital dermatitis by calendar months

Conclusions

With 20,000 animals , trimmed by one person, we reported that laminitis and rotation almost always occurred on pairs of legs. The other diseases recorded were not bilateral but there was almost no difference between the proportion of affected legs, no the prevalence of lesion, by left and right hind legs. The most common lesion was laminitis, followed by interdigital dermatitis , rotation of the medial hind claw and digital dermatitis. More often we saw a combination of laminitis and other abnormalities at the same time on the same foot. This was also the case with rotation of the medial hind claw. A wave shaped prevalence of digital dermatitis by calendar month was seen. Usually the highs and lows occurred in the same months each year.

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ELECTRONIC DATA RECORDING DURING CLAW TRIMMING

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Introduction

Modern technology makes it possible to record electronic data during claw trimming in the stable. Using this technology it is possible to simultaneously link the diagnoses with recording of basic cow data like registration number, date of birth, pedigree and milk yield data and then integrate the new data. Thus the history of the condition of the cow's claws and the breeding is registered permanently. Information about pedigree and claw health is a vital element for the future selection of animals according to their history of leg problems.

The concept of three programmes

The main programme is in the "data server". Here all the basic data of an animal or/of a farm are filed. Under "client" the farms are listed with their addresses. From here you order the latest and ‚new' basic data of the cows.
With the pocket pc you work in the stable.

Details

Available data are recorded on "data server". These data (breeding and yield, etc.) you download from internet or CVS, with new ones. Here you find ear number, farm number, birth of date, mother, father, date of calving, day of calving, number of calves and yield data like milk yield, milk composition and cell count. You cannot exclusively work with the "data server" programme, you have to use it in combination with "client" programme.

In the "client" programme you select a farm and thus can work with the data of the herd and the animal as the "data server" will automatically open when the pc has started. Here as well as on the pocket pc you can correct or add data. The history of the herd and the animals have been filed for the complete period of data recording.

The main recording takes place on the pocket pc. The data for the cow and farm can be entered directly in the stable without a pen. The buttons are designed for finger tip entries. The link between the pocket pc and the pc makes it possible to exchange new data.

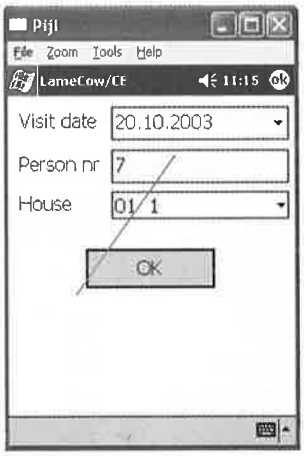
The actual procedure

Via the internet you can ask for the latest animal data after the most recent recording visit at the data processing centre. For this a "declaration of agreement" by the farmer is mandatory. The latest data are provided in a special file. The different units with their data are updated into the "client" programme ("data server") via ADIS-import.
This occurs automatically when the pocket pc asks for the data of the herd and animals. You select a herd on the pocket pc. Here you always have the "farm list", with the parameters of the farms you worked with once. You can add new farms to this list at any time. Only after importing data from the pc to the pocket pc is this "farm list" refreshed'.
The pc is used to gain new data via the internet. This can also be done by the use of the "compact flash card" directly with the pocket pc from an external data server. It is possible to serve several users with one "data server". The data must be provided from a third person here. Contact is made automatically by the FTP connection on the pc or an MSN link.

Procedure in the stable

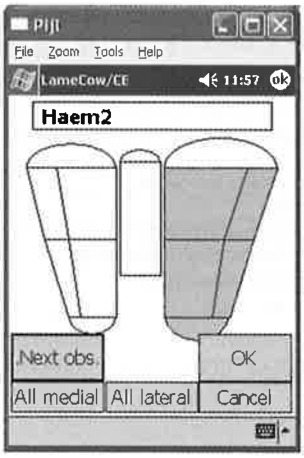
First you select the parameter of the farm and fill in the missing data (for example changes to the farm.) Then you start work on the animal and the pocket pc.

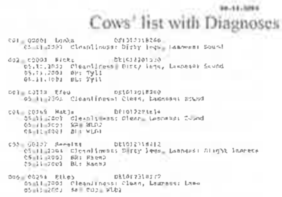
What do you want to do? Visit date etc.



Has everything been filled in and have the necessary adjustments and
changes been made? You can have a look at the cow list with each animals' history and individual yield features. "Visit" asks for individual features which may have undergone a change between trimming sessions.
The " date of visit" (visit date) can be extended over several days. Each trimmed animal is given a number from that person, who has trimmed the cow. The farm is registered where the animals is kept during trimming.

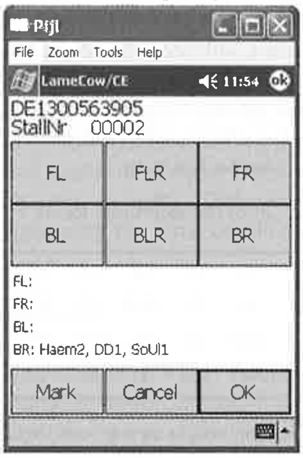
Put in the cow number. Clean or Lame





You enter the number of the animal. You can select either the farm's registration number or the last five digits of the life number.
Cleanliness and lameness have to be filled in before you can proceed to the next task.

Choose the leg or pair of legs Make your diagnose



To which leg or pair of legs do you have to add a diagnosis?
You select diagnosis or diagnoses. A score between 1 and 3 is available. When you tap the button once, score 1 comes up, with two and three tips on the buttons score 2 and score 3 come up accordingly.
If you chose a wrong diagnosis, another tip will delete the scores and you can start again. Up to 17 different diagnoses are available and you can choose as many as necessary.

The zones can be activated in different fields. All 17 diagnoses pop up in the left upper corner. Only if each diagnosis has been assigned to a zone, can you continue with the next leg or a different animal.

Finally you can print a cow list, 2 tables and an analysis of the diagnoses with the pocket pc in combination with a portable printer and the infrared interface. These data are taken home and filed on the "data server" to be ready for use at the next session.

Conclusion

We have created a recording programme which is easy to transport in a pocket pc and easy to use on the farm. The diagnoses are filed with the basic data of the animals and stored. Integration into the rest of the data at the central processing centre is possible and the farmer can call up the status of each animals. Even after the animal has left the farm, its data remains stored.
Thus you don't lose information about former generations, especially data about the sires of cows.
The farmers get a printed version of the diagnoses of the claw trimming in the stable immediately and the results can be discussed with him.
Our programme is important for the evaluation cow foot health and the data can be useful as criteria for the (breeding)-selection of cows.

EFFECTS OF REGULAR CLAW TRIMMING IN DIFFERENT HOUSING SYSTEMS

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Introduction

Claw disorders are a major problem in modern intensive dairy production. Lameness in cattle is a multi-factorial disease. Factors reported to contribute to the development of lameness include environment, nutrition as well as infectious, genetic and behavioural causes. The majority of lesions does not result in lameness, but if not treated they can lead to severe problems.

Changes in dairy farming systems over the past years have seen a dramatic decline in the number of dairy units and at the same time, an increase in the number of cows kept at each of the remaining units. Animal welfare laws necessitate changing of existing structures. Lameness is a major economic and welfare problem in dairy herds. Environment has a major impact on the incidence of lameness. Ongoing economic pressures, the consumers demands for safe and healthy food as well as the claim of the animals for optimal housing conditions has led to a process of rethinking in Austrian agriculture and thus to the building of loose housing systems. The typical housing system in Austrian dairies is still tied housing with short or long stalls. The object of this field study was to show the effect of a regular claw trimming in different housing systems.

Material and Methods

Animals/herds

164 cows (Simmental, Holstein Friesian and Red Friesian) of ten dairy farms with an almost equally high milk yield were used for this study in the years 1997 and 1998. Five farms had a tied housing system with a short or a long stall which is typical for Austrian dairy farms whilst the other five had a loose housing system with cubicles. All farms had to be member of a breeding association. About 50% of the cows of each farm were selected at random. Cows which were pregnant (7 months and more) at the time of the first examination were excluded because of the risk of abortion due to the stress of claw trimming at this stage of pregnancy. Before the examination started a farm survey had been done. General data of the farm structure and special data on housing, feeding, and performance were collected.

Evaluation of the claws

In this study the claws were examined, trimmed (functional claw trimming) and evaluated three times at month 1 (I), 7 (II) and 13 (III) by the claw scoring system of BOOSMAN et al. (1989) modified by STANEK (1994). The sole of the claws was divided into 4 zones, and hemorrhages and discolorations were evaluated. Furthermore alternate grooves and ridges, the concavity of the dorsal wall and the sole relief and fissures in the white line were also included in the score. Massive alterations like double sole (purulent or non-purulent), sole ulcer, ulcer at different localizations and toe ulcer got bad marks accordingly. The sum of all these alterations of all eight claws was the so called "cow claw score". The median of all "cow claw scores" (CCS) of a farm resulted in the "farm claw score" (FCS).

Results

The results of the examination of the claws are summarized in table 1, 2 and 3. The farm claw scores of the first examination (FCS I) were in a range between 13 and 47. Very large differences concerning claw injuries exist between the different houses within the same type of housing, especially in the tied housing system (T1 to T5). The values of claw scores of farms with loose housing (L6 to L10) were in a smaller, but altogether higher range. The third examination showed almost similar CCS and FCS values in tied housing and a clearly visible decrease of the scores (CCS and FCS) in loose housing.

Table 1: Farm claw scores (FCS 1 - 3) of the examined farms 1 to 10.

Farm	T1	T2	T3	T4	T5	L6	L7	L8	L9	L10
FCS I	20	13	47	34	36	39	34	35,5	42	37,5
FCS II	17	15	34	36	31,5	29,5	32	34	34,5	28,5
FCS III	20	16	35	32	27,5	16	23	30	27	27

Table 2: Minimal, maximal and median values of the "cow claw score" (CCS)

	Tied housing (T)			Loose housing (L)		
CCS	I (n 81)	II (n 75)	III (n 65)	I (n 83)	II (n 82)	III (n 68)
Minimal CCS	0	5	5	3	5	3
Maximal CCS	105	136	67	87	88	65
Median CCS	27	29	27	37	31,5	25

Table 3: Frequencies of claw disorders in %

	Tied housing (T)			Loose housing (L)		
Claw disorder	I (n 81)	II (n 75)	III (n 65)	I (n 83)	II (n 82)	III (n 68)
Double sole	20,98	12,00	12,31	28,92	17,07	8,82
Ulcer	8,64	8,00	12.31	8,43	4,88	5,88
DD	19,75	4,00	10,77	19,28	21,95	17,65
HHE	19,75	14,67	18,46	21,69	46,34	22,06

Discussion

The cow claw scores (CCS) of the individual animals determined at the three examinations were comparable to the values published by BRANDESJSKY (1993) and BODLAK (1996) which had been using the same scoring system (numbers possible ranging from 0 to 136). This claw score compiles all relevant information on alteration of the claws caused by type of housing, but also those caused by laminitis. Causes for haemorrhages with an alteration of the colour of the claw horn or fissures and cracks lie in the past as it takes two to three months for the changes to become apparent.
The results of the farm claw scores (FCS) showed the following: 1. Tied housing (T): The farm claw scores of farms T1 and T2 which had good claw conditions in the first examination did not differ much. In farms T3 and T5 which had the highest claw score values in the first examination had an obvious improvement of claw health. 2. Loose housing (L): All five farms showed a clearly visible improvement of claw health.
The farm claw scores developing differently over time depending on the housing system used (higher scores compared with the initial examination and the progressing decrease of the claw scores in the farms employing loose housing systems in the course of the three examinations at time of the claw trimming) led to the assumption that claw trimming does indeed play a significant role in the quality of the claw horn. In the loose housing system claws are usually trimmed only on demand, in the tied stall systems at least once a year in spring (before the grazing period). Claw trimming proved successful in improving the claw condition in loose housing systems.

