PEER REVIEWED

Anatomical Measurement of Sole Thickness in Cattle following Application of Two Different Trimming Techniques

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Abstract

Thin soles with complications and lameness have become a major problem in large dairies within the US. The cause is multifactorial, including excessive removal of sole horn during maintenance claw trimming procedures. This study compared sole horn thickness after trimming, using two commonly practiced trimming methods. Results showed that an adaptation of the Dutch trimming method resulted in significantly fewer thin soles as compared to the second method where the white line was used as an appraisal for sole horn thickness.

Résumé

Les problèmes de sole mince entraînant des complications et des boiteries deviennent de plus en plus importants dans les grandes fermes laitières des États-Unis. La cause de ces problèmes implique plusieurs facteurs, notamment la taille excessive de la corne plantaire lors du taillage régulier des onglons. Cette étude compare l'épaisseur de la sole après le taillage suite à l'utilisation de deux méthodes habituelles de taillage. Les résultats indiquent qu'une variation de la méthode hollandaise de taillage entraîne moins fréquemment des problèmes de sole mince que la méthode où la ligne blanche est utilisée pour évaluer l'épaisseur de la corne plantaire.

Introduction

The rate of sole horn wear depends largely on the hardness and water content of the claw.[4] Variations in water content are dependent on the structure of the claw as well as environmental and management factors.[4] There seems to be a relationship between the amount of intertubular horn and water absorption.[4] Sole horn contains 16.4 +/- 1.9 horn tubules per square mm, compared to the horn of the wall, which contains 79.1 +/- 16.3 per square mm.[2,4] Sole horn therefore contains more intertubular horn, and thus has a higher water content (25% in hind claws).[2,4] Under certain environmental conditions, water content of front claw horn can be as high as 70%.[4] As claw horn is continually exposed to high moisture conditions in modern dairy operations, an increased rate of wear can be expected, particularly in the presence of other complicating factors:

- **Concrete.** Long distances cows walk to be milked. This is greatly amplified if cows are milked three times a day. In addition, aggregates in new concrete can cause an increased rate of sole horn wear.
- **Social factors.** Commingling of animals, for example mature versus young and newly purchased animals.
- **Poor cow comfort.** Factors such as overcrowding, poor stall design, heat stress and insufficient bedding may decrease down time.
- **Horn quality.** Subacute laminitis is associated with poor horn quality. Thin soles have been observed in heifers suffering from subacute laminitis even before calving (Shearer, van Amstel, unpublished observations).
- **Poor stockmanship.** Forcing cows to move at a faster pace on hard walking surfaces could increase the rate of sole horn wear.

- **Claw trimming.** Excessive removal of sole horn during normal maintenance claw trimming procedures.

Thick soles, a consequence of claw horn overgrowth, may lead to complications resulting from altered weight bearing dynamics within the claw.[5,6] When toe length increases and the sole at the toe becomes thicker, there is a palmar/plantar displacement of the weight bearing axis, concentrating load bearing forces in the heel. This may predispose to traumatic injury of the corium between the flexor tuberosity of the third phalanx and the sole.[5,6] This in turn may result in hemorrhage in the sole at the "typical place" or the sole-heel junction, or in sole or heel ulcers in more severe cases.[5,6]

The claw capsule (epidermis), including the sole, should provide optimal protection to the corium (dermis) within the claw. Sole thickness of 0.20-0.28 inches (5-7 mm), which corresponds to a dorsal wall length of 3 inches (7.5 cm), has been reported to be optimal to provide sufficient protection for the average adult Holstein cow.[5] Greenough *et al*[3] reported normal sole thickness at the apex of 0.20–0.40 inches (5-10 mm), and 0.32–0.60 inches (8-15 mm) at the heel-sole junction. Using trimmed cadaver claws, Kofler *et al*[4] found sole thickness to be 0.30 inches (7.5 mm) at the apex, 0.28 inches (6.9 mm) mid-sole and 0.28 inches (7.1 mm) at the heel-sole junction.

The estimation of the sole horn thickness in live cows is difficult. Using cadaver legs, Kofler *et al*[4] found a good correlation between the use of ultrasound and direct measurement of sole horn thickness in sagittal sections of the claw. Other subjective methods for estimating sole horn thickness include compression of the horn using finger pressure or hoof testers.[5] The length of the dorsal wall may be another subjective indicator of sole horn thickness.[5] Toussaint Raven,[5] in his description of the Dutch trimming technique, correlates a sole thickness of 0.20-0.28 inches (5-7 mm) with a dorsal wall length of 3 inches (7.5 cm).

