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269.429.0300 fax 269.429.3852 hq@asabe.org www.asabe.org

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Effects of Liner Compression on Teat-End Hyperkeratosis

Maddalena Zucali

University of Milan, Italy

Douglas J. Reinemann, Ph.D.

University of Wisconsin-Madison, 460 Henry Mall, Madison, WI, USA 53705,

Alberto Tamburini, Ph.D.

University of Milan, Italy

Robert D. Bade

University of Wisconsin-Madison, 460 Henry Mall, Madison, WI, USA 53705,

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Abstract. *The teat canal is an important barrier against microorganism invasion of the udder. The degree of teat-end hyperkeratosis (HK) is a dynamic condition. Development of HK is influenced by many factors: some animal dependent, some dependent from seasonal condition and some from milking management. In particular milking vacuum and liner compression (LC) can influence teat-end condition. A quarter-udder experiment was performed with four liners each applied one quarter of 75 Holstein cows for a period of 3 weeks. Teat-end HK was assessed weekly. The results of this study confirm that the risk developing HK increases with liners that apply greater pressure to the teat end when closed. The risk of developing HK was highly influenced by the duration of milking and initial teat-end HK score.*

Keywords. *Milking Machines, liner compression, hyperkeratosis, teat-end roughness*

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Introduction

The teat canal is a primary barrier against invasion of mastitis pathogens into the udder. Maintenance of good condition of teat skin and tissues surrounding the canal is an important part of a program to obtain high quality milk. Short-term physiological effects of machine milking include teat congestion indicated by tissue swelling, hardness and color changes while HK is a longer-term of teat skin (Mein et al., 2001). Teat ends with rough surface is more difficult to clean during pre-milking preparation and provide a site for bacteria colonization. Neijenhuis et al., (2001) found a correlation between increased risk of clinical mastitis and very rough teat-ends. Hyperkeratosis (HK) of the skin surrounding the teat canal opening is a result of the stresses applied to skin when the milking liner collapses on the teat end.

Liner compression (LC) is a critical factor in reducing teat tissue congestion during milking and it can also influence peak flow rate and milking speed. At the same time excessive LC contributes to the development of teat-end HK (Capuco et al., 1994). Too much LC may also remove excessive amounts of keratin from the teat canal which makes teats more susceptible to infections. HK is also an undesirable condition also because it may contribute to cow discomfort during milking (Hamann, 2000). LC equal to mean arterial pressure (about 12 kPa) is thought to be sufficient to relieve congestion with additional LC providing no additional benefit for congestive relief (Mein et al., 1987). More recently it has been speculated that the LC required to relieve congestion has also been thought to increase as the milking vacuum level increases (Mein et al., 2003a).

The liner properties that influence the level of LC include; material type, age, wall thickness, vacuum difference across the liner wall during the d-phase of pulsation and other physical design elements. For a given claw vacuum, LC increases decreasing liner wall thickness (Mein et al., 2003a). Liners absorb butter fat and lose tension as they age, typically resulting in a reduction in LC (Mein et al., 2003b). The duration of milking, as affected by milk production level, milking frequency, and thresholds applied to automatic cluster removal also affect HK (Rasmussen, 1999). HK is also influenced environmental conditions (humidity and temperature) and genetics (teat shape and dimension) (Mein, et. al., 2001; Shukken et al., 2006).

A recent survey of teat-end condition on commercial farms indicated that the percentage of cows with rough or very rough teat ends averaged about 50% with some farms exceeding 70% and some farms less than 20% (Bade et al., 2007b). This study was undertaken to better understand the milking machine factors that contribute to rough teat ends.

Materials and Methods

The study was conducted on 75 Holstein cows, milked twice per day in the University of Wisconsin-Madison dairy cattle teaching and research facility milking parlor from 30 May to 20 June 2007. Milk yield per milking was 13.5 ± 4.97 kg with parity of 2.3 ± 1.23 and average days-in-milk of 239 ± 148.8 days. The automatic cluster removers were set at a flow threshold of 0.6 kg/min and a delay of 3 seconds, milking system vacuum level of 44.5 kPa, pulsation rate of 60 pulsations per minute and pulsation ratio of 60:40 for the duration of the study as well as the several months before the study commenced.

A quarter-udder experiment was performed by installing four different types of liners (A – left front, B – right rear, C – left rear, and D- right front) on each of the four clusters in the milking parlor so that each quarter of every cow was milked with the same liner for a period of one month. Liner B was used on all clusters for several months prior to the start of this experiment. Liners A, B, and C were all Nitrile rubber liners which differed primarily by increasing wall thickness. Liner D was a silicon liner that is round in the open position and triangular shaped when collapsed. In addition the outer walls of the liner were fixed to the inner walls of the shell at three points.