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THE INVENTION OF "THE PORTABLE CATTLE CRUSH"

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We invented the portable for easy operation under any circumstances without assistance.

This portable cattle crush net weight is 150 kg. A wide abdominal belt is attached to the two manual gears on the upper frame.

The operation of the portable cattle crush is quite simple. When the front part of the device is lifted about 30 degrees, the center of the gravity shifts toward the rear wheels, and the entire crush is balanced nicely. At this point, it can be moved around with high stability.

For treatment, an injured cow is first tethered to the nearby stanchion or the post (Fig. 1). Then, the portable cattle crush can be moved toward the animal from their rear end (Fig. 2, 3, 4). Cows usually become tense and try to move backward, but rarely move sideways (Fig. 5). Next, the abdominal belt (80 cm wide) must be connected to the gears, to lift the animal's weight of approximately 300 kg (Fig. 6). This means the crush will be anchored and stabilized with the total weight of 450 kg. And this partial weight support lets the animal stand easily and safely on three legs during treatment. This device enables us to give necessary treatment to both front and rear limbs (Fig. 7, 8, 9). When the treatment is completed, the portable crush can be rolled away(Fig 10).

Lameness is one of the three major health problems in dairy cattle, along with infertility and mastitis. Therefore, both early diagnosis and treatment are crucial as well as its prevention. The most difficult part of treating lameness in cattle is to lift and fix the animal's leg. If all cows lift their leg and stand still, the treatment of lameness will be as easy as artificial insemination. This is why an easy and safe method to lift and fix the animal's leg is needed.

Although manual retaining technique can be performed anytime, anywhere and without any assistance, it would require great experience, skill and physical strength. Nevertheless, it is still impossible to check the animal's condition thoroughly, and it may be considered impractical as a general technique.

There are other effective ways to examine lameness, such as suspending the leg using a rope tied over the beam. However, this method cannot guarantee successful treatment every time and sometimes causes animals to fall. This is not safe for both human and animals. Above all, this method is only effective on hind limb.

There are several disadvantages in using a conventional fixed type cattle crush. For example, it is extremely difficult to move a scared stiff animal to the crush. This cannot be done by one person alone and assistance by other people will be required. In other casess, if the crush is installed at the return aisle or the exit, treatment must wait until all milking is completed. This is also inconvenient for the treatment of dry cows. Using the portable cattle crush allows us to treat lameness by single person under any situation without any help. Since it has its own wheels, the crush can be transferred anywhere it's needed, and stored anywhere in the farm.

As the size of dairy farms increases, their labor has to be divided. Therefore, it is important for us to be able to treat animals without help, to increase efficiency of the work on the farm.

Effect of hoof trimming several times of the year, using a crush equipped with a compressor, is essential as a preventive care to the dairy cattle. It is also important to treat lameness as soon as noticed. We believe the portable cattle crush gives us the same convenience as a stethoscope in daily routine, letting us treat lameness so easily and safely.

Fig. 1

Fig. 2

Fig. 3

Fig. 4

Fig. 5

Fig. 6

Fig. 7

Fig. 8

Fig. 9

Fig. 10

CAN DIFFERENT OBSERVERS RELIABLY ASSESS LAMENESS IN DAIRY COWS?

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Abstract:

Lameness score is a key element of clinical examination, prevalence surveys and welfare assessment. The effects of individual treatment or preventive steps in a herd are frequently measured as changes in the degree or prevalence of lameness, which is often measured by more than one observer. Thus, agreement among observers is a prerequisite of detection of changes in lameness. In this study, we have investigated the agreement between observers, using a 4-point scale for lameness scoring.

As a part of a welfare assessment protocol, 3 observers scored lameness on 40 cows from each of 3 dairy herds with Holstein-Friesian cows held in loose-housing cubicle systems on concrete slatted floor. Observations from 3 farms were pooled, and the 3 observer pairs scored the same 79, 115 and 117 cows. The observers used a 4-point scoring system that consisted of: 0: no lameness; 1: slightly lame; 2:obvious lameness; 3: Severe lameness.

The prevalence of each score was; score 0: 83% (range 67-95%), score 1: 13% (range 3-29%), score 2: 3% (range 1-4%) and score 3: 1% (range 1-2%). Thus, the overall prevalence of lameness in the 3 herds taken together varied between 5 and 33%, depending on observer. The 3 observer pairs agreed on the degree of lameness for 78% (range 72-87 %) of the cows, the average Kappa value was 0,28 (range 0,23-0,34) and weighted kappa 0,40 (range 0,35-0,47). The low kappas were mainly due to disagreements regarding slightly lame and non-lame animals.

The results suggest that observer variation in lameness score could indeed be a source of bias. The agreement could be improved either by practice or by a more detailed description of the scoring system, especially concerning slight lameness. This should be considered when research is planned and results are interpreted.

PRESSURE DISTRIBUTION UNDER THE HOOFS OF TRIMMED DAIRY CATTLE COMPARED TO UNTRIMMED

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Abstract:

The distribution of pressure applied at the weight bearing surface of claws during the stance phase was assessed in 14 cows, both before and after trimming. Pressure measurements of front and rear feet were collected from mature Holstein cows using a pressure sensitive film system Matscan ? (Tekscan Inc.). Baseline data were collected prior to trimming from each cow during a single stride. Claws were visually trimmed and balanced according to the method of Toussaint Raven for evaluating the effect, if any, on pressure distribution within and between the claws of each foot. The middle point within the stance phase (mid-stance) of front limbs and rear limbs of the cows was selected for the analysis. The distribution of pressures for un-trimmed and trimmed claws within four pre-selected regions were compared. The analysis was done using a mixed model for repeated measurements from SAS? and tested for variations in pressure distribution within claws between the two groups. There was a small evidence ($p < .0702$) that the regions within claws varied within the two groups according to G vs.R (group-region) interaction for Least Squares Means of pressure (psi). On the other hand, there was significant evidence ($p < .0011$) that the regions varied between groups when the model was tested with pressures normalized to the total pressure applied on the claws (G vs.R interaction for Least Squares Means of percent (%) of total pressure). The results have shown that a slight percentage of the total pressure on heel and lateral sole was transferred to the medial sole but contributed little for balancing the claw.

TREATMENT AND CONTROL OF CLAW DISEASES

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To be asked to present a state-of-the-art lecture on treatment and control of claw diseases is indeed an honour and a challenge. The past decade has seen many advances in the understanding of pathogenic processes leading to diseases of the digit of cattle and the resulting information has suggested new avenues for treatment and control which may be used to supplement our existing methodologies. I believe we have come a long way from the time when our only option in the handling of bovine digital diseases was to treat "Footrot" with systemic antibiotics or by amputation although these two methods still have a place in the armamentarium of the bovine practitioner today. Armed with a better understanding of anatomy and physiology of the hoof, a better appreciation of the role of factors leading to sub clinical laminitis (SC) and the role SC plays in the development of non-infectious claw diseases, we are better able to effectively treat and control (perhaps even prevent?) this very expensive and painful spectrum of diseases leading to lameness and loss of production. Infectious claw diseases are a leading source of lameness in intensive production facilities and the increasing international spread of such problems remains a major concern within the industry and our profession. Intensive efforts are underway to develop effective methods of diagnosis, control and treatment, the last of which is made even more difficult by the ever increasing constraints of national and international institutions to restrict the use of effective treatment regimens in the interest of consumer protection and long-term health considerations for both human and animal populations. To present an overview of current methodologies to treat and control claw diseases within this framework is therefore both a motivating and intimidating task.

The documentation of developments in treatment and control of claw disease is largely found, not surprisingly in the well-documented proceedings of this meeting published bi-annually. In particular the last ten years of proceedings have contained the majority of new and relative information available for those of use interested and involved in claw diseases. The other major source of contemporary information is the proceedings of the world cattle association, which meets around the world each year. The "fraternity" of claw trimmers, animal scientists and veterinarians who regularly attend these meetings and frequently publish in other journals tend to present their information first in "our" proceedings. Textbooks continue to serve as reliable sources of basic information, provide a broad based overview and perspective valuable for the first step into the realm of digital diseases but lag behind in transferring the most up to date information in our rapidly developing specialty. The advent of Internet access to digital textbooks which can be updated almost instantaneously on a chapter-by-chapter basis should provide up to date information to practitioners worldwide - I'm looking forward to seeing such a book dedicated to digital diseases in cattle.

I will present my overview with a preliminary look at recent advances in anatomical information, which has provided a solid basis for understanding newer concepts in biomechanics, physiology and pathophysiology. This will be followed by a section on state of the art comments on treatment of infectious and non-infectious diseases of the claw. The final section will review control of claw diseases from the perspective of recent developments in monitoring incidence of claw diseases for the purposes of diagnosis and evaluating treatment methodologies.

Anatomy:

While the anatomy of the bovine digit has not changed (to my knowledge) for a significant period of time, our understanding of the anatomy and functional anatomy has made significant strides within the last few years, which affects our therapeutic opportunities.
The group from the Department of Veterinary Anatomy from the Free University of Berlin (Budras, Mülling, Westerfeld) has expanded our understanding of the anatomy of the claw lamina/lamellae, which is so crucial to the health, and functionality of the digit. Not only have they continued to examine the claw but also in combination with interdisciplinary support from other colleagues have integrated their findings with patho-etiological factors to further shed light on the role of disease processes leading to alterations to the integrity of the suspensory apparatus of the claw which for many of us is an additional approach to the evaluation of claw disorders.
Observations of gross anatomical relationships and normal histological findings combined with scanning electron micrography have lead to a better understanding of the three dimensional aspects of the supporting structures within the claw and clearly define the uniqueness of the bovine claw in comparison with the anatomy of the equine hoof. In doing so they have added a new understanding of biomechanics and pathological processes of so called laminitis which has increasingly been considered as a multifactorial disease and is coming under

increasing scrutiny as to its exact role in specific diseases such as claw ulceration.

The group from the University of Zürich (Lischer, Ossent) have combined clinical and pathological experiences to produce a new perspective on the functional aspects of biomechanics of the sole and heel of the claw in our cattle populations. The presence of fatty digital cushions as supportive structures in the heel and sole region as additional weight bearing factors supplementing the reduced carrying capacity of the bovine suspensory apparatus of the claw is an example of this. Biochemical analysis of fat cushion quality relative to age and susceptibility to sole ulceration has provided an insight into factors which might be managed during periods of high risk for development of claw disease and opened a new perspective into areas to further evaluate factors influencing the development of disease in different age groups. The metabolic changes occurring during the beginning of lactation in heifers may be affecting the cushioning capability of the fat within the claw and be reflected in a predisposition to development of sole ulcers. The work of Paulus and Nuss (2002) relating to sole thickness measurements provides further information relative to physical factors to this critical area.

The ability to measure claw physical properties using such techniques as Rahman Spectrometry (Petrie et al, 2002) if further expanded could produce a new insight into physical aspects of claw wall properties and their role in health and disease. The role of genetic factors related to horn quality and predisposition could in the future add another dimension to the ongoing battle with both infectious and non-infectious diseases of the digit.

