Technote 9

Preventing and managing teat sores and cracks

In this technote:

1. Defence mechanisms of the teat canal
2. Assess teat skin and teat ends systematically
3. Manage teat condition
4. Check important milking machine factors
5. Seek advice from your veterinarian if problems persist

Maintaining healthy teat skin is essential for effective mastitis control. Teat condition reflects the quality of environmental hygiene, milking management and performance of the milking machine, and is a useful indicator of intramammary infection risk.

Mastitis risk increases as bacterial load at the teat end increases. Teat sores and cracks provide sites for bacterial growth and are painful, leading to increased kicking and defecation during milking, and poor milk let-down. By contrast, healthy, undamaged teat skin is easier to keep clean and reduces the risk of new infections.

① Defence mechanisms of the teat canal

Mastitis occurs when bacteria enter the mammary gland, typically through the teat canal. Four physical components of the teat canal protect against bacterial invasion:

- tight closure and sealing of the teat canal between milkings;
- adherence of bacteria to the keratin lining;
- shearing and removal of keratin during milk flow; and
- drying and re-sealing of the canal post-milking.

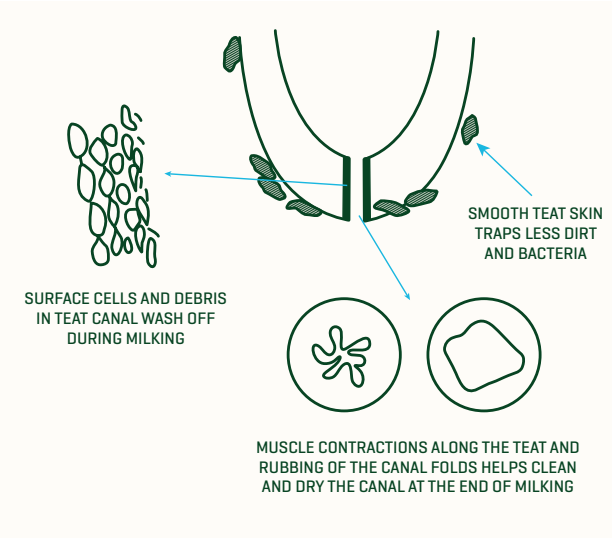
Disruptions to any of these increase susceptibility to infection.

The teat canal, about 10-12 millimetres long and highly folded when closed, is lined by a modified epithelial layer, continuous with teat skin. It is the first and most important barrier to bacteria entering the udder, and new infection risk is increased if:

- the teat canal is relatively wide, indicated by a high peak milk flow rate. Teats with high milk flow rates had higher infection rates in the dry period (Dodd & Neave 1951) and in lactation, when exposed to high bacterial challenge (Grindal & Hillerton 1991).
- the teat canal is shorter than average (Grindal *et al* 1991; Lacy-Hulbert & Hillerton, 1995).
- the keratin fails to seal the canal effectively between milkings or in the dry period (Williamson *et al* 1995). Artificial removal of keratin at the end of milking led to higher infection rates when exposed to high bacterial challenge (Capuco *et al* 1992).

Keratin is a wax-like substance produced by the cells lining the teat canal. It serves as a temporary seal between milkings and a more permanent plug throughout the dry period. Keratin is a protein complex that contains lipids, and is a major structural component in skin, hair, nails and hoof cells. It can trap bacteria and help them to be removed at each milking.

Defence mechanisms of the teat end



Physical mechanisms help resist bacterial penetration through the teat canal (Williams 1984; Williams & Mein 1985; Lacy-Hulbert & Hillerton 1995; Paulrud 2005). At a microscopic level:

- a lipid film in mature keratin layers aids easy opening and cleaning during milking, and
- effective re-sealing after milking prevents bacterial migration.

Keratin cells, held loosely in this lipid film, trap bacteria (see Figure above). During milking, milk flow and liner pulsation flushes away keratin and bacteria, while the lipid film is replenished continuously from the underlying epithelium. After teat cups are removed, muscle contractions 'wring' the teat canal dry, disrupting milk columns and preventing capillary movement of bacteria through the teat canal.

Practical consequences include:

- During normal milking, the milk stream under vacuum has sufficient force to shear and remove the outer layer of mature keratin cells lining the teat canal, helping keep it clean.
- Liner pulsation applies cyclical pressure around the teat end, physically loosening keratin debris so it can be flushed away in subsequent pulsation cycles. Approximately 40% of mature keratin cells are removed with normal pulsation, compared with about 25% without pulsation (Capuco *et al* 1994).

- Milking without pulsation results in accumulation of keratin within the teat canal and is associated with higher rates of new intramammary infection, likely due to prolonged retention of contaminated keratin (Lacy-Hulbert *et al* 1996).
- Keratin's highly convoluted, lipid-coated surface can entrap lipophilic bacteria such as *Staph. aureus*, *Strep. dysgalactiae* and *Corynebacterium bovis*. These pathogens may colonise the teat canal and use lipids and milk residues to support growth (Mamo *et al* 1987; Calvinho *et al* 1996).
- Most mastitis pathogens are non-motile and rely on passive movement of milk within the teat canal. Resealing and mild dehydration of keratin between milkings may reduce movement of contaminated milk toward the gland.
- Components of keratin may possess intrinsic antimicrobial properties, contributing to the natural defence of the teat canal (Smolenski *et al* 2015).

These natural defence mechanisms likely explain why more frequent milking lowers the risk of mastitis infections, by regularly flushing the teat canal.

By contrast, the higher infection risk in the early dry period may be due to the absence of this flushing mechanism, allowing pathogens to persist in the teat canal.