The touch point (vacuum required to collapse the liner until the opposing walls just touched) were measured for liners A, B, and C. The touch point could not be measured for liner D because the opposing walls never touched. LC was measured using the Start-of-Milk-Flow Method as described by Mein et al. (2003a).

Table 1. Liners characteristics

Liner	Liner Material	Wall Thickness (mm)	Un-mounted Length (cm)	Mounted Extension (%)	Mounted Tension (N)	Touch point (kPa)	Liner Compression (kPa)
A	Nitrile	2.5	13.1	18	81	11.9	18
B	Nitrile	2.7	13.1	18	88	12.9	15
C	Nitrile	2.9	13.1	18	91	17.3	13
D	Silicon	2.6	14.0	10	--	na	9

Statistical Analysis

Logistic regression analysis was carried out by using SAS software (SAS Institute, 1991) to examine the association between independent variables and teat score, a binary dependent variable (N or S called 'good', R or VR called 'bad'). A reference category was designated for each variable, having an odds ratio (OR) of 1. An OR of >1 implies an increased likelihood, whereas an OR of <1 implies a reduced likelihood. For each category of independent variable, teat score was compared with teat score of the reference group for that variable (Patton et al., 2007). The model used was:

$$\text{Teat Score} = \text{Liner} + \text{Score1} + \text{Mtime}$$

Where: Teat Score = dependent variable (good / bad)

Liner = Liner effect (A / B / C / D)

Score1 = effect of the teat score before the experiment (N / S / R+VR)

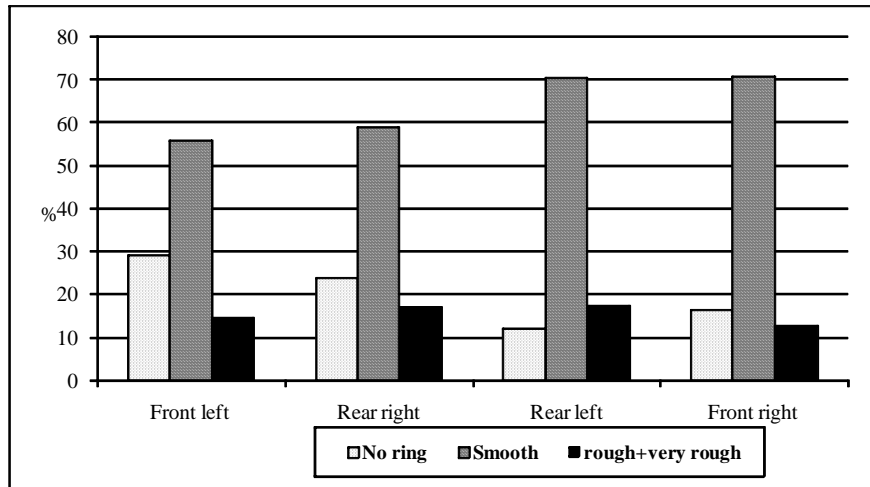
Mtime = Milking Duration (<4.30 minutes / 4.30-5.30 minutes / >5.30 minutes)

Relationships between teat end HK score, type of liner, milking time and number of lactations were also evaluated for the 75 cows by a multiple correspondence analysis (CORRESP procedure; SAS Inst. Inc.) to produce a graphical representation of the rows and columns of a contingency table (Sandrucci et al., 2007).

Results

The teat-end HK scores of cows recorded at the beginning of the study are illustrated in Figure 1. The distribution of the initial Teat-end HK scores was similar across quarters (and therefore, treatments). The distribution of teat-end HK scores at the start of the study was quite good with just 15% of the teats scoring R or VR compared to a recommended target level or 20% given by Teat Club International (Mein et. al., 2001). The milking conditions prior to the start of the study were quite moderate regarding vacuum levels with moderately aggressive settings for automatic cluster removal resulting in minimal over-milking. In addition milking frequency of these cows was twice per day as compared to the majority of commercial farms reported in the field study by Bade et al., (2007b) which milked three times per day.

Figure 1. Teat-end HK scores at the start of the study.



The progression of teat-end HK scores during the four weeks of the experiment and for each treatment liner (quarter) are illustrated in figures 2 through 5 (Week 1 = initial score before liner treatments applied) . Teat-end HK score using liners 1 and 2 showed an increasing during the experiment from about 20% to about 30% of score R and VR (Figures 3 and 4).