Ultrasonographic examination in the evaluation of normal and abnormal structures affected in lameness has progressed at a rapid rate. To date most applications in orthopaedics have been applied to proximal regions but distal limb problems in joints and tendons are readily examined for diagnostic and prognostic purposes. The group from Vienna (Köfler, Stanek,) have examined and documented almost every conceivable orthopaedic structure available to the application of ultrasound probes both transcutaneously and internally. In many clinical examinations of individual animal (occasionally herd outbreaks) the ultrasound findings further add to diagnostic and prognostic decisions.

The search for a better understanding of disease processes involves the attempt to find markers of degenerative and septic processes and indicators of success or failure in the monitoring of treatment regimens. Matrix metalloproteinases (MMP's) are proteolytic enzymes secreted by macrophages, epithelial cells, endothelial cells and fibroblasts within the extra cellular matrix. They are involved in the metabolic turnover of proteoglycans in normal healthy joints as well as in disease processes and are identified and quantitated by the use of enzyme immunoassay techniques performed on synovial fluid aspirates. As such they can be considered to be markers of processes occurring within a specific joint (Sumner-Smith, 2002). Matrix metalloproteinases have been examined relative to their role in degenerative joint diseases by a number of researchers. Arcan et al., in 2002 demonstrated the presence of MMP's in cattle with ongoing septic joint disease. Proteolytic enzyme analysis relative to degenerative, septic and other aetiologies continues to develop as another aid in evaluation of joint disease and lameness evaluation. We can expect further progress in the understanding and treatment of lameness in conjunction with continued research in the area of applied pathobiology in the near future. It thus behoves us to keep abreast of the new information relating to mediators of inflammation and disease and the application thereof in our field.

Treatment of claw diseases

Infectious diseases

The use of topical medications with or without bandages to treat infectious conditions of the limb and digit will probably always be controversial and remain in the realm of personal preference of the claw trimmer or veterinarian involved. Likewise is the controversial topic of which medications are allowed to be used in infectious (and infected) conditions, the difference however is that this decision will not remain solely within the domain of the veterinarian but will continue to be at the discretion of governing bodies (such as national or international agencies) with far-reaching powers. In Europe today, one must always be aware of the ever-changing regulations regarding the distribution and use of a vast number of medical products, which were previously not so strictly controlled. What was allowed last month or last year may have been disallowed last week. One example of this is the products available for the topical treatment of digital dermatitis and for application in footbaths. The access to current electronic data "on the net" relative to the latest status on medication is becoming increasingly important for all practitioners.

The use of footbaths to treat and control infectious conditions of the claws has become an environmental issue particularly when products containing trace minerals are used.

Non-infectious diseases

Nutritional aspects pertaining to quality of claw and sole integrity and ability to withstand physical, and septic challenges continues to play a role in the preventive measures to maximise performance and optimise well-being. Nutritional supplementation appears to improve claw horn strength (Meyer et al. 2002, Guguchi et al. 2002,) and optimise health and resistance to disease, I am certain more information will continue to be presented on this topic in the future

Functional claw trimming as effectively described by Shearer and van Amstel (2002) remains the backbone of maintaining good health status and improving the welfare of the cow as well as providing the opportunity for regular assessment of claw health within a herd. The question is not should we do it but rather how can we more effectively promote its universal application by qualified health professionals. This theme should continue to be presented and promoted within this group on an ongoing basis.

Surgical procedures

There have not been a large number of new surgical procedures developed for the treatment of lameness during the past few years. Refined surgical techniques are not always cost effective for standard production animals but are readily justified for the valuable breeding and high production animals. The standard therapies for septic joints continue to be flushing with various cannulae or in the best case scenario with concurrent arthroscopic methods including tenoscopy.

The procedure of joint arthrodesis to salvage joints severely damaged by infection or trauma has been practiced for many years and reflects human intervention to supplement the normal, natural process of ankylosis. The term "joint resection" which suggests surgical removal of all or part of a joint should to my mind be differentiated from "joint arthrodesis" which is defined as surgical fusion and is "de facto" the complete obliteration of all the joint space with subsequent bone fusion and precludes any form of joint movement.

Evidence based evaluations of techniques such as claw amputation versus distal interphalangeal (DIP) joint resection such as used by Heppelmann et al, 2002 to compare the success rates of the two surgical techniques, joint resection versus claw amputation, is an important approach to continuous evaluation of surgical as well as non-surgical procedures at our disposal. The simple documentation of new or modified surgical techniques without appropriate evaluation may be interesting but does little to inform the practitioner as to the relative merits of established versus "new" procedures. It is important to evaluate the results of such testing critically and limit conclusions to the strict results of the study to ensure the readership remains clearly informed. It is all too tempting for someone scanning the literature to equate joint resection with surgical arthrodesis and therefore imply conclusions which may not have been intended by the authors.

Pseudoarthrosis is defined as a "false joint" and in most cases is considered an orthopaedic failure or at least a troublesome complication in fracture healing. It is significant to note that various forms of pseudoarthrosis exist and may be defined according to stage of development and/or desired function.

Simple pseudoarthrosis is a fibrous union between the bone fragments, which allows mobility. This form of arthrodesis may persist or may develope further to a fibrous form.

Fibrous pseudoarthrosis is a form of false joint formation in which fibrous or even hyaline cartilage may form in the intervening space between fragments.

Neoarthrosis (new joint) is the category reflecting the highest form of development of a pseudoarthrosis in which clefts form in the fibrocartilagenous union and become lined with a membrane with many features of a synovial membrane surrounding hyaline cartilaginous tissue covering the opposing boney ends (Jubb and Kennedy 1963, Sumner-Smith 2002).

The intentional creation of a pseudo or neoarthrosis such as in the case of the "paired joints" of the fetlock remains an interesting application of the above concepts.

Control of claw diseases

Claw disease monitoring programs to identify and monitor the significance and status of lameness and claw disease within herds are considered to be important to most people who are concerned with "herd health management". Closer scrutiny frequently reveals a lack of practice of this principle when compared to efforts and systems used to monitor udder health and milk quality, reproduction, metabolic status of the herd and infectious disease within an integrated herd health program. De Kruit's article on an integrated approach to health management while complete in scope is typical of many who appear to place little emphasis on lameness and tend to focus on milk production, reproduction, housing, infectious diseases etc. when planning such programs. Greenough (2003) in his article, which focuses on subclinical laminitis, suggests the importance of such integration in the evaluation of claw diseases. The question of why such programs do not adequately emphasize and implement lameness evaluation protocols for the control and treatment of claws diseases should be addressed.

There remains the question of the treatment and control of claw diseases on an individual or herd basis. In this case "state of the art" when it refers to the use of medical products must be considered on a very fluid basis and when considering application within the various countries comprising the European union it is anything but united. While there is a Veterinary Formulary for Europe which is published every few years, the guidelines for medications which are allowed for use, for example in the treatment of claw diseases seem to change on a much more frequent basis. In addition, the regulations pertaining to the use of veterinary medication frequently differs between each country and may not be covered by information found in the European Veterinary Formulary. The situation is further complicated by the classification of whether a product or active ingredient is a considered as a pharmaceutical drug or a product for herd prophylaxis (the same active ingredient may have one or both classifications). The veterinarian is frequently asked to treat an individual, small group or large herd problem and must then decide on how to apply the many aspects of the ever changing regulations. The current status of the various drugs for use in the treatment of claw diseases is available via direct consultation from informed pharmacologists and through the Internet.

The role of environmental and management effects on the develop of claw and leg diseases is covered in a review type article published in 2002 by Webster and focuses on identification of risk factors, aetiology and pathogenesis of infectious and non-infectious disorders and pain relative to their significance in control and treatment of claw diseases. There is a myriad of publications on effect of housing, feeding and other management factors on development and incidence of lameness and claw diseases in producing dairy cattle. Stanek and co-workers have recently extended this concept and looked different housing arrangements on claw diseases of fattening bulls and role of robotic milking on lameness, which will be presented during this meeting.

Pain control continues to gain an increasing profile in all aspects of veterinary medicine including digital pain Webster (2002). In a review of pain control in food animals, George (2003) considerable effort is expended to describe drug treatments for painful livestock including the use of opiods and non-steroidal anti-inflammatory drugs and specific indications and dosages. Very little information was presented regarding the control of digital or distal limb pain and suggests that much work needs to be done to address this problem. Evaluation of treatment regimens, stage of development of infectious disease and evaluation of degree of pain as a measure of efficacy of treatment was presented by Bathina and coworkers (2002). Currently funding has been made available within the European union for studies on animal welfare, which logically includes work on factors influencing bovine lameness problems viewed from the perspective of optimising welfare in order to prevent situations leading to manifestation of pain. Hopefully this will provide practical guidance to a long neglected aspect of the treatment of claw diseases.

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SEPTIC ARTHRITIS OF THE DISTAL INTERPHALANGEAL JOINT IN HF COWS: CONTROLLED CLINICAL STUDY COMPARING THE EFFICACY OF DIGITAL AMPUTATION AND RESECTION OF THE COFFIN JOINT

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Introduction

Inflammations of the pododerma in the sole and wall area tend to perforate without appropriate treatment. Subsequently, deeper structures are involved in the purulent inflammatory processes, such as deep flexor tendon, deep flexor tendon sheath, bursa podotrochlearis, navicular bone, and the distal- and middle phalanx. Commonly the septic process proceeds into the nearby distal in-terphalangeal joint (DIP-joint). Treatment of such cases requires a resolute surgical approach.

Digital amputation (DAmp) is a relatively uncomplicated procedure with a broad spectrum of indications (Kofler 1988). However, the affected claw is lost; thus, the remaining claw has to carry the whole load. Since this may be disadvantageous in present housing systems, other radi-cal but claw conserving methods for treatment of septic arthritis of the DIP-joint are suggested alternatively. Distal interphalangeal joint resection (DJR) is supposed to have a similar spectrum of indication as DAmp. In contrast to the simple resection of the deep flexor tendon and the navi-cular bone (Assmus 1964) the expected ankylosis of the coffin joint after DJR should bring about sufficient stability to prevent hyperextension (tipping) in the treated claw (Köstlin und Nuss 1988). However, DJR needs considerable more surgical skills than DAmp.

Thus, the objectives of this controlled prospective and randomized clinical study were to investi-gate, (a) whether DJR covers the same spectrum of indications as DAmp and (b) to compare the therapeutic success rate of these methods. Therefore, the healing process, development of lame-ness and the survival rate were compared between animals with similar clinical initial situations either treated by DAmp or DJR, respectively.

Material and methods

Fifty-two dairy cows with septic arthritis of the coffin joint due to a perforating pododermatitis and without other concurrent diseases, admitted to the Clinic for Cattle, were included in the study (German Holstein Friesian: [mean + s] milk yield 8140 960 kg, age 5.5 2.3 years). Animals were submitted from 45 farms; 36 cows were housed on the farm in free stalls with cu-bicles (33 slatted flooring, 2 asphalt flooring, 1 straw mattress) and 16 animals originated from tie stalls (6 straw bedding, 10 rubber mats with grids). The average farm size was 58.4 cows. Twelve animals were pregnant at the time of surgery.

The musculoskeletal system of the animals was examined clinically in standing position, during movement and more in detail in lateral recumbency (examination table; including arthrocentesis of the coffin joint). X-rays and sonography were performed on the defect claw. The septic arthri-tis of the coffin joint was caused by a perforating pododermatitis either of the sole in 40 animals (77%), of the abaxial wall in 9 cows (17%) or interdigital phlegmona in 3 cows (6 %). After di-agnosis of septic arthritis of the coffin joint, cows were accepted for the study and thereafter they were randomly assigned to the DAmp-group (N = 26) or the DJR-group (N = 26) regardless of the origin, pregnancy, and diagnosis.