This study evaluates thickness of the sole apex using two different adaptations of the method described by Toussaint Raven.[5]

Materials and Methods

Cadaver legs of calves and adult cattle from various breeds originating from a slaughterhouse were collected and stored in a freezer. Both front and back legs were included in the study but not identified. Abnormal claws, such as corkscrew claw and those with claw horn lesions such as sole ulcer, were excluded. However, claws with signs of laminitis, such as horizontal wall fissures and concave dorsal wall ("buckled" claw) were included. Legs were thawed overnight in water prior to trimming and measurement procedures. The legs were divided into the following groups:

Group 1 (Non-Trimmed Group): Ninety legs from adult cattle with a dorsal claw wall length of 3 inches (7.5 cm). The dorsal walls of all the claws in this group were either straight or only slightly concave. The wall length was measured using a 3-inch (7.5 cm) gauge from where the palpable hard horn starts below the coronary band to the end of the toe.

Group 2 (Dutch Trimmed Group): Sixty-six legs from adult cattle with wall horn overgrowth (toe length in excess of 3 inches [7.5 cm]). Claws with concave dorsal walls were randomly divided between Groups 2 and 3. Both groups therefore had some claws with straight and some with concave dorsal walls. The exact distribution of claws with straight or concave dorsal walls was not recorded. Claws with severe concavity of the dorsal wall were not included in the study.

All claws were trimmed using hoof knives and an angle grinder based on an adaptation[6] of the method by Toussaint Raven.[5] The trimming procedure included the following steps.

Step 1. Using the gauge, the length of the front wall of the smaller of the two claws (based on visual appraisal) was reduced to 3 inches (7.5 cm). In cases where the dorsal wall was buckled, the wall distal to the notch was thinned until it formed a straight line with the proximal part of the wall. Next, thickness of the wall and sole was pared down to within 0.20 inches (5 mm) at the toe (Figure 1). The bearing surface of the wall and sole was kept flat.

Step 2. Using the trimmed claw as a guide, the toe of the larger claw was reduced to the same length. Next, the bearing surface of the larger claw was reduced to the same level. Thus, when holding the front walls together and at the same level, the weight-bearing surfaces of both toes were flat and balanced.

Step 3. The innermost back portions of the soles of both claws were sloped toward the interdigital space. The slope began at the point where the axial white line departs from the weight-bearing surface upward along the axial wall.

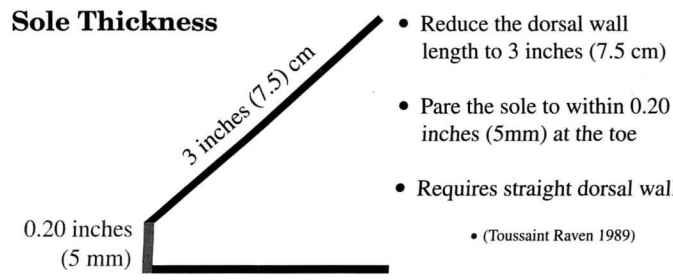

Figure 1. Guideline for sole thickness [Step 1, Group 2]. Claw as viewed from the lateral side.

Step 4. The heels were balanced between the two claws while ensuring that a flat weight-bearing surface was maintained along the heel, sole and abaxial wall.

Group 3 (trimmed using white line appraisal, referred to as the White Line Trimmed Group): Forty-eight legs from adult cattle with dorsal wall overgrowth (toe length in excess of 3 inches [7.5 cm]). Claws were trimmed using the same procedure as for Group 3, except for Step 1, which was carried out as follows:

Using the gauge, the length of the smaller of the two claws (based on visual appraisal) was reduced to 3 inches (7.5 cm). If present, concavity of the dorsal wall was left. Next, the thickness of the wall and sole was pared down until the white line reconnected at the toe (Figure 2). The bearing surface of the wall and sole was kept flat.

Using a band saw, claws from all three groups were cross-sectioned 1.2 inches (3 cm) behind the toe. Sole thickness immediately adjacent to the abaxial white line was determined by using a 2-inch (5-cm) long flexible ruler with an accuracy of 0.04 inches (1 mm).

Statistical Analysis

The following categories were defined for the purposes of the statistical analyses of this study: 0-0.16 inches (0-4 mm), 0.20-0.28 inches (5-7 mm), and 0.32 inches (8 mm) and above. Soles in the 0-0.16 inch (0-4 mm) category are defined as Thin, those in the 0.20-0.28 inch (5-7 mm) category as Optimal, and those in the 0.32 inch (8 mm) and above category as Thick. In order to determine if the proportion of soles falling into each category differed by group, contingency table analyses were performed. Due to low frequencies in some cells, p-values based on asymptotic theory would be questionable. As a result, permutation tests were performed to obtain exact p-values using StatXact (version 4.0).