LC applied by liner 1 and 2 was higher (17.5 kPa and 14.6 kPa respectively) than 12 kPa, mean arterial pressure, so it could not bring any benefit effects on relieving congestion. At the same time an excessive LC, like in this case, can lead poor teat-end condition.

Using liners 3 and 4 Teat-end HK score remained almost stable around 20 % of score R and VR during all the experiment. This is probably caused by less LC applied by liners 3 and 4, because of thick wall thickness of the liner 3 and liner design of the liner 4 (Figure 5 and 6). The results of visual assessment of teat end photographs are presented in Figure 6.

Figure 2. Teat-end HK scores during the experiment using liner A.

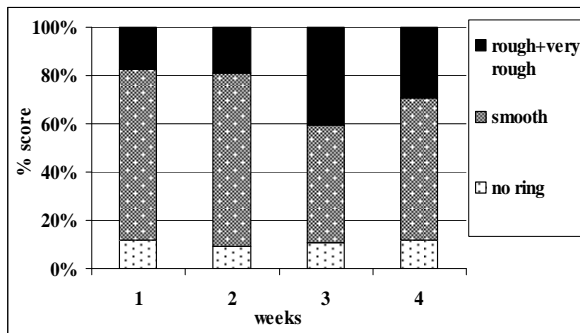


Figure 4. Teat-end HK scores during the experiment using liner C.

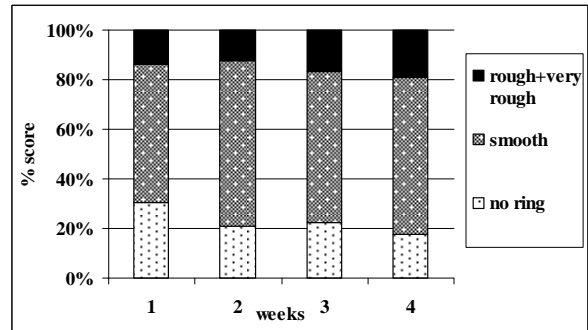


Figure 3. Teat-end HK scores during the experiment using liner B.

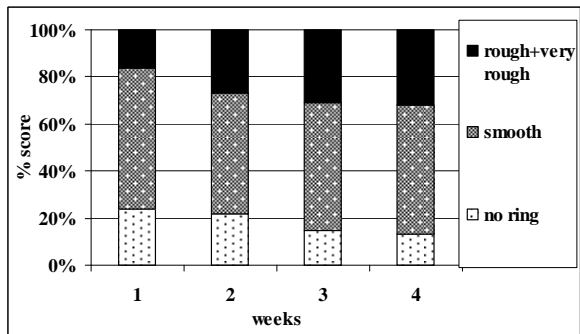
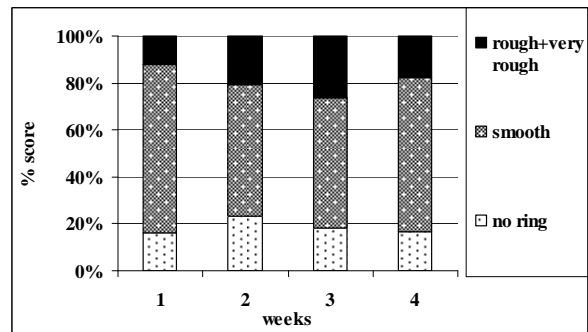


Figure 5. Teat-end HK scores during the experiment using liner D.



Examination of Figures 2 through 5 indicate no substantial difference between liners C and D, while liners A and B showed a slightly greater trend toward R and VR scores.

The results of the multiple correspondence analyses assessing the relationships among the following class variables: Liner, Teat-end HK scores and duration of milking time is shown in Figure 6. The parameters nearer one another are more closely correlated than those far from each other. Teat-end HK score R and VR are most closely related to long milking duration and liners A and B, While teat-end HK score S (smooth rings) is most solely related to short milking duration and Liner D. Teat-en HK score N is most closely related to Liner C and medium milking duration (4.3-5.3 min) .