All surgeries were carried out in lateral recumbency after retrograde intravenous anaesthesia (15 ml Procainhydrochlorid 2%; V. digitalis dorsalis communis III) in combination with a local retrograde intravenous antibiosis (3 Mio IE Penicillin-G). Surgical procedures: DAmp: the af-fected claw was amputated 0.5 cm distally to the coronary band using a Liess wire saw, tendons were removed as far as possible and the middle phalanx was exarticulated in the second interpha-langeal joint. DJR: the distal part of the deep tendon and the navicular bone were removed from plantar. Thereafter a canal with a diameter of 10 mm was drilled through the coffin joint parallel to the coronary band using a surgical drill (6.3 bar, 21,000 rpm, 6 mm). Axially and ab-axially, about 5 mm broad bone bridges at the distal and middle phalanx were left. The counter-lateral healthy claw was raised by a wooden block (12.5 x 6 x 3 cm). In all cows, benzyl penicillin was administered into the opened tendon sheath and chlortetracycline ointment was applied to the wound. After DJR, for prevention of a tipping claw, the treated claw was fixed in a bended posi-tion for period of 90 days p.op. by wrapping elastic bandages over the dorsal wall of the treated claw and through a dent (1 cm deep) carved into the undersurface of the wooden block. All cows received systemically antibiotics (ampicillin-trihydrate 10 mg/kg BW, sc, q 12 h) for 5 subse-quent days post operationem (p.op.).

Follow up examinations were performed 7, 14, 28, 90 and 200 days and finally two years post surgery.

Results

Six months p.op. 8 cows of the DAmp-group and 9 cows of the DJR-group had been culled; two years after surgery, 21 animals of each group had left the farm. Persistent lameness was beside mastitis and infertility one of the main reasons for slaughtering (6 DAmp-cows, 5

DJR-cows).

None of the DJR cows required subsequent DAmp. On average, the lameness score decreased significantly faster in cows of the DAmp-group as compared to cows of the DJR-group (Figure 1). It took about 4 weeks until cows of both groups showed a comparable mild degree of lameness (L I-II).

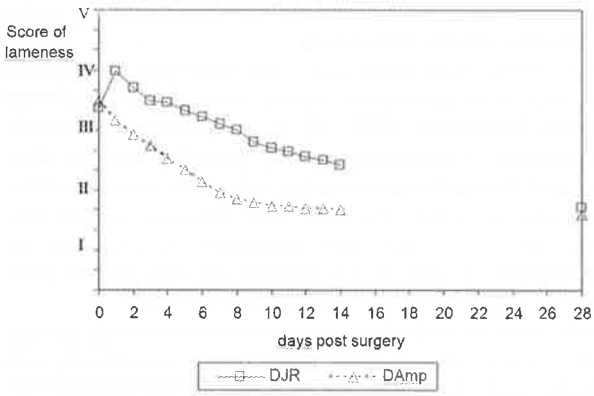

Fig. 1: Score of lameness post DAmp (N=26) or DJR (N=26) in cows with septic arthritis of the coffin joint

In general, three bandage renewals (BR) carried out on day 7, 14 and 28 d p.op. were sufficient to achieve a wound occlusion in 24 DAmp-cows and in 23 DJR-cows. After DAmp one cow devel-oped an osteomyelitis of the proximal phalanx (2 additional BR); one cow suffered from a skin lesion at the coronary band (2 additional BR). After DJR two cows developed a subcutaneous abscess at the coronary band (2 additional BR); one exhibited a tendovaginitis of the common flexor tendon sheath (3 additional BR).

In 7 cows after DJR and in 3 cows after DAmp the lateral claw of the contra-lateral limb devel-oped sole defects within 120 days p.op. requiring additional treatment. Two cows of the DAmp group were culled after detection of a deep sole ulcer in the remaining claw. Following DJR, one cow showed a sole ulcer affecting the formerly blocked claw. A tipping claw was observed in spite of prophylactic measures in 8 of 17 cows within 200 days p. op.. At this time an ankylosis in the coffin joint was diagnosed by x-ray in two of the 17 investigated animals after DJR.

Discussion and conclusion

Perforating pododermatitis and septic arthritis of the distal interphalangeal joint in cows include regularly various inner structures of the claw in the destructive purulent inflammatory processes. Since altered tissue is removed bounteously almost all of such cases can be treated by digital am-putation. According to the study design in this investigation cows which underwent DJR had a comparable initial situation in the affected claw as cows of the DAmp-group. Thus, results re-vealed a nearly comparable variety of indications for DJR

Following DAmp, the remaining claw at the treated limb bears early substantial weight, as indi-cated by a rapid decrease in the degree of lameness in these cows (fig.1), while animals after DJR remained severely lame leading to an overload of the contra-lateral limb. Accordingly, more sole defects in the contra-lateral limb developed in DJR-cows. I contrast, after DAmp the remaining claw of the treated side had to carry more load which went ahead with a higher number of pro-found sole ulcers at this claw. Treatment of these defects is always complex and prognosis never-theless poor. Contrary to the results of Köstlin und Nuss (1988) after DJR only rarely defects affecting the remaining claw were found.

In agreement with other studies (Köstlin und Nuss 1988, Jeong 1993), the majority of the ani-mals (81%; 21 animals DAmp vs. 21 animals DJR) had been culled after two years irrespectively of the surgical interference. In both groups in about 25% of the cases culling was attributable to persistent lameness. Thus, in this regard results revealed no advantage of DJR over DAmp.

The obligate resection of the deep flexor tendon in DJR leads in the further healing course to hyperextension and therefore does not allow a physiological load bearing of the treated claw. For that reason prevention measures are recommended for at least six weeks after surgery to avoid the development of a tipping claw. Although this was executed consequently even over a period of 90 days p.op., in this study in about 50% of the DJR-cows only a tipping claw was success-fully averted. However, there was on the other hand no indication that successful prevention of a tipping claw had any effect on the survival rate of the DJR cows.

In conclusion, since the degree of lameness decreased rapidly after surgery and the surgical tech-nique is easy and quick, digital amputation appears advantageous over the resection of the distal interphalangeal joint in dairy cows with septic arthritis of the coffin joint. However, the substan-tial risk of claw disorders at the remaining claw after DAmp, which are usually irreparable, has to be considered.

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EFFECT OF LAMENESS TREATMENT ON PAIN AND MILK PRODUCTION IN DAIRY CATTLE

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Abstract

Pain experienced by lame cows is a serious welfare concern. This study investigates the effectiveness of NSAID therapy or application of foot blocks to lame dairy cows as part of their lameness treatment on pain alleviation and milk production. Pain was assessed using daily activity level monitors and a 5-point locomotion scoring system. Daily milk yields were recorded to investigate the economic aspect of each treatment. A total of 270 lameness treatments were carried out over a 7-month period. Foot lesions were classified as either acute digital skin lesions or chronic claw horn lesions. Acute lesions were randomly assigned to NSAID/ no NSAID, while chronic lesions were randomly assigned to NSAID/ block/ no further treatment. The effect of treatments on activity levels, locomotion scores and milk yields were investigated. The results indicated complex interactions between the foot lesions presented, and the treatments administered.

Introduction

The pain experienced by lame cattle can be relieved or controlled by treatment. Toussaint Raven (1985) suggested that unloading a diseased claw could reduce pain and aid healing. This can be achieved by trimming or attaching a block to the healthy claw of an affected digit. A veterinary surgeon could prescribe analgesic agents to alleviate digital pain and potentially reduce the degree of hyperalgesia experienced by the animal post-treatment (Whay et al., 1998).
The effectiveness of treatments currently available to the farmer, cattle foot trimmer or veterinary surgeon has not been assessed quantitatively and their cost effectiveness is unknown. Therefore, this study investigates the effect of three lameness treatments on pain control, welfare and milk production in dairy cattle.
Costs associated with lameness include increased labour, reduced milk yield, cost of treatment, reduced fertility and increased culling with subsequent herd replacement costs (Kossaibati and Esslemont 1997). In this study, the basic cost of each treatment was compared only with the associated effect on milk production.

Materials and Methods

Data were collected from a single commercial herd over a 7-month period, while all cattle were housed in a single cubicle building. All cattle were locomotion scored twice weekly using a 5-point numerical rating scale (O'Callaghan et al., 2002). Lame cattle were identified as those assigned locomotion scores 3 to 5 on the scale. The pain experienced by cattle as a result of lameness was assessed using the subjective locomotion scoring system and daily activity monitoring.
Pedometers were fitted to a lower hind limb of each cow to allow daily activity monitoring, (Afimilk 9.00, Fullwood Fusion Electronics 1999). As each cow entered the milking parlour a stationary antenna recorded both her identity and the pedometer counter value. The time of milking was also recorded. The steps taken between records were the differences between successive counter values. Differences divided by the appropriate time interval yielded the activity level in steps per hour (steps/hr).
Milk yields by individual cows were automatically recorded at each milking (Afimilk 9.00). For consistency, milk yields were divided by the time difference between successive milkings to provide the variable yield/hr.
All lame cattle had their feet trimmed according to the Toussaint Raven (1985) method. All foot lesions were classified as either acute (digital dermatitis/ foul) or chronic (sole ulcer/ white line disease). Lesion severity was scored as mild, moderate or severe. All infectious skin lesions were treated with topical antibiotic. Cows presenting with acute lesions were randomly assigned one of two possible treatments; NSAID therapy/ no NSAID. Cows presenting with chronic lesions were randomly assigned one of three possible treatments; NSAID therapy/ application of a foot block (Demotec 95, Siegfried Demel, Germany)/ no further treatment.

Data handling and statistical analysis

All data were collated in Microsoft Excel 2000 (Microsoft Corporation. 1985-1999). Minitab 13.1 (Minitab Inc. 2000) and SAS software package (SAS Institute, Inc. 1990) were used for the analyses. The relationship between locomotion scores and the variables steps/hr and yield/hr were investigated using the 'Means' procedure in SAS. The steps/hr and yield/hr associated with different types and severity of foot lesion were similarly investigated. The effect of treatment on locomotion was examined by comparing scores attributed to cows within 7 days before treatment against the frequency of all subsequent locomotion scores associated with each pre-treatment score, recorded up to 30 days post treatment. The effect of treatment on steps/hr and yield/hr was quantified and tested with least squares regression analysis, using the generalised linear modelling (GLM) procedure in SAS. The dependent variables steps/hr and yield/hr were fitted to three classification variables: 'treatment'; 'before/after' and 'lesion severity'.
Critical significance level was set at $P = 0.01$.

Results

Over the duration of the study, 270 lameness treatments were carried out. Table 1 presents the number of each treatment carried out. The median steps/hr and yield/hr associated with each locomotion score are shown in Table 2. Higher locomotion scores were associated with lower activity levels. The relationship between locomotion scores and milk yield was less clearly defined.

Table 1. Distribution of treatments allocated to cows presenting acute and chronic lesions

Lesion type	Treatment	Number
Acute	NSAID therapy	76
	No NSAID	76
Chronic	NSAID therapy	37
	Application of foot	35
	No further treatment	46

Table 2. Median steps/hr and yield/hr associated with locomotion scores attributed to cows

Locomotion score	Steps/hr	Yield/hr
1	82.5	0.91
2	78.9	0.91
3	69.6	0.92
4	59.9	0.96
5	56.9	0.84

The median steps/hr and yield/hr values associated with different types and severity of foot lesion are presented in Table 3. All moderate and severe lesions were associated with lower activity levels than mild lesions.