➜ **Technote 14** describes the importance of the keratin plug in the teat canal at drying-off.

② Assess teat skin and teat ends systematically

Systematic assessment of teat skin and teat ends is essential, as changes in teat tissue integrity of the barrel, teat end and canal, can compromise udder defence mechanisms. Farmers, veterinarians, and other advisers require simple and reliable methods for evaluating teat health during milking, especially when initial observations suggest potential problems (Ohnstad 2010).

➜ Use Sheet I of the DairyNZ **Mastitis Investigation Kit** to record teat condition scores – see **Technote 13** for more information.

Teat Club International, an informal group of udder health researchers and advisers, developed a protocol for systematic examination of teat condition, along with guidelines for interpreting observations (Hillerton *et al* 2001, 2002a; Mein *et al* 2001; Neijenhuis *et al* 2001c; Reinemann *et al* 2001). Later work expanded these guidelines to include:

- effective management changes or machine settings that provide successful solutions,
- expected timelines for improvement, and
- confidence levels for each recommendation (Ohnstad *et al* 2007).

These guidelines form the foundation of this Technote.

Teat condition can be influenced by multiple factors, which can be broadly grouped into three categories:

- milking-induced (machines and management),
- environmental, and
- infectious causes.

Table 1 summarises the main conditions in the first two categories, and discussed further in Sections A and B, with infectious causes addressed separately in Section C below.

Table 1. Teat conditions arising from milking-induced and environmental effects in Australia and New Zealand.

Milking-induced	Environmental
Discolouration	Skin dryness and chapping
Firmness or swelling	Teat orifice roughness and hyperkeratosis
Wedging of the teat end	Abrasions and cuts
Openness of the teat orifice	Photosensitisation, sunburn, frostbite
Petechial haemorrhages	Chemical damage
Hyperkeratosis (thickening of the skin at the teat orifice)	Allergic reactions
	Insect bites

A. Short-term, milking-induced changes in teat condition

Short-term changes are those that occur in response to a single milking. Primarily due to faults in milking management or machine function, they may present as:

- discolouration - reddened, bluish, purplish or very pale teats seen immediately after milking;
- firmness or swelling of the teat or "ringing" around the upper barrel;
- wedging of the teat end;
- excessive openness of the teat orifice.

Specific causes or contributing factors are summarised in Table 2.

Generally the teat takes some hours to recover its full integrity even under good milking conditions (Neijenhuis *et al* 2001b). Improvements in teat condition should therefore be evident immediately after the milking at which the specific fault or faults have been correctly identified and fixed.
Full resolution may take one or more days.

Table 2. Primary causes (1) or exacerbating influences (2) on short-term changes in teat condition induced by milking.

	Teat colour	Swelling at teat base	Firmness/hardness of teat end		Orifice
Observation	**Red/blue**	**'Ringing'**	**Hard**	**Wedged**	**Open**
Machine factors					
High milking vacuum	1	1	1		1
Faulty pulsation	1		1	1	
Prolonged b-phase			1		
Short d-phase	1		1		
Long d-phase				1	
Liners:					
• Wide bore liner with tapered barrel	2	2	2		
• Aged (i.e. stiff or very pliable walls)	2	2			
• High tension (i.e. stiff walled liner)	2		1	1	1
Mouthpiece:					
• Deep chamber	2	2			
• Small diameter	2	2			
• Stiff mouthpiece		2	2		
Mismatch of liner and teats	2	2			2
Milking management					
Long dribble times (flow below 1L/min per cow)	1	1	1		
Overmilking (flow below 400 ml/min per cow)	1	1	1		1
Teatcup crawling	2	2	2		

Evaluating machine-induced, short-term changes

1. Colour changes

Some teats show redness at the teat end or over the entire teat after cluster removal. Others may appear white and feel cold initially, then redden within 30-60 seconds. More severe cases show blue or purple discoloration. These changes may be worse for short, slender, or oedematous teats that are poorly supported by the liner.

Reddish discolouration, or congestion is exacerbated by over-milking, especially with wide-bore liners or tapered liners with wide upper barrels, or by excessive cluster weight, high milking vacuum, faulty pulsation or a mismatch between type of liner and average teat size.

Bluish discolouration, or cyanosis, may result from liners with a small mouthpiece diameter relative to the internal diameter of the barrel, or liners mounted at unusually high tension.

Highly pigmented or black teats cannot be evaluated reliably and must be excluded from colour-based evaluations. Colour changes are classified according to the proportion of light-coloured teats which, when examined within one minute of cluster removal, are:

- **Normal** - pink.
- **Red** - part of, or the entire teat, may be reddened.
- **Blue** - part of, or the entire teat appears to be tinged with blue or purple.

Because the causes of reddened or bluish teats may differ, red and blue classes should be recorded separately. However, analysis is simplified by combining changes into a single category **'Red or Blue'**.

➜ **Technote 6** provides more information on liner selection and matching liners to clusters.

2. Swelling at or near the teat base

When examined after milking, some teats may show a visible line or swelling around the upper part of the barrel, where they were in contact with the liner mouthpiece. This may appear as a palpable thickened ring. Cows with udder oedema or within one week post calving should not be assessed, as the swelling may be physiologically normal.

Common causes include: high mouthpiece vacuum associated with wide-bore liners; over-milking, especially with wide-bore liners or tapered liners with wide upper barrels; liners with a large mouthpiece chamber; teatcup crawling; or liner mouthpiece lips that are unusually stiff or narrow in relation to teat size.