The results of the logistic regression analysis (Table 3) indicate that the initial teat-end score and the duration of milking (as influenced by milk yield and other cow factors) had a large influence on the risk of developing a poor HK score (R or VR). Teats that started with a score of N were less likely to become R and VR than teats starting with a score of S. Not surprisingly, teats that began the experiment with a score of R or VR were much more likely to end the experiment with a score of R or VR than teats starting the experiment with a score of S. This is probably an indication of the importance of teat size and shape on the risk of developing HK as well as the difficulty for teats to 'recover' from the development of rough teat ends. Cows (teats) with milking duration <4.3 min were much less likely to develop HK than cows (teats) with a milking duration > 5.3 minutes, probably due to the decreased number of time the liner collapsed on these teats. While liner type also had an influence on the risk of HK, it was not as large as the influence of milking duration. The risk of developing HK score R or VR was

maximized with liner B and minimized with liner C. Comparisons across other liners were not significant.

Figure 6. Multiple correspondence coordinates for: Liner (LA, LB, LC, LD), Duration of milking (<4.3, 4.8, >5.3) and final teat-end HK score (NR = no ring, SR = smooth ring, R = rough or very rough ring)

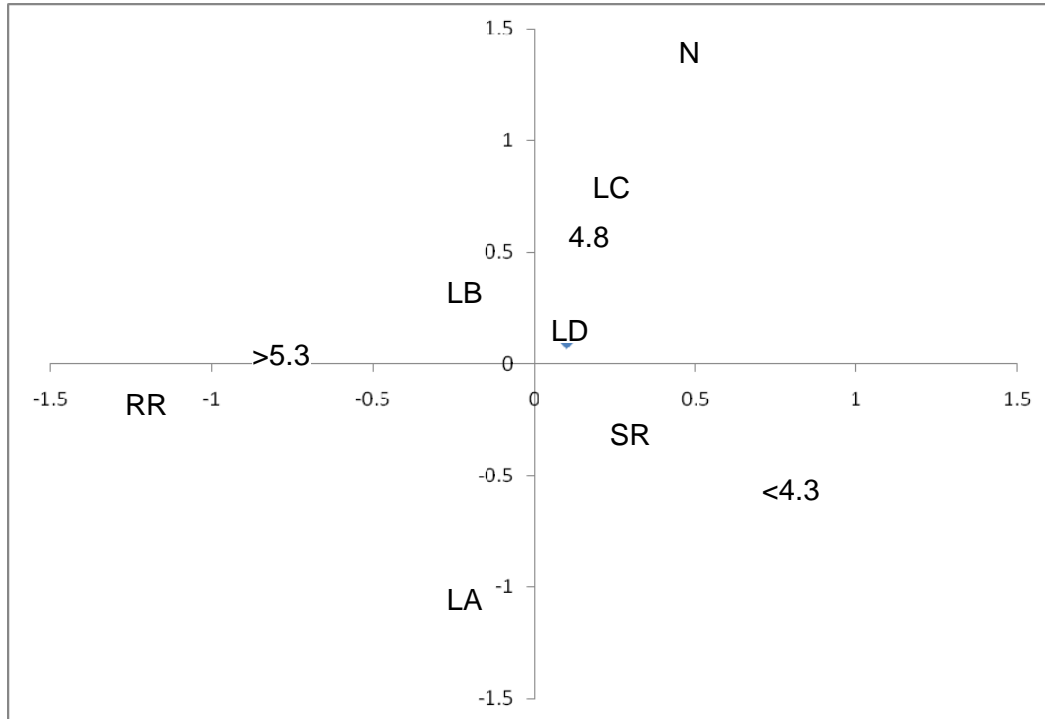


Table 3. Logistic regression results for risk of developing R or VR teat-end HK score.

Liner:	Odds Ratio	P-Value
A vs B	0.84	0.09
C vs B	0.36	0.01
D vs B	0.57	0.46
Initial Teat-end HK score:	Odds Ratio	P-Value
N vs S	0.38	<.0001
R+VR vs S	34.2	<.0001
Mtime:	Odds Ratio	P-Value
<4.30 min vs >5.30 min	0.29	<.0001
4.3-5.3 min vs >5.30 min	0.5	0.74

Discussion and Conclusions

Milking duration and initial teat-end HK scores had a larger influence on final teat-end HK scores than liner type and liner compression. However, there are indications that liner compression does contribute to the development of teat-end HK. Each form of analysis had at least one indication that increased LC was associated with increased HK score; however the results of the different statistical analyses were not entirely consistent. The level of teat-end HK was much lower in this study than on a selection of commercial farms in Wisconsin that milk cows 3 times per day. Initial teat-end HK scores were quite good, milking conditions were gentle, and milking was performed twice per day in this study. As a result there were not large changes in the response variable of teat-end HK scores during the 3 weeks of this study. Detectability of differences in teat-end HK scores due to liner characteristics would likely be improved by blocking cows on milking time, using cows that are milked 3 times per day and extending the period of the study.

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