Table 3. Median steps/hr and yield/hr associated with different lesion parameters

Lesion type	Lesion severity	Median steps/hr	Median yield/hr
	Mild	90.0	0.78
Acute	Moderate	74.8	0.89
	Severe	76.7	0.86
	Mild	106.1	0.72
Chronic	Moderate	70.5	0.92
	Severe	71.4	0.76

Generally, the frequency of non-lame locomotion scores increased after treatment. However, the continued presence of locomotion scores of 3 and 4 post treatment indicated that many cows continued to display lameness up to 30 days after treatment.

Analysis of the data using least squares regression revealed variable results. Treatment of mild acute lesions with a NSAID resulted in significant increases of up to 18 steps/hr ($p<0.001$, S.E. 3.63) compared with treatment without NSAID. NSAID treatment of moderate acute type lesions made no difference to activity levels and reduced activity associated with severe acute lesions by up to 5 steps/hr ($p<0.01$, S.E. 1.90). In comparison, NSAID treatment of moderate and severe acute lesions, increased yield/hr by 0.3kg/hr and 0.1kg/hr ($p<0.0001$, S.E. 0.02) respectively, compared with treatment without NSAID.

Basic foot trimming of mild chronic type lesions resulted in the highest activity levels after treatment. NSAID therapy of these lesions was associated with reduced activity by up to 49 steps/hr ($p<0.0001$, S.E. 4.71), while foot blocks were associated with similarly reduced activity levels after treatment of up to 54 steps/hr ($p<0.0001$, S.E. 5.13), compared to basic treatment of foot trimming only. In comparison, treatment of moderate severity chronic lesions with NSAID therapy was associated with increased activity by up to 11 steps/hr ($p<0.0001$, S.E. 2.77), while application of foot blocks was associated with reduced activity levels by up to 21 steps/hr ($p<0.0001$, S.E. 3.85), compared with basic treatment. Basic foot trimming with or without the application of foot blocks to cows presenting severe chronic lesions resulted in similar daytime activity levels post treatment. However, NSAID therapy resulted in reduced daytime activity by 9 steps/hr ($p<0.001$, S.E. 2.35). Milk yields associated with mild chronic type lesions were not affected by treatment type. However, NSAID therapy of moderate chronic lesions was associated with increased yield/hr values of up to 0.55kg/hr, while application of foot blocks were associated with increased values of up to 0.33kg/hr. In each case these differences were significant at the $p<0.0001$ level, (S.E. 0.03-0.04). Application of foot blocks to cows with severe chronic lesions resulted in increased yield/hr by 0.29kg/hr ($p<0.0001$, S.E. 0.03), while NSAID therapy increased yield/hr by up to 0.08kg/hr ($p<0.01$, S.E. 0.03), compared with basic treatment.

Discussion

The results of this study emphasise the difficulty of assessing pain in large groups of animals and applying generalised results to individual cases. They also reflect the individuality and variability of recovery and emphasise the importance of incorporating the nature and severity of foot lesions into decisions on treatment.

Preliminary results suggested that milk yields were relatively independent of the type and severity of foot lesions. Since the cows in this study were all treated after peak lactation, they naturally produced less milk as the study progressed. However, when treatments were analysed according to lesion severity, the yield/hr values of all cows presenting moderate or severe foot lesions, irrespective of type, who received NSAID were higher than those cows that received only basic foot trimming. Foot blocks produced a similar result in cows with moderate and severe chronic lesions. Therefore, the cost of treatments may potentially be recovered through improved milk production.

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THERAPY OF SEPTIC DIGITAL FLEXOR TENOSYNOVITIS AND CONCURRENT SEPTIC ARTHRITIS OF THE FETLOCK JOINT IN 2 CATTLE - NEW SURGICAL APPROACH FROM PLANTAR VIA THE DIGITAL FLEXOR TENDON SHEATH WALL

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Introduction

Septic inflammations of synovial cavities of distal limbs are a frequent cause of lameness in cattle: the distal interphalangeal joint and the digital flexor tendon sheath are most frequently affected (1-12). Especially in cases where penetrating puncture wounds proximal or distal to the dew claws have been responsible for septic inflammation of the digital flexor tendon sheath, also with involvement of the directly dorsal adjacent fetlock joint or the proximal interphalangeal joint recess assessment includes a thorough clinical, ultrasonographic and radiographic examination of the swollen region (5-8).
This report describes 2 cases of septic tenosynovitis of the hind limb digital flexor tendon sheath. One was a fibrinous-purulent tenosynovitis in the right lateral digit of a 4.7 years old Simmental cow, the other a sero-fibrinous tenosynovitis in the right lateral digit of a 2.5 years old Charolais bull - and a concurrent sero-fibrinous arthritis of the adjoining fetlock joint, caused in both patients by sharp puncture and laceration wounds over the digital flexor tendon sheath area, which were treated using a novel surgical approach to the affected fetlock joint.

Material and Methods

Case 1: The cow, showed grade 3 (out of 4) lameness on the right hindlimb, a distinct and painful swelling of the whole lateral digital flexor tendon sheath area from the pastern to mid-metatarsus and moderate swelling around the fetlock joint. A small puncture wound was found on the axial aspect of the lateral dew claw. Ultrasonographic examination confirmed the clinical diagnosis and arthrocentesis revealed the nature of the effusion. A fibrinopurulent tenosynovitis of the right lateral digit and a concurrent sero-fibrinous arthritis of the adjoining fetlock joint was diagnosed.

Case 2: The bull, showed grade 4 (out of 4) lameness on the right hindlimb, extreme swelling over the bulbs of the heel reaching proximally over the whole tendon sheath area to mid-metatarsus, distinct swelling of the coronet, moderate swelling dorsal and plantar to the fetlock joint and an older, infected lacerated wound on the lateral bulbs of the heel covered with granulation tissue. Radiographic and ultrasonographic examination and aspiration of synovial fluid from the digital flexor tendon sheath and fetlock led to the final diagnosis: sero-fibrinous tenosynovitis in the right lateral digit, a concurrent sero-fibrinous arthritis of the adjoining fetlock joint, infection of the deep digital flexor tendon over the distal sesamoid bone and septic serous arthritis of the distal interphalangeal joint.

Surgical approach:

After preparation of the digital and metatarsal region for surgery, in both cattle a wooden block was attached to the sound medial claw. Both patients were given an intravenous regional anaesthesia using 40 ml of procainehydrochloride (Minocain 2%, Atarost, Germany) with a rubber tourniquet proximal to the tarsus.
In the Charolais bull, starting from the laceration wound all the infected tissues were resected: the deep digital flexor tendon at its insertion and the distal sesamoid bone was removed, the distal interphalangeal joint was resected by drilling a 8 mm wide hole through the joint space from plantar to the dorsal wall and the distal interphalangeal joint was lavaged from the plantar surgical wound and the dorsal dril canal.
In both patients the digital flexor tendon sheath was opened starting from the original penetrating wound. The superficial and deep digital flexor tendons and large amounts of clotted fibrinous masses adhering to the tendon sheath wall and the tendons and purulent exudate were removed.
After cleansing and lavage of the tendon sheath in the cow, a small puncture wound of the fetlock was detected joint capsule directly distally of the abaxial proximal

sesamoid bones.
In the Charolais bull just at the same site a fibrin clot was strongly attached and a canal into the plantar fetlock joint pouch was discovered robe filled with clotted fibrin.
In both patients this small canal was enlarged using a scalpel with a 11 blade and in addition a second approach to the plantar fetlock joint pouch was carried out, making a 2-3 cm long and about 5 mm wide incision between the two abaxial branches of the suspensory ligament. In this way a large access to the joint pouch was created allowing removal of fibrin clots of about 1-2 cm size using a curette and permitting effective joint lavage. In addition, a hypodermic needle (2.1 mm diameter) was inserted into the dorsal pouch and a teat catheter into the small distal joint capsule canal. 3-5 liters of 0.9% isotonic saline solution with dilute 0.1% polyvidon-iodine-solution were used for irrigation.
Both incisions of the fetlock joint capsule were drained with small pieces of Ligasano -polyurethane-soft foam dressing material (Ligamed medical products, Cadolzburg-Wachendorf, Germany) to avoid premature closure, and the wound of the digital flexor tendon sheath was also covered with Ligasano . The tendon sheath wound was not sutured. A support bandage using sterile dressing material was applied. The operated digit was fixed in its correct position on the wooden block using a metal wire which was inserted through a 3 mm drill hole on the tip of the claw to avoid a possible overextension of this digit due to the removal of the deep digital flexor tendon.
A systemic antiinflammatory therapy using 3 mg ketoprofen per kg body mass (Romefen 10%, Merial) was given for 4 days and 20.000 IU benzyl-penicillin and 20 mg streptomycin per kg body weight (Peni-strepto , Virbac Laboratoires) was administered for 10 days.
In both patients the digital flexor tendon sheath and the opened fetlock joint were lavaged daily for 3 consecutive days using the same solution and same amounts. After this time the original swelling was clearly reduced and the synovial fluid of the fetlock joint appeared nearly normal. After the last joint lavage the joint capsule insertions were no longer drained, and only the digital flexor tendon sheath wound was covered with Ligasano -polyurethane-soft foam dressing material and a firm bandage until day 10-14 postoperatively.

Results

In these two patients, the lameness improved rapidly within the next 10-14 days, the surgical wounds closed rapidly with granulation tissue and the patients were discharged home 16 and 17 days respectively after surgical intervention showing grade 1 lameness.
When the progress of these patients was checked by phone 6 weeks later, complete healing of the wounds was reported and the animals were no longer lame. Telephone follow-up 12 months later revealed that the animals were without lameness, showing no weightbearing problems and normal digits conformation.

Discussion

This new surgical approach to an infected fetlock joint through the plantar wall via the surgically opened digital flexor tendon sheath showed no detrimental effects on healing of the infected joint: after removing the Ligasano -polyurethane-soft foam drainage this incision between the two lateral branches of the suspensory ligament was closed by fibrin adhesions and later by secondary wound closure. Using this technique in bovine patients showing a purulent digital flexor tenosynovitis and a concurrent septic arthritis of the fetlock joint as described, a second skin incision for arthrotomy of the plantar pouch from lateral which would be necessary otherwise, could be avoided.
It is a very easy and effective approach in cases when severe septic inflammation of the digital flexor tendon sheath invades the fetlock joint pouch.

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Introduction

Septic inflammations of synovial cavities of distal limbs are a frequent cause of lameness in cattle: the distal interphalangeal joint and the digital flexor tendon sheath are most frequently affected (1-12). Especially in cases where penetrating puncture wounds proximal or distal to the dew claws have been responsible for septic inflammation of the digital flexor tendon sheath, also with involvement of the directly dorsal adjacent fetlock joint or the proximal interphalangeal joint recess assessment includes a thorough clinical, ultrasonographic and radiographic examination of the swollen region (5-8).

This report describes 2 cases of septic tenosynovitis of the hind limb digital flexor tendon sheath. One was a fibrinous-purulent tenosynovitis in the right lateral digit of a 4.7 years old Simmental cow, the other a sero-fibrinous tenosynovitis in the right lateral digit of a 2.5 years old Charolais bull - and a concurrent sero-fibrinous arthritis of the adjoining fetlock joint, caused in both patients by sharp puncture and laceration wounds over the digital flexor tendon sheath area, which were treated using a novel surgical approach to the affected fetlock joint.

Material and Methods

Case 1: The cow, showed grade 3 (out of 4) lameness on the right hindlimb, a distinct and painful swelling of the whole lateral digital flexor tendon sheath area from the pastern to mid-metatarsus and moderate swelling around the fetlock joint. A small puncture wound was found on the axial aspect of the lateral dew claw. Ultrasonographic examination confirmed the clinical diagnosis and arthrocentesis revealed the nature of the effusion. A fibrinopurulent tenosynovitis of the right lateral digit and a concurrent sero-fibrinous arthritis of the adjoining fetlock joint was diagnosed.