Swelling at or near the teat base when examined within one minute of cluster removal is classed as:

- **Normal** – no ring, little or no swelling, and teats that have a visible mouthpiece lip mark or 'garter mark' (Hillerton *et al* 2000).
- **Swollen** – if there is marked swelling or a palpable thickened ring.

Excessive teatcup crawling occurs when a teat cup moves so far up the teat that the passage of milk from the udder to the teat is obstructed.

3. Firmness at or near the teat end

Teats should feel soft and pliant after milking. Some may contract as the cups come off, or in response to touch. Teats that feel swollen, firm, hard or cold are an indicator of congestion. Factors commonly responsible include: over-milking, wide-bore liners, high vacuum, pulsation failure, insufficient rest phase (d-phase) or prolonged open-phase (b-phase) during pulsation.

Teat ends may appear flattened or wedge-shaped after milking. Wedging describes the flattened shape of the teat end due to the compressive load applied by the opposing walls of a collapsed liner. Typically, this wedging will be slight but severe wedging may occur with hard liners, high liner tension, prolonged d-phase or failure of liners to open fully.

Teat ends are classified by visual examination, with palpation, as:

- **Normal** – soft and supple.
- **Firm** – firm, swollen or hard or noticeably wedged.

4. Openness of the teat orifice

Immediately after milking, the teat orifice may appear fully closed, slightly open or in extreme cases, has a funnel-shaped opening about the size of a match-head.

Factors associated with short-term, post-milking openness of the teat orifice include: high milking vacuum, over-milking, heavy cluster weight, or high liner tension.

Teat orifices are classified by qualitative assessment within one minute of cluster removal as:

- **Closed**
- **Open** – more than 2 millimetres wide or deep.

When estimating the degree of openness, it may be helpful to mentally compare the width and depth of an open orifice with that of a common object such as a match-head (~3 mm in diameter) or the shaft of the match (~2 mm). Flicking the teat end or blotting away milk residue with a clean paper towel may assist assessment.

B. Medium to long-term, milking induced or environmentally induced changes in teat condition

Medium-term changes refer to teat tissue changes that develop over several days or weeks. Specific causes, and exacerbating influences, are summarised in Table 3.

Medium-term changes take longer to resolve than short-term changes. While some improvement may be visible within a few milkings once the underlying cause is corrected, full recovery can take several weeks.

Table 3. Primary causes (1) or exacerbating influences (2) on medium to long-term changes in teat condition induced by milking or environmental factors.

	Teat skin		Teat end
Observation	**Rough/scaly skin, cracks or lesions**	**Haemorrhages**	**Hyperkeratosis**
Duration	**Medium-term**	**Medium-term**	**Medium-long term**
Machine factors			
High milking vacuum		1	1
Faulty pulsation		1	
Liners: • Wide bore liner with tapered barrel		1	
• Aged (i.e. stiff or very pliable walls)		1	1
• High tension (i.e. stiff walled liner)		1	1
Milking management			
Long dribble times (flow below 1L/min per cow)			1
Overmilking (flow below 400 ml/min per cow)		2	1
Chemicals (or insufficient emollient)	1		2
Environmental factors			
Cold, wet, windy weather	1		2
Mud/manure (e.g. from intensively grazed or stand-off areas)	1		
Sunburn or forage-related photosensitisation	1		
Infectious skin lesions	1		

Evaluating medium to long-term changes

1. Petechial haemorrhages

Petechial, or more extensive haemorrhages, indicate vascular damage to teat tissue. Machine-induced haemorrhages of the teat skin may take several days to become evident and are commonly associated with pulsation failure, shortened d-phase, high vacuum or prolonged overmilking. Chronic cases are usually linked to extended periods of over-milking (see Table 3). Incidence is lower in herds milked with narrow-bore liners, at low vacuum, and/or with automatic cluster removers.

Improvement generally requires optimisation of vacuum and pulsation settings to improve teat end massage during pulsation, alongside correction of cluster position and tubing support. Where cluster position is poor, eliminating vacuum and/or pulsation faults may not provide a complete solution. Some improvement should occur within a few milkings but full resolution may take up to 4 weeks.

Petechiae (on lightcoloured teats) are classified by close examination of the teat end as:

- **Normal** – no evidence of petechial haemorrhage
- **Mild** – Small pin-prick red spots in discrete areas or very diffuse across the teat end.
- **Moderate** – Dense red spots, affecting a discrete area.
- **Severe** – Coalescing spots forming a bruise or sore, with or without open lesions.

2. Teat skin condition - environmental factors

Healthy teat skin has a protective fatty acid layer that suppresses pathogen growth. Damage removes this layer, allowing colonisation by pathogens such as *Staph. aureus.* Cold, wet or windy weather can cause dryness, roughness or chapping, leading to formation of cracks that provide sites for infection. Severe winter weather can have an immediate effect on teat skin roughness, with teat skin cracking occurring within 1-2 days (Timms 2004). At more moderate temperatures (-3 to 24°C), use of a teat spray containing more emollient (8% compared to 2%) improved teat skin condition significantly over 4 weeks (Rasmussen & Hemling 2002).

Environmental factors such as cold, wet or muddy conditions can lead to hardening or thickening of the teat skin by impairing circulation or drying the skin surface, potentially progressing to teat end hyperkeratosis (see below). Poor teat skin condition is usually most obvious immediately after cluster removal.

Factors that exacerbate environmental skin damage include:

- low emollient concentrations in the teat disinfectant
- poor teat spray coverage
- older style or poorly maintained milking equipment
- over-milking
- new installations lacking quality control of the set-up (Hillerton *et al* 2000, 2002b).

In the absence of cracks and sores, dry teat skin does not increase new mastitis infection rates (Rasmussen & Larsen 1998).