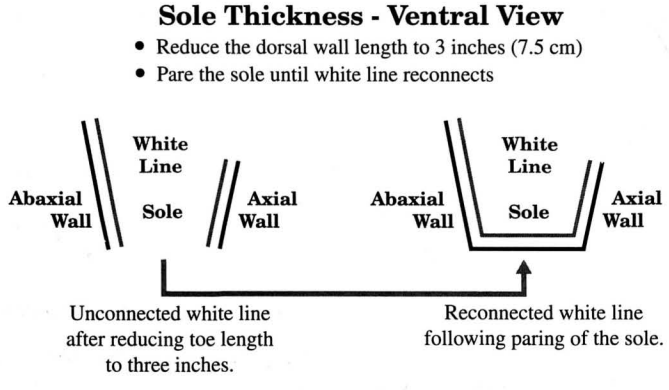

Figure 2. Guideline for sole thickness [Step 1, Group 3]. Claw as viewed from the ventral side and weight bearing surface.

In addition to this, it is important to determine which method is the most uniform. The aim of the trimming methods is to mimic the normal population as closely as possible. Levene's test was used to compare the two trimming methods with regard to homogeneity of variances. Given that the data were somewhat non-normally distributed, an adaptation of Levene's test by Brown and Forsythe[1] for non-normally distributed data was used, whereby the median is utilized in the place of the mean. Furthermore, due to the non-normality of the data, permutation methods to determine exact p-values were used. Analyses were performed with C-ISM2 Software.

Results

Table 1 summarizes the descriptive statistics for sole thickness for each of the three groups.

As it has been established that soles that are Thin (4mm and less) and Thick (8mm and above) can lead to lameness,[5] it is more effective to describe the data in terms of the three categories that were referred to above, i.e. Thin, Optimal and Thick. Table 2 illustrates the sole thickness frequencies in each category by group.

Contingency table analyses indicated that the groups differed in the proportion of soles falling into each sole thickness category, L^2 (4, N = 204) = 12.73, exact p = .02. Follow-up analyses found no difference between any of the groups on the proportion of soles in the Thick category as compared to soles in the Optimal category, L^2 (2, N = 195) = 0.19, exact p = .93. There was also no difference between the Non-Trimmed Group and the Dutch Trimmed Group in the proportion of soles in the Thin category as compared to soles in the Optimal category, L^2 (1, N = 66) = 0.07, exact p = 1.00. The White Line Trimmed Group, however, had a higher proportion of soles in the Thin category than did the Non-Trimmed Group, L^2 (1, N = 64) = 9.28, exact p = .01. Based on the non-significant differences between the Non-Trimmed and Dutch Trimmed Groups, and the significant differences between the Non-Trimmed and White Line Trimmed Groups in the above comparisons, it follows that the White Line Group has a significantly higher proportion of soles in the Thin category than the Dutch Trimmed Group.

Levene's test of homogeneity of variances for the Dutch Method Group and the White Line Method Group comparison was significant, W = 5.35, p = .02. For the Dutch Method Group and the Non-Trimmed Group, Levene's test was not significant, W = 0.21, p = .68. This test was significant for the White Line Method Group and the Non-Trimmed Group, W = 9.28, p = .00. The variances of the Non-Trimmed and the Dutch Method groups were similar, whereas the variance of the White Line Method Group differed significantly from both the Non-Trimmed Group and the Dutch Method Group.

Table 1. Descriptive statistics for sole thickness by group.

Group	Sole thickness descriptive statistics		
	Mean	Std. deviation	Range
1. Non-Trimmed	0.33″ (8.2 mm)	0.09″ (2.3 mm)	0.16-0.56″ (4-14 mm)
2. Trimmed Dutch Method	0.33″ (8.2 mm)	0.10″ (2.5 mm)	0.16-0.60″ (4-15 mm)
3. Trimmed White Line Method	0.33″ (8.4 mm)	0.14″ (3.6 mm)	0.12-0.68″ (3-17 mm)

Table 2. 3 X 3 frequency table for sole thickness by category and by group.

Group	Sole thickness category		
	Thin	Optimal	Thick
1. Non-Trimmed Group *(N = 90)*	1 (1%)	38 (42%)	51 (57%)
2. Dutch Trimmed Group *(N = 66)*	1 (2%)	26 (39%)	39 (59%)
3. White Line Trimmed Group *(N = 48)*	7 (15%)	18 (37%)	23 (48%)

Discussion

In this study, legs were collected in pairs but were not identified as being front or back or from which breed they originated. For these reasons, certain independence assumptions may have been violated. Most of the subjects in this study were beef cattle that lived predominantly on pastures. However, some of the subjects came from dairies where they were exposed to concrete. It is not possible to obtain information from the abattoir related to the environmental origins of the cows. Although overgrowth and sole thickness may vary with breed, environmental and nutritional conditions, the influence of these conditions probably had a minimal effect on this study for the following reasons: 1) The legs were randomly assigned for Groups 2 and 3. 2) Abnormal claws, such as screw claw and claws with horn lesions such as sole ulcers, were excluded. 3) Specific guidelines were followed for the trimming procedures in Groups 2 and 3.