Case 2: The bull, showed grade 4 (out of 4) lameness on the right hindlimb, extreme swelling over the bulbs of the heel reaching proximally over the whole tendon sheath area to mid-metatarsus, distinct swelling of the coronet, moderate swelling dorsal and plantar to the fetlock joint and an older, infected lacerated wound on the lateral bulbs of the heel covered with granulation tissue. Radiographic and ultrasonographic examination and aspiration of synovial fluid from the digital flexor tendon sheath and fetlock led to the final diagnosis: sero-fibrinous tenosynovitis in the right lateral digit, a concurrent sero-fibrinous arthritis of the adjoining fetlock joint, infection of the deep digital flexor tendon over the distal sesamoid bone and septic serous arthritis of the distal interphalangeal joint.

Surgical approach:
After preparation of the digital and metatarsal region for surgery, in both cattle a wooden block was attached to the sound medial claw. Both patients were given an intravenous regional anaesthesia using 40 ml of procaine-hydrochloride (Minocain 2%, Atarost, Germany) with a rubber tourniquet proximal to the tarsus.

In the Charolais bull, starting from the laceration wound all the infected tissues were resected: the deep digital flexor tendon at its insertion and the distal sesamoid bone was removed, the distal interphalangeal joint was resected by drilling a 8 mm wide hole through the joint space from plantar to the dorsal wall and the distal interphalangeal joint was lavaged from the plantar surgical wound and the dorsal dril canal.

In both patients the digital flexor tendon sheath was opened starting from the original penetrating wound. The superficial and deep digital flexor tendons and large amounts of clotted fibrinous masses adhering to the tendon sheath wall and the tendons and purulent exudate were removed.

After cleansing and lavage of the tendon sheath in the cow, a small puncture wound of the fetlock was detected joint capsule directly distally of the abaxial proximal

sesamoid bones.
In the Charolais bull just at the same site a fibrin clot was strongly attached and a canal into the plantar fetlock joint pouch was discovered robe filled with clotted fibrin.
In both patients this small canal was enlarged using a scalpel with a 11 blade and in addition a second approach to the plantar fetlock joint pouch was carried out, making a 2-3 cm long and about 5 mm wide incision between the two abaxial branches of the suspensory ligament. In this way a large access to the joint pouch was created allowing removal of fibrin clots of about 1-2 cm size using a curette and permitting effective joint lavage. In addition, a hypodermic needle (2.1 mm diameter) was inserted into the dorsal pouch and a teat catheter into the small distal joint capsule canal. 3-5 liters of 0.9% isotonic saline solution with dilute 0.1% polyvidon-iodine-solution were used for irrigation.
Both incisions of the fetlock joint capsule were drained with small pieces of Ligasano -polyurethane-soft foam dressing material (Ligamed medical products, Cadolzburg-Wachendorf, Germany) to avoid premature closure, and the wound of the digital flexor tendon sheath was also covered with Ligasano . The tendon sheath wound was not sutured. A support bandage using sterile dressing material was applied. The operated digit was fixed in its correct position on the wooden block using a metal wire which was inserted through a 3 mm drill hole on the tip of the claw to avoid a possible overextension of this digit due to the removal of the deep digital flexor tendon.
A systemic antiinflammatory therapy using 3 mg ketoprofen per kg body mass (Romefen 10%, Merial) was given for 4 days and 20.000 IU benzyl-penicillin and 20 mg streptomycin per kg body weight (Peni-strepto , Virbac Laboratoires) was administered for 10 days.
In both patients the digital flexor tendon sheath and the opened fetlock joint were lavaged daily for 3 consecutive days using the same solution and same amounts. After this time the original swelling was clearly reduced and the synovial fluid of the fetlock joint appeared nearly normal. After the last joint lavage the joint capsule insertions were no longer drained, and only the digital flexor tendon sheath wound was covered with Ligasano -polyurethane-soft foam dressing material and a firm bandage until day 10-14 postoperatively.

Results

In these two patients, the lameness improved rapidly within the next 10-14 days, the surgical wounds closed rapidly with granulation tissue and the patients were discharged home 16 and 17 days respectively after surgical intervention showing grade 1 lameness.
When the progress of these patients was checked by phone 6 weeks later, complete healing of the wounds was reported and the animals were no longer lame. Telephone follow-up 12 months later revealed that the animals were without lameness, showing no weightbearing problems and normal digits conformation.

Discussion

This new surgical approach to an infected fetlock joint through the plantar wall via the surgically opened digital flexor tendon sheath showed no detrimental effects on healing of the infected joint: after removing the Ligasano -polyurethane-soft foam drainage this incision between the two lateral branches of the suspensory ligament was closed by fibrin adhesions and later by secondary wound closure. Using this technique in bovine patients showing a purulent digital flexor tenosynovitis and a concurrent septic arthritis of the fetlock joint as described, a second skin incision for arthrotomy of the plantar pouch from lateral which would be necessary otherwise, could be avoided.
It is a very easy and effective approach in cases when severe septic inflammation of the digital flexor tendon sheath invades the fetlock joint pouch.

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THE CURRENT STATE OF KNOWLEDGE ON (PAPILLOMATOUS) DIGITAL DERMATITIS IN DAIRY CATTLE: WITH PARTICULAR REFERENCE TO CONTROL

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Introduction

Digital dermatitis was first described in Italy in 1974 (Cheli and Mortellaro, 1974) and in the UK in 1988 (Blowey and Sharp, 1988). The disease was reported in the USA in 1980 as interdigital papillomatosis (Rebhun et al., 1980). Read and Walker discussed a similar but more often proliferative disease, papillomatous digital dermatitis (footwarts), in 1994 (Read and Walker, 1994a; Read and Walker, 1994b). Histopathologic and immunohistochemical evidence indicate that papillomatous digital dermatitis (PDD) and digital dermatitis (DD) are the same disease (Read and Walker, 1998a), therefore, the abbreviation (P)DD will be used throughout the text to designate both terms. Dairy producers reported seeing (P)DD in California in the mid-1980's but most observed (P)DD on their dairies for the first time in the early 1990's (Rodriguez-Lainz et al., 1996b; Wells et al., 1997)). (P)DD has been reported in many countries of the world, most commonly on confinement dairies (Cruz et al., 2001; Demirkan et al., 2000; van Amstel et al., 1995) but has been reported on pastured cattle also (Blowey and Sharp, 1988; Rodriguez-Lainz et al., 1999; Somers et al., 2003).

(P)DD is one of the most common causes of lameness and is an animal welfare concern for the dairy industry. Economic losses result from premature culling, decreased milk production, decreased reproductive efficiency, and cost of treatment (Hernandez et al., 2002; Rebhun et al., 1980). British researchers calculated the economic loss from a case of (P)DD to be approximately 114 EUR per cow/lactation (Esslemont and Peeler, 1993).

Epidemiology, Pathogenesis, and Etiology

The most common location of (P)DD lesions is on the palmar surface of the rear foot near the skin-horn junction bordering the interdigital space (Read and Walker, 1998b). Histopathologically, (P)DD is characterized by a combination of ulcerative and proliferative changes consisting of ulceration of tips of dermal papillae, epidermal hyperplasia with parakeratosis and hyperkeratosis, colonization and invasion by profuse numbers of spirochetes, and inflammation (Read and Walker, 1998b). Lesions are circumscribed, erosive to papillomatous, painful, and often surrounded by hyperkeratotic skin with hypertrophied hairs (Read and Walker, 1998b). Lesions are found less commonly on the palmar rear feet near the dewclaws and on both hind and front feet near the dorsal commissure of the interdigital cleft.

The precise etiology of (P)DD is unknown but is considered to be multifactorial with environment, management, and microbial factors (Read and Walker, 1998b; Rodriguez-Lainz et al., 1996a; Rodriguez-Lainz et al., 1996b; Rodriguez-Lainz et al., 1998). Earlier research identified that two risk factors for a high prevalence of (P)DD are wet conditions and purchasing replacements from off-premises (Rodriguez-Lainz et al., 1996a; Wells et al., 1997; Wells et al., 1999). Other management conditions that may be involved in (P)DD are those thought to contribute to poor digital skin health, i.e. any condition that causes poor foot hygiene.

The microbes identified most consistently from active lesions are spirochetes of the genus Treponema (Borgmann et al., 1996; Choi et al., 1997; Collighan and Woodward, 1997; Demirkan et al., 1998; Demirkan et al., 1999b; Doherty et al., 1998; Döpfer et al., 1997; Moter et al., 1998; Read et al., 1992; Walker et al., 1995; Walker et al., 1998). These spirochetes comprise the bulk of the colonizing mat of microbes found on active lesions and are also found invading the epidermis and dermis (Demirkan et al., 1998; Moter et al., 1998; Read et al., 1992; Walker et al., 1995). Treponemes isolated from (P)DD are similar to those that cause periodontal disease in humans (Edwards et al., 2003a; Edwards et al., 2003b). The infectious component of (P)DD may be complex, possibly involving several other anaerobic bacteria which may play a symbiotic role (Read et al., 1999; Read and Walker, 1997; Walker et al., 1994). However, it appears that spirochetes may play a primary pathogenic role because a sequential ultrastructural study of the experimentally transmitted disease in calves showed that spirochetes were the first microbes to invade and colonize the epidermis and dermis (Read and Walker, 1996).

Other bacteria have been less consistently identified (Demirkan et al., 1999b; Murray et al., 2002; Schütz et al., 2000). Three distinct phylogenetic types of Treponema spp. have been identified by US researchers (Walker et al., 2001). Workers from Germany have identified another, novel strain (Schrank et al., 1998) and other strains may be involved (Trott et al., 2003). There is no evidence of viral involvement (Read et al., 1995b; Zemljic, 1994).

In a California study, antibodies against two antigenically distinct Treponema spp. were increased on dairies with (P)DD compared to (P)DD-free dairies (Walker et al., 1997). Cattle with (P)DD on a high prevalence dairy were much more likely to have antibodies against Treponema spp. than were cattle without lesions on the same dairy (Walker et al., 1997). Each of the two Treponema spp. produced specific antibodies and did not cross-react with each other or with other common spirochetes associated with diseases of cattle (Walker et al., 1997). Workers in Iowa were able to demonstrate that the Treponema spp. elicited cellular as well as humoral immune response in cows with active (P)DD lesions (Moeller et al., 1999). Higher prevalence of clinical disease in younger animals of an endemically affected herd suggests that immunity may develop in older cows or that younger cows are more susceptible (Read and Walker, 1994b).

Recent research in Sweden found that herds that ranked high for dermatitis (DD) also ranked high for verrucose dermatitis ((P)DD), heel-horn erosion, and interdigital hypertrophy (Manske et al., 2002a). These researchers made no distinction between ID and DD since interdigital dermatitis and early digital dermatitis are very similar and occur in the same area, but they did make a distinction between erosive digital dermatitis (DD) and verrucose dermatitis (PDD). Several others have proposed that ID and DD are similar diseases (Blowey et al., 1994; Read and Walker, 1998b; Vokey et al., 2001; Walker et al., 1995; Walker et al., 2002).