Teat skin condition is classified as:

- **Supple** – smooth, soft, healthy skin.
- **Dry** – scaly, flaky or rough skin but with no cracking.
- **Lesion** – any open lesion, chap or crack on the barrel or teat end (See section C below).

The dryness of black teats tends to be over-estimated by observation alone. Evaluation is improved by lightly rubbing the teat skin with a finger, when wearing a latex glove.

3. Teat skin condition - chemical irritation

Chemical irritation of the teat skin may show as reddening, drying or roughening of the teat skin, typically on the teat barrel rather than the teat end. Aggressive chemicals may induce epidermal hyperplasia or a temporary thickening, scaliness or leathery appearance (Hillerton *et al* 2002a).

Chemical irritation may arise from disinfectant type, concentration, or inappropriate emollient content, often worsening the effects of harsh weather. Emollients act as humectants (moisturisers) or reduce evaporation from the skin to restore teat skin condition (Hemling 2002). Severe irritation can peak after 1-3 days and may require 3-5 weeks to heal (Fox 1992), with more moderate cases resolving in 10-14 days (Rasmussen 2003).

Modern iodine disinfectants (pH ≥3.5) are less irritating than earlier formulations and produce little evidence of teat irritation with appropriate use of emollient. Sensitivity is extremely rare. Chlorhexidine solutions are mild in most cases and unlikely to have an adverse effect on teat skin.

Classification of this condition is described in section 2 above.

4. Teat skin conditions – photosensitisation

Photosensitisation primarily affects nonpigmented, hairless teat skin exposed to sunlight. Early signs include restlessness (including kicking at the udder and abdomen), teat irritation, and reddened, oedematous skin. As the condition progresses, affected skin becomes dry, leathery, or sloughs off in sheets.

Primary photosensitisation occurs when photodynamic plant compounds are retained in the bloodstream rather than being excreted in the bile. Spring eczema is one example, linked to grazing of lush spring pasture.

Secondary (hepatogenous) photosensitisation arises from liver damage that limits its ability to clear photodynamic chlorophyll break-down products from the bloodstream. Common causes include ingestion of facial eczema spores, or blue-green algae, or grazing certain plants such as St. John's Wort, lantana, ragwort or lupins (see "Diseases of Cattle in Australasia" by Parkinson *et al* 2010 for more).

Treatment involves removing the source of irritation, providing shade, adjusting the diet and using topical sunblocks or barrier creams to alleviate symptoms. If liver damage is present, it becomes the primary focus of treatment e.g., oral zinc oxide supplementation.

Sunburn can also occur on light-coloured teat surfaces and should be distinguished from photosensitisation. Good teat spray coverage and use of teat salves or sun blocks after milking can prevent progression to mastitis.

Classification of this condition is described in section 2 above.

5. Teat end hyperkeratosis

Teat end hyperakeratosis (HK) is variously described as roughness, thickness, teat rings and fronds at the teat end. It is rare in heifers but common in machine milked animals (Sieber and Farnsworth 1981; Neijenhuis *et al* 2000).

The amount of HK varies over lactation, typically increasing from calving to peak production and decreasing towards drying off. It also increases progressively with parity (Shearn & Hillerton, 1996; Neijenhuis *et al* 2000), and longer, slender or pointed teats are more prone, suggesting a genetic influence.

Hyperkeratosis is often influenced by seasonal cold, wet weather conditions (Table 4), likely due to reduced blood circulation. Skin thickens in response to mechanical forces applied to it. Exposure to prolonged low milk flow periods (<1 L/min) at start and end of each milking increases HK development. Milking related issues that also affect HK include:

- inappropriate vacuum
- high liner compression
- prolonged machine-on time, leading to overmilking.

Note that hyperkeratosis is not associated with faulty pulsation. Chemical irritation by disinfectants can exacerbate HK but high-emollient disinfectants may not reliably improve it (Britten *et al* 2004).

Teat Club International recognises that a small amount of HK may be a normal adaptive response to machine milking but more severe forms increase the risk of:

- new intramammary infections (Neijenhuis *et al* 2001a, 2001c; de Pinho Manzi *et al* 2012)
- teat canal colonisation with *E. coli* (Paduch *et al* 2012),
- prevalence and incidence of *Staph aureus* infections (Pantoja *et al* 2020), and increased SCC (Guarín *et al* 2017).

Hyperkeratosis is classified according to the teat end scores described in Table 5 below.

Noticeable improvements in teat ring roughness take about 4 weeks after elimination of the specific cause.

Table 4. Major risk factors affecting teat end hyperkeratosis

Risk factor	Reason for increased likelihood of teat end hyperkeratosis
Pointed teats	The load applied by the closing liner is on a smaller area of teat surface
Increasing age	The 'wrinkle factor' in all species
Higher production	Cups are on for longer
Peak lactation	Cups are on for longer
Udder washing	Water and chemicals reduce skin moisture and elasticity
Cups on before let-down	Longer period of milk flow below one litre per minute
Low thresholds for Automatic Cluster Removers (ACRs)	Longer period of milk flow below one litre per minute
Over milking	Longer period of milk flow below one litre per minute
High vacuum	Greater stress on teat tissues – more stretched in the open liner and squeezed in the closed liner
Stiff liner mouthpiece	The lip acts like a tourniquet which slows or restricts outflow of blood from the teat wall when the liner is collapsed
Liners mounted at high tension	The region of greatest local pressure is applied just above rather than at the teat end. This restricts outflow of blood from the teat tip (acts like squeezing a grape until the skin splits)

Table 5. A scoring system for teat end hyperkeratosis (from Mein *et al* 2001)

Score	Description	Illustration
N	**No ring** The teat end is smooth with a small, even orifice. This is a typical status for many teats soon after the start of lactation.	
S	**Smooth or slightly rough ring** A raised ring encircles the orifice. The surface of the ring is smooth or it may feel slightly rough, but no fronds of old keratin are evident.	
R	**Rough ring** A raised, roughened ring with isolated fronds or mounds of old keratin extending 1-3 mm from the orifice.	
V	**Very rough ring** A raised ring with rough fronds or mounds of old keratin extending 4 mm or more from the orifice. The rim of the ring is rough and cracked, often giving the teat end a 'flowered' appearance.	