A sole thickness of 0.20 inches (5 mm) is considered to be the minimum thickness necessary to avoid secondary complications related to thin soles.[5] However, a sole thickness in excess of 0.32 inches (8 mm) may be important as secondary complications related to uneven weight bearing result when soles are thick, particularly at the toe.[5]

There are several different approaches to claw trimming in cattle. One of the more generally accepted methods is that described by Toussaint Raven.[5] His trimming strategy, recognized as functional claw trimming, not only offers guidelines for re-establishing appropriate weight bearing, but by retaining a 0.20-0.28 inch (5-7 mm) sole thickness, ensures adequate protection to the solar corium. This sole thickness of 0.20-0.28 inches (5-7 mm) generally correlates with a wall length of 3 inches (7.5 cm).[5] This study found that non-trimmed claws from adult cattle (Group 1) with a dorsal wall length of 3 inches (7.5 cm) had a mean sole thickness of 0.33 inches (8.2 mm), with a standard deviation of 0.09 inches (2.2 mm). In addition, 99% of claws in Group 1 had a sole thickness of at least 0.20 inches (5 mm) and above. These findings did not differ significantly from those of Group 2 (Dutch Trimmed Method) which had a mean sole thickness of 0.33 inches (8.2 mm), with a standard deviation of 0.10 inches (2.5 mm). Sole thickness of 0.20 inches (5 mm) and above was recorded for 98% of claws in Group 2.

The method described for Group 2 (Dutch Trimmed Group) may become more difficult to apply where normal claw capsule conformation is lost, such as with laminitis. Application of this method is dependent on a straight dorsal wall, which in many cases is concave ("buckled"). This will interfere with the correct application of Step 1 unless the wall is straightened, which requires the use of either a rasp or angle grinder. This may be viewed as adding too much time to the claw trimming procedure, or weakening the wall by thinning it. In stand-up trimming chutes, both visualization and reaching of the dorsal wall is more difficult. For these reasons, a further adaptation to the Dutch trimming method described by Toussaint Raven[5] is being used. In this method, the dorsal wall is not straightened, instead, reconnection of the white line during paring of the sole after the toe has been shortened is used as the guideline to estimate sole thickness (Figure 2). In this study, application of this trimming method (White Line Trimmed Group) resulted in a mean sole thickness of 0.33 inches (8.4 mm), with a standard deviation of 0.14

inches (3.6 mm). Although this was not significantly different from both Groups 1 and 2, only 85% of claws had a sole thickness of at least 5 mm and above. This did result in a significantly greater frequency ($p < .01$) of sole thickness scores in the Thin category, as compared to Groups 1 and 2 (Table 2). Therefore, it appears that if a 5 mm sole thickness is taken as the minimum value required for adequate sole horn protection, application of the White Line method may predispose a larger percentage of cows to developing thin sole problems as compared to the Dutch method. Since there are several management and environmental factors (see above) present in large dairy operations which predispose to thin soles, application of the White Line method should be done with great caution.

A further evaluation of a particular claw trimming technique may include the homogeneity of variance. Ideally, application of a particular trimming technique should result in the least variation of sole thickness. In this study, based on the sole thickness categories (Thin, Optimal and Thick) as described above, the Dutch Trimmed Group (Group 2), did not differ significantly from the Non-Trimmed Group (Group 1) in terms of homogeneity of variance. However, the White Line Trimmed Group (Group 3) showed significantly more variation as compared with the other two groups. From this data, therefore, it would seem that the Dutch Trimming Method leads to more uniform results than does the White Line Method.

It should also be noted that, of the three categories (Thin, Optimal and Thick), all three groups recorded the highest percentages in the Thick category (0.32 inches [8mm] and above) (Table 2). This suggests that the ranges for the categories set in this study may be too narrow, particularly those that were set for the Optimal and Thick categories. Studies correlating sole thickness and distribution of load (weight) bearing within the claw using ultrasonographic and computer imaging techniques may provide further information.

Conclusions

When compared to a non-trimmed group of normal claws, which had a dorsal wall length of 3 inches (7.5 cm) and a mean sole thickness of 0.33 inches (8.2 mm), application of the claw trimming technique as described by Toussaint Raven[5] gave more consistent results and significantly fewer claws with thin soles (less than 0.16 inches [4 mm]) as compared to an adaptation of the same technique in which reconnection of the white line is used as a guideline to determine sole thickness.

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