Different flooring systems have been associated with reduced occurrence of (P)DD. Swedish workers (Hultgren and Bergsten, 2001) found that the odds ratio for (P)DD was 0.23 for tie stall cows on rubber slats when compared to tie stall cows with solid flooring. Dutch workers compared claw health on cows housed on slatted floor, slatted floor with scraper, solid concrete floor, straw yard, and a zero-grazed group (Somers et al., 2003). They found that cows in straw yards had far fewer claw disorders and those cows on the slatted floor with scraper had less ID and (P)DD than the cows on the slatted floor. The flooring systems in these studies that resulted in fewer cases of (P)DD were those in which cows had better foot hygiene.

Transmission

The mode of transmission is unknown but clinically and subclinically affected cows and fomites might be sources of infection for naive herds (Rodriguez-Lainz et al., 1996a; Wells et al., 1997; Wells et al., 1999). There have been numerous anecdotal reports from farmers, veterinarians, and claw trimmers that they first observed (P)DD on dairies after livestock from off premises were purchased.

Read and Walker hypothesized that animals may be predisposed to (P)DD by prolonged exposure of digital skin to oxygen-depleted, wet, organic material (Read and Walker, 1994b). They were able to achieve experimental transmission to calves using scrapings from active lesions and found that prolonged moisture and reduced access to air were necessary for successful transmission (Read and Walker, 1996; Read, 1997). Sequential ultrastructural study of experimentally transmitted (P)DD in calves demonstrated that spirochetes were the first bacterial morphotype to invade and colonize the epidermis and dermis (Read, 1997).

Treatment and Control

Early anecdotal reports indicated that (P)DD lesions responded to treatment with topical antibiotics, thereby supporting the hypothesis of bacterial etiology. Numerous studies demonstrated a clinical response to antibiotics applied as a topical spray treatment or under a bandage (Berry et al., 1996; Berry et al., 1998; Berry et al., 1999b; Berry et al., 1999a; Berry and Maas, 1997; Blowey, 1994; Blowey and Sharp, 1988; Britt et al., 1996; Britt and McClure, 1998; Brizzi, 1993; Graham, 1994; Guard, 1995; Guterbock and Borelli, 1995; Hernandez et al., 1999; Read and Walker, 1998b; Reed et al., 1996; Shearer et al., 1998; Shearer and Elliott, 1994; Shearer and Elliott, 1998). Non-antibiotic products have also been reported to be efficacious (Britt et al., 1996; Britt and McClure, 1998; Hernandez et al., 1999; Read and Walker, 1998b). The most commonly used topical antibiotic treatments are oxytetracycline, lincomycin, and lincomycin/spectinomycin. Antibiotic milk residue violations due to topical application of antibiotics have not been reported (Britt et al., 1999; Brizzi, 1993; Hartog et al., 2001; Mortellaro, 1994). Parenteral antibiotics have not been consistently effective.

In more recent studies, oxytetracycline applied as a topical spray was more effective than either hoof trimming alone or glutaraldehyde as a topical spray (Manske et al., 2002c). The same researchers also found that claw trimming twice per year was effective in reducing laminitis related lesions but not moderate-to-severe heel horn erosion or (P)DD (Manske et al., 2002b).

US workers treated (P)DD-affected cows with either lincomycin or a non-antibiotic cream (soluble copper with peroxide and a cationic agent, Victory Foot Cream®, Westfalia Surge, Inc.) under a bandage (Moore et al., 2001). They found that both the lincomycin and the non-antibiotic cream significantly reduced pain, lesion activity, lesion size, and decision to retreat when examined 29 days after treatment. The lincomycin was significantly more effective than the cream in reducing lesion size and avoiding retreatment. This study also found that cows in the 3rd or greater lactation were more likely to have a healed lesion than cows in lactation 1 or 2 when examined 29 days after treatment (Moore et al., 2001).

British workers compared valnemulin to lincomycin as a topical spray for treatment of (P)DD (Laven and Hunt, 2001). Each animal was treated twice, 48 hours apart with either 25 ml of 0.6 mg lincomycin/ml or 25 ml of 100 mg valnemulin/ml. Both treatments resulted in significant improvement in (P)DD when examined 14 d after treatment (Laven and Hunt, 2001).

Earlier research reported that footbaths containing 5% formalin (Blowey and Sharp, 1988; Brizzi, 1993; Mortellaro, 1994), lincomycin (1-4 g/l) (Brizzi, 1993), oxytetracycline (1-4 g/l) (Brizzi, 1993; Guard, 1995; Mortellaro, 1994), copper sulfate (0.25-1 g/l) (Guard, 1995; Mortellaro, 1994), or zinc sulfate (20%) (Mortellaro, 1994) provided control of the disease in infected herds.

Recent footbathing experiments in Sweden found that a higher proportion of cow's feet affected by (P)DD were cured by acidified copper sulfate (Hoofpro+®, SSI, Julesburg, CO, USA) than by water alone (Manske et al., 2002c). These researchers also noted that the copper solution had no preventive effect.

US workers found that the use of a proprietary, non-antibiotic product (Double Action™, West Agro, Inc., Kansas City, MS, USA) reduced the prevalence of (P)DD lesions requiring foot wrapping with lincomycin or oxytetracycline at claw trimming (Seymour et al., 2001; Seymour et al., 2002). Other workers in the US found that another proprietary, non-antibiotic product (Victory®, Westfalia Surge, Inc., IL, USA) improved lesion scores on cows with (P)DD 12 d after treatment (Gradle et al., 2002). No concurrent control treatments were used in these experiments, however.

British researchers compared 3 non-antibiotics (copper sulfate (2%), formalin (6%), and peracetic acid (1%)) to erythromycin (2.1 g/L) in footbaths for the treatment of (P)DD (Laven and Hunt, 2002). Cow's feet were cleaned with a hose before they were walked through a 3 m long footbath. Each cow spent at least 20 seconds in the footbath. Mean lesion scores were significantly reduced with all 4 treatments and there were no significant differences between any of the groups (Laven and Hunt, 2002). These workers used erythromycin as a positive control in this study because it had been previously demonstrated to be efficacious (Hartog et al., 2001; Laven and Proven, 2000) and they were interested in whether the non-antibiotics could be substituted for the antibiotic. These workers noted that the test herd had (P)DD as a mild, endemic disease and that they only observed cows for 21 d following treatment.

Earlier British research (Arkins et al., 1986) found that 5% formalin footbaths improved interdigital lesions but did not prevent new individual interdigital lesions. Blowey reported anecdotal success using prolonged formalin footbathing as proposed by Adrian Gonzales at the International Ruminant Digit Symposium in Banff in 1994 (Blowey, 2000). There is speculation that formalin used in moderation might be less damaging to the environment than copper sulfate but the human health hazards of formalin are considerable.

Footbathing with antibiotics is the most common treatment for (P)DD in the UK (Laven, 2001), whereas antibiotic footbaths are rarely used in the US and topical antibiotic sprays or footwraps are more common (Shearer et al., 1998; Shearer and Elliott, 1998). Cows in the US that use footbaths walk through them when exiting the milking parlor on the way back to their pen. Most cows pass through the footbaths rapidly and return immediately to the freestall barns. This is in contrast to European studies where cows are made to stand in the footbaths and then in a clean environment for a period of time before returning to their pens (Hartog et al., 2001; Laven, 2001).

Up to 60% of successfully treated cows may develop recurrent lesions in 7 to 15 weeks (Berry et al., 1999a; Read and Walker, 1994b). Spontaneous regression of lesions and resolution of lameness may occur rarely. Chronic or recurrent cases in otherwise healthy adult cattle have been reported suggesting that if immunity to (P)DD does develop, it may be incomplete or temporary.

Diagnosis

Identifying the prevalence or presence of (P)DD is the first step to controlling the disease. Zemljic studied the histopathologic criteria for (P)DD diagnosis based on loss of the epidermal barrier, invasion by spirochetes, and inflammation in Slovenia dairy farms (Zemljic, 2000). Results from this study showed that 79% of biopsies submitted satisfied these criteria. Taking skin biopsies and submitting them for histopathology is not a practical method for diagnosing disease for treatment. Another screening method for detection of this disease was evaluated in Chilean dairies. This diagnostic method, known as water-jet test (WJT) with bright light, is based on gross appearance, location, and lesion sensitivity (pain) to the water jet (Rodriguez-Lainz et al., 1998). Efficiency of WJT was compared to examination of each foot on restrained cows in a chute (gold standard). The WJT can be used as a cost-efficient method for (P)DD diagnosis with a sensitivity of 0.72 and a specificity of 0.99 (Rodriguez-Lainz et al., 1998). Evaluation of antibody response to (P)DD-associated Treponema spp. is another method used to determine prevalence of (P)DD in terms of exposure rather than clinical infection. ELISA for serum antibodies to (P)DD treponemes was significantly higher on cows with lesions than on cows without lesions (Walker et al., 1997).

Vaccination

While many treatment and control measures such as antibiotic and non-antibiotic topical sprays, footwraps, and footbaths, as well as regular hoof trimming have been found to be effective control measures, they are expensive, labor intensive, and the recurrence of the disease is still high (Berry et al., 1999a; Read et al., 1995a; Read and Walker, 1994b; Shearer et al., 1998; Shearer and Elliott, 1998; Zemljic, 2000). An efficacious and cost-effective vaccine against (P)DD would prevent disease and, thus, decrease treatment and other disease associated costs.

Although (P)DD is multifactorial and the precise etiology has not been determined, there is compelling evidence that invasive spirochetes play a major role either as primary or secondary pathogens in (P)DD lesions (Borgmann et al., 1996; Choi et al., 1997; Collighan and Woodward, 1997; Demirkan et al., 1998; Demirkan et al., 1999a; Demirkan et al., 1999b; Doherty et al., 1998; Döpfer et al., 1997; Keil et al., 2002; Moter et al., 1998; Read et al., 1992; Walker et al., 1995). Immunocytochemical staining showed that spirochetes in skin lesions were identified by polyclonal antisera to Borrelia burgodorferi, Treponema denticola, and Treponema vincentii but not to monoclonal antisera for B. burdorferi or T. pallidum (Demirkan et al., 1998). Two strains of Treponema spp. were cultured and characterized as the most predominant strains of spirochetes associated with (P)DD (Walker et al., 1995; Walker et al., 1998). These and other studies have shown that the treponemes associated with (P)DD are similar to but distinct from the treponemes involved in human periodontitis (Demirkan et al., 1999b; Edwards et al., 2003a; Edwards et al., 2003b; Schrank et al., 1998; Trott et al., 2003).

Results from a serology study with control groups suggests that anti-Treponema antibody titers in vaccinated animals with Treponema bacterin (Novartis Animal Health, Inc.) increased 5.6, 10.4 and 27.2-fold after one, two and three doses, respectively, while no change in ELISA antibody levels was detected on placebo controls (Keil et al., 2002). Another clinical trial where 150 out of 300 healthy adult Holstein cows were vaccinated with an inactivated autogenous Treponema bacterin (Novartis Animal Health, Inc.) showed a considerably higher (P)DD incidence on control animals (14.7%) than on vaccinates (1.3%) 45 days after the third vaccination (Keil et al., 2002). Similar results were obtained on a second controlled clinical trial where 80 Holstein heifers were vaccinated with autogenous Treponema bacterin and housed in low (P)DD incidence growing pens. After completion of vaccination series (30 days), they were moved to a high incidence (breeding) pen. A 74% and 63% reduction of (P)DD lesions was found in vaccinates at 9 and 18 weeks post-vaccination respectively (Keil et al., 2002). In these studies, immunization of cattle with Treponema bacterin lead to a significant reduction in clinical disease.