C. Teat conditions due to infectious agents

Infectious teat skin lesions provide an important indication of overall hygiene, mastitis control practices and milk quality management on a farm. Any decline in teat skin integrity can negatively affect milk quality, milk safety, and udder health, and some infections pose health risks to staff.

Most infectious lesions are caused by viruses, pus-forming or necrotising bacteria, or fungi, and may affect the teat end, teat barrel or udder skin. Typical lesions are summarised in Table 6 and the more common conditions are described further below.

Table 6. Summary of the typical features of infectious agents that can affect teat condition.

Organism type	Condition or agent	Typical lesion
Virus	Pseudocowpox*	Local, red angry lesions in the early stages that develop over a couple of days into small, raised, circumscribed lesions with dark red centres. A characteristic ring or 'horseshoe' shaped scab may be seen when crusts fall away. People are occasionally infected with purple 'milkers' nodules on their fingers.
	Bovine herpes mammillitis*	Numerous, raised, oedematous plaques about 1-2 centimetres in size. Lesions can cover a large part of the teat surface. The skin sloughs off leaving raw ulcers that are subsequently covered with dark coloured scabs.
	Teat warts/papilloma*	Appearance varies with strain of virus from 'rice grain' in appearance, to fronds.
	Foot and Mouth Disease (exotic)	Occasionally, the virus causes vesicular lesions and erosions on teats (exotic) before they appear in the mouth or hoof.
	Vesicular stomatitis (exotic)	Lesions are similar to, and need to be differentiated from, Foot and Mouth Disease.
Bacteria	*Staph. aureus,* *Strep. dysgalactiae* *Trueperella pyogenes*	Primary bacterial infections present as pustules. They may be necrotising, especially when *Staph. aureus* is involved. Secondary bacterial infections may cause significant changes in the appearance of other lesions, making diagnosis difficult.
	Blackspot* or *Fusiformis necrophorum*	Lesions look like craters with raised edges and have a black spot of ulceration or scab in the centre. They often involve the teat end.
Fungi	Ringworm or *Trichophyton spp.*	A characteristic grey-white encrustation. The infection may spread to milking staff.

** See page 13 for images of these conditions.*

1. Viral infections of teat skin

Viral teat infections vary in severity and infectivity but are generally uncommon in dairy industries where good udder hygiene and routine post-milking teat disinfection is practiced. Early low-pH iodine disinfectants were virucidal, and modern disinfectants plus emollients reduce skin damage that enables virus entry. Multi-use ointment containers are a frequent source of spread; single-use containers and clean gloves are recommended.

Some exotic diseases can cause lesions on teats (Hillerton *et al* 2001; Parkinson *et al* 2010). Differential diagnosis for unusual teat lesions should include:

- Foot and Mouth Disease (FMD),
- Vesicular stomatis (VS),
- Bovine herpes mamillitis (BHM),
- Ringworm (fungal).

Pseudocowpox

Pseudocowpox, a paravaccinia virus, causes acute infections in young cows after calving or cows introduced to a herd that has the virus. Spread of infection can be relatively slow. Immunity is short-lived, lasting four to six months, leading to some herds developing chronic infections.

Early lesions are painful so affected animals do not enjoy being milked. The characteristic ring or 'horseshoe' scab (Table 6) usually heals without scarring in 3-6 weeks. Milkers may develop localized lesions on their hands, i.e. 'milkers' nodules'. There is no specific treatment, so management relies on minimising spread by milking infected cattle last, glove use, and thorough teat disinfection.

Teat warts or papilloma

Six papillomavirus strains cause teat warts. Some form flat, smooth 'rice grain' warts (BPV-5) whilst others produce more frond-shaped warts with epithelial projections, up to 1 cm in length (BPV-1 or BPV-6). Young animals are most susceptible to papilloma viruses and typically develop immunity after joining the milking herd. Most warts regress within 5-6 months. Warts spread via liners and hands, and infect skin abrasions.

Some may interfere mechanically with liner function or obstruct the teat canal. Damaged warts, particularly the frond type, can become infected with *Staph. aureus*, *Truperella pyogenes* or *Strep. dysgalactiae.* Frond-type warts can be surgically removed or snipped. Teat disinfectants containing chlorohexidine or iodine are generally virucidal and may help reduce spread. Salicylic acid dips have been used on heifers overseas.

➜ **Technote 7.2** provides more information on the antimicrobial spectrum of active ingredients of teat disinfectants available in NZ.

2. Bacterial infections of teat skin

Bacteria cause primary lesions or colonise existing lesions caused by machine-induced damage, environmental factors or viral infections.

Staph. aureus, *Strep. dysgalactiae* and *Truperella pyogenes* are ubiquitous on the skin of dairy cows and can be a major source of new intramammary infections and clinical mastitis, in lactating and non-lactating cows.

Historical studies demonstrated strong associations between teat lesions and high new infection rates and clinical mastitis (Dodd & Neave 1970; Kingwill *et al* 1970). Even small lesions significantly increased risk of mastitis, particularly when located near the teat canal (Agger & Willeberg 1986).

