Non-healing (nh) bovine hoof horn lesions, characterised by penetration of the horn capsule and association with white line disease (nhWLD), and sole ulcers (nhSU) are frequently encountered in dairy herds endemically affected by bovine digital dermatitis (BDD) (Blowey, 2011; Evans et al., 2011; Holzhauer and Pijl, 2011; Nouri and Ashrafi-Helan, 2013). The exposed corium is frequently infected with Treponema spp. (Evans et al., 2011). In contrast to the more common types of BDD, nhWLD and nhSU are associated with more severe lameness, often leading to claw amputation or slaughter (Blowey, 2011; Evans et al., 2011). The disease poorly responds to standard BDD treatment (Evans et al., 2011) and a more effective therapy for early lesions seems to consist of debridement followed by topical antibiotic and copper sulfate dressing, topical salicylic acid powder, and/or parenteral cephalosporin treatment (Evans et al., 2011; Holzhauer and Pijl, 2011).

This study investigated whether rigorous surgical debridement of nhWLD and nhSU lesions would promote clinical healing as evidenced by coverage of the lesion with new horn. The Institutional Ethics and Animal Care Commission of the Veterinary University Vienna approved this study.

Twenty nhWLD and 22 nhSU cases from 35 cows on three farms with endemic BDD were subjected to treatment. Locomotion was scored (Sprecher et al., 1997) when cows were led to the trimming table. Non-healing WLD and nhSU were diagnosed by clinical examination after claw trimming. They presented as profoundly painful, granular lesions within the claw horn (Fig. 1) exuding a typical, BDD-associated odour.

Treatment of extended nhWLD and nhSU cases consisted of functional claw trimming, application of a block on the sound partner claw, and retrograde intravenous anaesthesia using 15 mL of procaine hydrochloride 2% (Procainidor, Richter Pharma). Loose wall or sole horn was removed and the horn rim trimmed around the lesion using a hoof knife. All infected corium was removed with a scalpel blade (Fig. 1). The wound was then rinsed using saline solution, treated topically with chlorotetraacycline spray (CTC Blauspray, Novartis) and protected from de novo infection by a bandage consisting of 10 × 10 cm² sterile gauze, two layers of cotton, and self-adherent bandaging tape. The same regime was used for the treatment of smaller nhSU (<2 cm) but here only ice spray (Eis-Spray-Ratiopharm) was used to allow painless removal of the infected corium.

On day 0 (before treatment), and on days 10, 18 and 28, all lesions were photographed, their morphology and maximum diameter assessed (Fig. 1), and wound healing recorded. On days 10, 18, and 28, topical tetracycline treatment was repeated and new bandages were applied as indicated. Lesions were considered to have healed when they were completely covered by new horn.

Lesions were especially prevalent in herd 3 and so affected cows were treated twice with a 10-day interval in between (first visit: 9 cows, 13 lesions; second visit: 14 cows, 16 lesions), leading to additional data for farm 3 patients on day 38. Tissue samples from each lesion were PCR-screened for treponemal DNA (Brandt et al., 2011). 

Acquired data were not normally distributed. Differences between locomotion scores on day 0 and days 10, 18, 28 were assessed by
Wilcoxon test. The Mann–Whitney–U test served to analyse differences in the healing rate between nhWLD and nhSU, and Fisher’s exact test was used to analyse differences in healing rate between unilateral and bilateral lesions within 28 days. Spearman correlation coefficients were calculated for lesion sizes at day 0 and healing within 28 days. Significance was set at $P < 0.05$.

Disease specifications and responses to treatment are summarised in Table 1. Non-healing WLD and nhSU ranged from 1 to 5 cm in diameter. In seven cows, lesions affected the lateral claws of both hind limbs. A significant decrease in lameness from day 0 ($n = 35$ lame cows) was observed on day 10 with six cows found without lameness (17.1%; $P = 0.01$). On day 28, 15 (35.7%) of lesions were smaller but not completely covered by new horn. On days 10 and 18, it was necessary to renew blocks in seven cows.

Healing rates of the two different types of lesions such as nhSU (72.7%) and nhWLD (55.0%) within 28 days (Mann–Whitney–U test, $P = 0.23$), and healing rates of lesions in cows with unilateral and bilateral ($n = 7$) lesions did not significantly differ on day 28 (Fisher’s exact test, $P = 0.49$). Lesion size at day 0 significantly correlated with healing at day 28 ($r = 0.48; P = 0.01$). Diagnosis of nhWLD and nhSU was confirmed by detected intralesional presence of BDD-related Treponema spp. DNA (Treponema medium, Treponema pedis) (Sykora et al., 2013). None of the cases required digital amputation.