In a German study, no prophylactic or therapeutic effect of two herd-specific vaccines against (P)DD was obtained in a controlled clinical trial on a free-stall dairy. After isolating several anaerobic bacteria from (P)DD lesion biopsies, two vaccines were developed. Vaccine 1 had isolates from active (P)DD lesions and contained: Porphyromonas spp., Fusobacterium necrophorum, Bacillus stercoris, Prevotella bivia, and Peptostreptococcus indolicus. Vaccine 2 contained all the isolates from vaccine 1 as well as Treponema spp. (20% of total count). A placebo solution with no antigen was prepared as treatment 3. The vaccine with no treponemes showed evidence of a positive effect one year after the first vaccination. The vaccine with Treponema spp. showed no significant prophylactic or therapeutic effects on prevalence or severity of typical (P)DD lesions (Schütz et al., 2000).

An early Treponema bacterin study in California found the vaccine may have a reducing effect on lesion size and number but did not prevent transmission (Oliver, 1999). The study was conducted with vaccinated and control calves that were and then challenged using the experimental challenge model developed by Read and Walker (Read and Walker, 1996; Read, 1997).

In recent controlled, blind field studies to determine whether Treponema bacterin provided prophylactic and/or therapeutic effects for controlling (P)DD in cattle (Berry et al., 2004), a total of 420 and 740 Holstein cows were enrolled from two commercial California dairies with (P)DD prevalence of 27% and 29% respectively at pre-vaccination parlor evaluation. All lactating cows from each herd were vaccinated with either Treponema bacterin (under development by Novartis Animal Health, Inc. and conditionally licensed by USDA) or placebo (adjuvant with no Treponema) a. The total herds of cows were vaccinated 3 times at 3 week intervals per label instructions, while cows were restrained in stanchions for their regular, daily estrous detection and breeding. This meant that cows were in all stages of lactation and reproductive status in contrast to the Nebraska study discussed later in this paper. Investigators were blinded as to which cows received vaccine or placebo. Study cows were grouped according to their disease status prior to treatment (visible lesion, no visible lesion) and treatment received (vaccine, placebo). After completion of vaccination, all cows were visually examined for evidence of (P)DD monthly for 6 months. The screening test used was observation with a bright-light and water-jet test (WJT) in the parlor during milking. Reliable hoof trimmer records were examined to make sure (P)DD affected cows were not missed at the parlor examinations. A sub-sample of vaccine and placebo cows with no visible lesions were bled pre-vaccinating and at each of the observation periods for ELISA testing for Treponema antibodies.

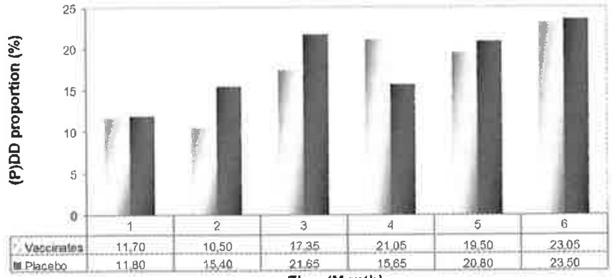

Figure 1. Average (P)DD proportion (%) per month for cows without visible lesions prior to vaccination with *Treponema* bacterin or placebo

A series of z-tests comparing the monthly (P)DD proportions of cows without visible pretreatment lesions from both dairies combined found no significant prophylactic effect (p-value averages ranging from 0.224 to 0.802), shown in Figure 1. In general, the proportion of vaccinates with subsequent (P)DD was lower than placebo groups during all months of observation, except during month 4. Therapeutic effects of Treponema bacterin among cows with visible pretreatment lesions were also non-significant (p-values ranging from 0.118 to 0.940). The proportion of animals with (P)DD in vaccinated animals was not significantly different from that of placebo animals at any of the observation times (not shown).

ELISA for serum antibodies to (P)DD-associated Treponema spp. revealed that a high proportion (34/78 or 44%) of cows with no visible lesions had titers compatible with exposure ($\geq$1600) prior to treatment (Table 1). These preliminary serological results indicate that many animals considered naive by visual observation actually had titers consistent with exposure, which may have contributed to the results indicating no benefit. Statistical analyses have not been performed but fewer of the ELISA negative vaccinates developed (P)DD lesions during the study when compared to the ELISA negative placebo cows.

Table 1. Comparison of visual observation and ELISA testing for Treponema antibodies prior to vaccination with Treponema bacterin or placebo (adjuvant with no Treponema antigens.

	ELISA		
Visual observation	Positive	Negative	TOTAL
Positive	6	4	10
Negative	34	34	68
TOTAL	40	38	78

In contrast to the above study, a study in Nebraska, USA found that a different Treponema bacterin (TrepShield HW®, Novarits Animal Health, Inc.) was efficacious in preventing new cases of (P)DD in heifers and cows (G.A. Anderson, Novartis Animal Health, Inc., personal communication). TrepShield HW® is fully licensed with the US Department of Agriculture. In this study heifers were vaccinated prior to calving and cows were vaccinated during the dry period in contrast to the California trials in which all cows in the herds were vaccinated at the same time. Cows and heifers were randomly assigned to vaccine or control groups. Cows and heifers were classified as (P)DD negative or positive based on the bright light and water jet test. The prophylactic portion of the study (pre-vaccination (P)DD negative cows and heifers) included 368 animals. The cumulative incidence is presented in Table 2.

Overall, the incidence of (P)DD was significantly lower in vaccinated compared to control animals. A statistical difference in incidence between vaccinates and controls was found for cows and heifers combined and heifers alone, but not for cows alone. In this study, serology was not performed. Based on the California studies with serology on dairies having a similar pre-trial prevalence to this Nebraska study (27%), we might speculate that a sizable proportion of the (P)DD negative animals in this study were not naive. If that were true, the vaccine would be more efficacious than these results indicate.

In the California study, vaccination of the whole lactating herd (in herds with a high prevalence) did not provide significant prophylactic or therapeutic effects to cows studied during 6 months. We speculate that using the vaccine on animals before they are exposed to the disease may prove to be more beneficial. On commercial dairies in the US those animals are most likely to be the breeding age heifers before they are exposed to the lactating cow herd.

Table 2. Cumulative incidence during the 4 weeks following calving, relative risk, and vaccine efficacy of a Treponema bacterin in vaccinated and control cows and heifers without visible (P)DD lesions at the beginning of the trial (prophylactic trial)

	Cumulative incidence (CI)
Overall	
Vaccinated	18.6% (33/177)[a]
Controls	28.8% (55/191)
Heifers	
Vaccinated	14.6% (13/89)[b]
Controls	26.6% (27/101)
Cows	
Vaccinated	22.7% (20/88)[c]
Controls	31.1% (28/90)

[a] p=0.023, [b] p=0.041, [c] p=0.208

Conclusions

It appears, that for all we have learned about (P)DD these last 30 years, there is still much more that we do not know. There are still many unanswered questions about the precise etiology, whether the treponemes are primary or secondary pathogens, the virulence factors for the treponemes, and where the treponemes live when they are not causing disease. Treatment with topical antibiotic and non-antibiotic products helps control (P)DD but recurrence is high and treatment must be on going. A new Treponema bacterin might offer some help in preventing (P)DD if we can vaccinate animals before they are exposed. The factors that seem to receive the least attention and, perhaps, might be the most important in controlling this disease are the hygiene of the environment for the cow's feet and biosecurity, especially when purchasing animals from off premises.

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AETIO-PATHOGENESIS OF ANAEROBIC INFECTIONS ASSOCIATED WITH BOVINE LAMENESS AND SOME HUMAN DISEASES

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Introduction

In clinical veterinary practice, infectious lameness has been described in textbooks from the early 1800s. Known colloquially as 'the fouls', specific lesions were accurately described: the shag foul was a circular lesion 2 cm diameter on the heel similar to greasy heels in horses and sounds similar to digital dermatitis; the stinking foul was an interdigital necrosis that was, almost certainly, interdigital necrobacillosis; the frog foul was a space-occupying lesion within the interdigital space but without any damage to the integument, the condition we recognise now as interdigital hyperplasia (Knowlson 1819). During the 1930s, infectious causes of lameness in both cattle and sheep were considered important only with regard to diagnosis of Foot-and-Mouth disease (Woolridge 1934), not for any economic or welfare reasons.
Today, cattle lameness is considered a major welfare issue in many countries where intensive dairy farming is commonplace. Surprisingly it is two infectious diseases associated with lameness, digital dermatitis in cattle and new variant footrot in sheep, which are causing currently the greatest problem for livestock farmers. The aetiopathology of both is unclear and hence control measures are largely ineffective (Demirkan et al 1999). Treatment and control is expensive in terms of time and labour, and there is concern that disposal of footbath solutions used for treatments may pollute the environment.

Aetiology

The list of microorganisms associated with infectious lameness in cattle, mostly facultative or obligate anaerobes, is large and expanding slowly. The most common diseases and the infectious agents associated with them are listed in Table 1, together with suitable references. Until recently, it was not possible to isolate and grow Treponeme spp in pure culture and much of the evidence of their association with digital dermatitis is based currently on serology. Otherwise, all other microorganisms have been isolated from lesions and identified by standard microbiological techniques.

Risk factors for digital skin infections

Gross anatomy of the interdigital space

The vertical distance between the ground and the cranial and caudal borders of the interdigital space varies consistently in adult cattle (see Table 2). These results suggest that the caudal aspect of the interdigital space is always closer to the ground and adjacent hairy skin is vulnerable to repeated and continuous contact with slurry, especially in housed cattle. This is the case more so for hind limb digits than those of fore limbs ,ince many cows stand half-in cubicles with their hind feet in the slurry passage. The continuous contact of the hairy skin of the heel of hind limbs with slurry may cause focal hydropic maceration of the epidermis at this site and predispose it to bacterial invasion.

Microtrauma to skin

The integument of the bovine digit is designed to form an effective barrier between the environment that surrounds it and the functional tissue within it. Thus, a keratinised hard horny capsule encases the 3rd phalanx and distal interphalangeal joint of all claws. The skin of the interdigital space between each claw is also modified. Sweat glands and hair follicles are absent and the stratum corneum of the epidermis comprises of anuclear stratified squamous keratinised cells arranged in layers up to 35 cells thick. This is a very substantial flexible protective barrier to external insults. Microorganisms can penetrate such a structure only following mechanical trauma that allows opportunistic pathogens access to adhere to the deeper layers of the epidermis. Only then can keratolytic enzymes produced by pathogens such as D. nodosus, or exotoxins produced by F. necrophorum, break down the epidermal barrier to expose sensitive and susceptible underlying dermal tissue to inflammatory changes or invasion by other opportunistic pathogens.
The hairy skin adjacent to the coronary band and interdigital space is not modified from that found elsewhere. It remains an effective mechanical barrier. However, the integrity of the epidermis is affected adversely by exposure to prolonged moisture and reduced access to air. The resultant hydropic maceration may predispose skin to infection by Treponeme spp to produce clinical lesions typical of digital dermatitis (Read and Walker 1998).

Biology of anaerobic pathogens associated with human disease

Human periodontal disease has many similarities with infectious lameness in cattle; the bacterial profile, a stratified epithelium that is invaded, a 'triggering event' that precipitates epithelial and connective tissue necrosis, a susceptible host. Syphilis, like digital dermatitis, has been associated with a Treponeme infection. In periodontal disease, the focus of research has been to understand the interactions between various microorganisms isolated from diseased gingiva; with syphilis, it is the biology of Treponemes associated with their pathogenicity.
Some of these research outcomes are described below:
Attachment and colonisation of epithelial surfaces
The pathogenic Treponeme pallidum attaches to its host cells and invades epithelium whilst non-pathogenic Treponeme spp do not have this ability. This adherence factor appears to contribute to prolonged bacterial sur-