Teat disinfectants are effective in reducing bacterial load and promoting healing, and postmilking disinfection of all teats remains a cornerstone mastitis control measure.

➜ **Technote 7** describes the characteristics of effective teat disinfectants and emollients.

Blackspot

Blackspot is a secondary infection of a teat-end lesion by the anaerobe *Fusiformis necrophorum*, under poor hygiene conditions. The resulting scab is pigmented black by the bacteria and the teat orifice may become blocked, leading to incomplete and very slow milking.

If more than 2-3% of teats are affected, herd hygiene and milking machine function should be reviewed, as blackspot is associated with short teat cup liners, failure of pulsation, excessive vacuum or over-milking.

Management involves:

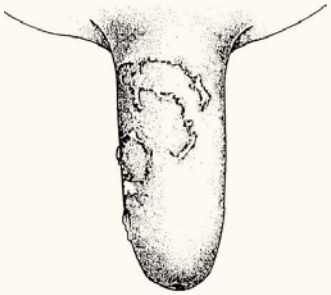
- treating lesions with iodine (or hydrogen peroxide);
- routine teat disinfection to minimise bacterial infection of lesions; and
- checking and correcting milking machine function.

3. Fungal infections of the teat skin

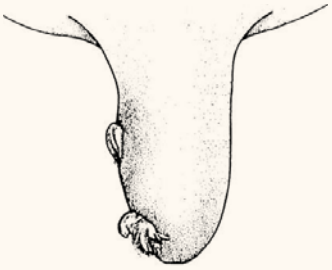
Fungal infection is most commonly caused by *Trichophyton* spp. and may involve the teat, but usually presents elsewhere on the body as greywhite, ash-like crusts (ringworm). The infection is highly contagious and may spread to milking staff (zoonotic). Herd immunity usually develops, though re-infection is common when susceptible animals enter the herd or when animals are immunosuppressed, as spores can survive in the environment for several years.

Few treatments are recognised and generally the disease is self-limiting over several months. In some countries, vaccines are available for calves to reduce incidence.

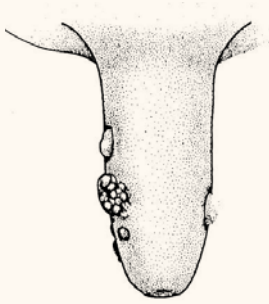
Examples of teat conditions associated with infectious conditions



Pseudocowpox

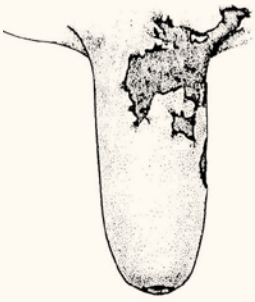


Filiform warts



Nodular warts

Blackspot



Bovine herpes mammillitis

Image by Dairy Australia

D. Systematic evaluation of teat condition in commercial herds

1. Deciding how many teats to observe

The most common weakness of teat evaluations is using sample sizes that are too small. Teat Club International (Reinemann *et al* 2001) recommended scoring all teats in the herd where possible, or assessing at least **80 cows or 20% of the herd** (whichever is greater).

In NZ, two approaches are supported:

- **Screening test to indicate issues:** assess 50 randomly selected cows to quantify potential issues and decide whether expert advice is needed.
- **In-depth assesment:** assess a larger, representative sample for diagnosing system faults or causes of teat damage.

NMAC (New Zealand Milk-Quality Advisory Committee) recommendation for investigations:

1. Assess all teats on **at least 100 randomly selected cows**, drawn from across mobs and throughout milking
2. Record results for **all four teats per cow**, where practicable
   - In some situations, cow-level recording may be preferred.
   - Table 7 compares these 2 methods.

Table 7. Evaluation methods involving cow or quarter level recording for a mastitis investigation

	Quarter-level recording	Cow-level recording
Procedure	1. Examine all teats of selected cows. 2. Score all non-normal quarters 3. Record cow and quarter details for each issue.	1. Examine all teats - score only **worst teat** per cow. 2. Assign this score to the cow. 3. Record scores (cow ID optional) 4. Note any patterns of damage (e.g., front vs rear, left vs right)
Benefits	• Measures prevalence accurately, at quarter level. • Enables reexamination of affected cows following intervention. • Valuable for detailed investigations, research, and quantifying response to management change.	• Faster, simpler and lower cost • Works for larger herds or rapid screening **NB Always produces higher prevalence estimates than quarter-level scoring**
Disadvantages	• Time-consuming • May require more labour • Quarters within a cow are not truly independent, so more quarters must be assessed to achieve statistical confidence.	• Less diagnostic detail, especially for quarter-specific problems. • Cannot reliably re-examine individual cows if no ID • Does not give a true teat-level estimate of prevalence, only the proportion of cows with **at least one quarter** affected