The treatment strategy resulted in healing in 27 lesions (64%) within 28 days and in 30 (71%) with additional monitoring on day 38. The procedure led to healing also in 28 (67%) of large lesions (diameter $\geq 4$ cm). In contrast to common acute BDD lesions in which post-treatment recurrence rates of 14.5–50% have been reported within 3 weeks (Kofler et al., 2015) to 11 months (Berry et al., 2012), none of the clinically healed nhWLD and nhSU cases recrudesced within the observation period. However, a longer follow-up is required to rule out the possibility of recurrence.

### Table 1

<table>
<thead>
<tr>
<th>Animals and disease</th>
<th>Farm</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>1</td>
<td>2</td>
</tr>
<tr>
<td>Total number of cows</td>
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<td>73</td>
</tr>
<tr>
<td>Number of cows with nhWLD/nhSU</td>
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<td>11</td>
</tr>
<tr>
<td>Number of nhWLD/nhSU lesions</td>
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<td>12</td>
</tr>
<tr>
<td>Number of cows with BDD lesions</td>
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<td>48</td>
</tr>
</tbody>
</table>

### Diameters of lesions before treatment

- nhWLD/nhSU diameter $< 2$ cm: 23.8%
- nhWLD/nhSU diameter $= 2$ cm: 33.3%
- nhWLD/nhSU diameter 2.1–3.9 cm: 14.3%
- nhWLD/nhSU diameter $\geq 4$ cm: 28.6%

Mean diameter nhWLD: 3.37 ± 1.34 cm
Mean diameter nhSU: 2.06 ± 1.02 cm

### Lameness scores before and after treatment

<table>
<thead>
<tr>
<th>Day 0 lameness score</th>
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<th>Farm 2</th>
<th>Farm 3</th>
<th>Total</th>
</tr>
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<tbody>
<tr>
<td>2</td>
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<td>23%</td>
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<tr>
<td>3</td>
<td>60%</td>
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<td>60%</td>
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<tr>
<td>4</td>
<td>17%</td>
<td>17%</td>
<td>17%</td>
<td>17%</td>
</tr>
</tbody>
</table>

Day 10 lameness score 1: 17.1% ($n = 6$), $P = 0.01$
Day 10 lameness score 2: 31.4% ($n = 11$)
Day 28 no lameness: 14%, $P = 1.00$
Day 28 lameness score 2: 64%
Day 28 lameness score 3: 22%

### Clinical healing rates after treatment

- Healing rate at 10 days: 21.4%
- Healing rate at 18 days: 38.1%
- Healing rate at 28 days: 64.3%
- Healing rate at 38 days: 71.4%
- Healing rate of nhWLD at 28 days: 72.7%
- Healing rate of nhSU at 28 days: 55.0%

nhWLD, non-healing white line disease; nhSU, non-healing sole ulcer.

**Fig. 1.** (A, B, C) Non-healing white line disease (BDD-associated white line disease) on the lateral claw of a right hindlimb before treatment (A) with the attached wooden block on the medial claw, after removal of all the loose wall horn around using a hoof knife (B), and after surgical excision of the infected corium layer (C). Lesion diameter was 5 cm.
There are reports on 61.5% and 90% of nhWLD and nhSU lesions being covered by new horn after 60 (Nouri and Ashrafi-Helan, 2013) and 90 days, respectively, when using topical debridement, salicylic acid and a bandage (Holzhauer and Pijl, 2011). For welfare reasons, no untreated control group was included in the present study, however, our results are comparable with the 68% healing rate of common sole ulcers after 30 days (Lischer et al., 2001). Incomplete healing in 12 (29%) lesions may be explained by the short treatment duration (Holzhauer and Pijl, 2011; Nouri and Ashrafi-Helan, 2013), and loss of the block, resulting in continuous pressure on the lesion and soaking of the bandage in slurry, thus promoting contamination of the still-exposed corium. Larger lesions required significantly more time to heal than smaller lesions.

In conclusion, the treatment procedure presented here can be implemented easily in practice. Regional retrograde anaesthesia allows complete, painless removal of loose horn, provides excellent conditions for visual inspection and rigorous surgical debridement of infected tissue. Additional systemic antibiotic treatment (Evans et al., 2011; Nouri and Ashrafi-Helan, 2013), which is usually associated with withdrawal times, is not necessary.

Conflict of interest statement

The authors of this paper have no financial or personal relationship with other people or organisations that could inappropriately influence or bias the content of the paper.

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