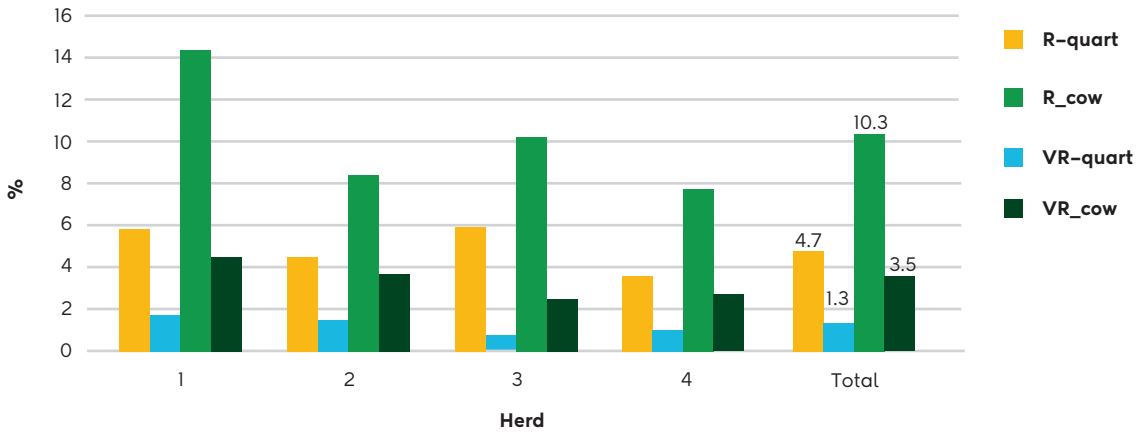
Interpreting prevalence: cow- vs quarter-level recording

Cowlevel scoring is a **parallel interpretation** of the four teats, meaning the cow is considered positive if **any** teat is affected. This inevitably produces higher prevalence estimates than quarter-level interpretation.

For example (Adamson, McDougall & Roberts, unpublished; see figure below), prevalence of damaged teat ends across 4 herds, involving 9,169 quarters and 2,202 cows was assessed as:

- Quarter-level prevalence:
  - Rough (R) teat ends = **4.7%**
  - Very rough (VR) teat ends = **1.3%**
- Cow-level prevalence (worst teat per cow):
  - At least one R teat = **10.3%**
  - At least one VR teat = **3.5%**

Variation in prevalence of rough (R) and very rough (VR) teat end scores when calculated at quarter or cow level across 4 herds.



2. Making the observations

Teat condition should be evaluated immediately after cluster removal and before teat disinfectant is applied. If a more detailed assessment of skin condition is needed, observations should be made before milking.

Practical guidelines for Teat Scoring:

- Handle cows carefully, especially in herds where animals are not accustomed to teat manipulation.
- Follow a consistent pattern to observe and record teats to avoid missing teats.
- Begin with visual assessment without touching the teat.
- Remove milk residue or debris with a clean paper towel if it obscures the teat end.
- Use proper lighting. Gently grasp the teat above the end and view from the side and end. If shed lighting is inadequate, use a headlamp for handsfree and safer assessment.
- Select a representative sample across all age and management groups. For herds with multiple mobs, include cows from all mobs. Sampling should occur throughout the milking, not only at the beginning or end.
  - Example: In a 400 cow herd where 50 cows are needed, examine every 8th cow (400 ÷ 50 = 8).
- Use efficient recording methods. A voice memo app on a smartphone is useful for solo observers; with two people, one can observe while the other records. A teat-scoring app can further streamline data capture (e.g., the UW-Madison **Teat End Scorer** app.
- Capture images. A smartphone or camera is valuable for documenting unusual lesions, supporting discussions with farmers or udder health experts, and for before and after comparisons (Reinemann 2007).

3. Interpreting the results

Once teat condition data has been collected, the prevalence of each condition should be calculated at either cow or quarter-level, depending on the recording method used.

Thresholds for intervention or **Triggers for Action** have been developed based on extensive field experience across multiple countries (Reinemann *et al* 2001). These thresholds vary according to:

- Which teat condition is being evaluated.
- Level of interpretation:
  - Cow-level prevalence of teat conditions is typically ~2.5 times higher than quarter-level prevalence, because a cow is counted as abnormal if *any* of her four teats is affected.
- Herd-specific circumstances including seasonal conditions, which may justify adjusting thresholds.

If the values for a particular teat condition exceed the thresholds in Table 8, further investigation of milking machine performance, management, environmental exposure or infectious causes is warranted

Use prevalence as a guide

Thresholds should not be treated as absolute rules. Some herds with teat abnormalities may fall slightly below the threshold because:

- The sample was not fully representative of the herd.
- The estimate lies near the lower 95% confidence limit of the threshold (see Table 8).

If there is uncertainty, or if other teat health or machine problems have been identified, more cows should be evaluated before reaching final conclusions.

Focus on Teat-Level Data First

The initial assessment should focus on the proportion of teats affected, as this provides the clearest indication of whether a herd-level issue is present. However, patterns within the data may provide important diagnostic clues:

- A large proportion of cows may have the same teat affected (e.g., all right rear teats), suggesting a cluster alignment issue.
- A few cows may contribute disproportionately to the total number of abnormal teats if they have multiple quarters affected, indicating a cow-specific or udder conformation issue.

Recognising these patterns is critical for differentiating machine-related, management-related, and cow-related causes.

Table 8. Trigger levels for action for different teat abnormalities (from Reinemann *et al* 2001 and Reinemann 2007).

		Trigger levels for:	
Criteria	**Description**	**Quarter-level**	**Cow-level**
Teat Colour	**Red/blue** Light coloured teats are visibly reddened (congested) or tinged with blue (cyanotic).	8%	20%
Swelling	**'Ringing' at teat base** Marked swelling or palpable rings at or near the top of the teat.	8%	20%
Firmness	**Hard or wedged** Teat ends are classified as firm, hard, swollen, or noticeably wedged.	8%	20%
Openness	**Open** Teat ends classed as open after milking.	8%	20%
Teat end	**Hyperkeratosis** Teats are scored R or V R	8%	20%
	Teats are scored as VR	4%	10%
Vascular damage	**Haemorrhages** Light-coloured teats have Moderate or Severe petechiation	4%	10%
Teat skin	**Dryness, Roughness** Teat skin scored as rough, dry and scaly.	4%	10%
Lesions	**Chaps, cracks** Teats have open lesions, cracks or chaps.	2%	5%

Colour, swelling near the top of the teat, firmness near the teat end, openness of teat orifice and vascular damage are **short to medium-term effects** primarily associated with milking machine faults or poor milking management resulting in long periods of low flow below 1 litre/minute and/or over milking.

Teat skin condition and teat end hyperkeratosis are **medium to longer-term effects** primarily associated with poor environment, management or chemical irritation, or cow factors such as teat shape, yield and genetics. They are exacerbated by machine milking, especially if poor milking management results in over milking or prolonged milking at a low milk flow rate. Faults in milking equipment are unlikely to be primary causal factors if one or more of the short-term changes are not obvious.

Table 9. Lower bounds for the 'trigger for action' (i.e. the lower 95% confidence interval) for number of quarters (or cows) when 'true' prevalence of the abnormality is 8%, 4% or 2% for quarters, or 20%, 10%, 5% for cows, based on a binomial distribution.

	Number of abnormal quarters detected		
	Quarter prevalence		
No. quarters (cows) examined	8%	4%	2%
100 (25)	0	0	0
150 (38)	2	0	0
200 (50)	4	0	0
250 (63)	7	0	0
300 (75)	10	0	0
350 (88)	13	0	0
400 (100)	**15**	**4**	**0**
500 (125)	22	7	0
600 (150)	28	9	1

	Number of cows with at least one abnormal teat detected		
	Cow prevalence		
No. cows examined	20%	10%	5%
50	6	2	0
100	**13**	**5**	**1**
150	17	8	2
200	25	12	4
250	32	16	6
300	41	20	8
400	57	28	11
500	74	37	15
600	92	46	19

Note: If the number of abnormalities is greater than the number listed for that sample size, then the herd prevalence of that condition is not different from the trigger level, with 95% confidence.

Statistical interpretations:

Table 9 shows the lower 95% confidence interval for

- number of quarters with abnormalities that correspond to a likely true prevalence of teat lesions of 8%, 4% or 2% quarters, or
- number of cows having at least one teat with an abnormality that corresponds to a likely true prevalence of 20%, 10% or 5% of cows.

Note that a variance inflation factor of 1.5 has been applied to account for 'clustering', whereby quarters within a cow are not independent of each other (S. McDougall *pers. comm.*)

Note that:

- If 200 teats are examined and fewer than 4 abnormal teats are found, it is 95% likely that the true prevalence is not different to 8% (but 4% and 2% cannot be ruled out).
- To confidently rule out a quarter prevalence of 4%, then more than 400 quarters (100 cows) need to be examined.
- If 6 or more cows out of 50 have at least one abnormal quarter, it is 95% likely that the true cow prevalence is not different from 20%.
- However, if no abnormalities are found, the true prevalence of 5% of cows cannot be ruled out. To confidently rule out a prevalence of 5%, more than 200 cows should be examined.
- If 100 cows were examined with no teat abnormalities, it is 95% likely that the true cow-level prevalence is <5%.

③ Manage teat condition

Minimise the build-up of mud on teats.

Reduce teat condition and hygiene problems caused by mud by maintaining clean, dry trough areas, farm tracks, laneways, feed pads and stand-off areas, and entrances and exits to the farm dairy.

If wet and muddy conditions cannot be avoided for lactating cows, and the rate of new clinical cases starts to increase, teats will need to be washed and ideally dried before each milking.

➜ **Technote 1** discusses ways to fix areas that make udders muddy.

Minimise water on cows' udders

➜ **Technote 5.4** discusses udder cleanliness and pre-milking preparation.

Check teat spray mix, particularly emollient concentrations

➜ **Technote 7** discusses addition of emollients to teat sprays and servicing of the teat spray equipment.

Avoid the use of teat ointments, especially those from tubs or jars

Teat ointments intended to improve teat condition can increase mastitis risk by promoting teatcup crawl, increasing bacterial exposure at the teat end, and prolonging bacterial contact time. Lubricating the teat-liner interface was found to significantly increase residual milk or strippings at the end of milking (Mein *et al* 1973). In addition, ointments dispensed from shared jars are readily contaminated with environmental bacteria.

Avoiding teat ointments is preferable. If used, select non-greasy formulations (e.g. sorbylene- or glycerol-based), use dispensing systems that minimise contamination (e.g. single-dose pump containers), and apply only after milking.

④ Check important milking machine factors

Call in a NZMPTA-certified milking machine tester if concerned that the operation of the milking machine is contributing to teat damage.

➜ **Technote 6** describes how to monitor and maintain milking machine function, and outlines tests that can be carried out by certified milking machine testers.

⑤ Seek advice from your veterinarian if problems persist

Farmers are urged to seek advice from their veterinarian if problems are identified with teat condition.

Many farmers, especially those who have participated in training, use triggers to identify when their milking system is not operating properly – including assessment of teat condition.

Farmer assessment of teat condition covers the same range as described in this Technote, alerting them to changes in teat skin colour, swelling, hardness and teat ends. However, it is the adviser's role to investigate these alerts, including a thorough teat assessment, to better understand the situation.

➜ **Technote 13** and the **Mastitis Investigation Kit** provide a systematic approach to investigating problems.

Acknowledgements

DairyNZ acknowledges the valuable input of veterinarians, milk quality advisers, and industry stakeholders who contributed to the development and review of these resources. Most are representatives of the National Milk-Quality Advisory Committee (NMAC) and have given generously of their time and expertise for the technical review.

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*** = Teat Club International papers**

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