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Wound Occlusion Following Stem Injuries: A Comparative Analysis of Plastic Wrapped and Unwrapped Trees

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Abstract. Background: Trees near construction sites and roads are exposed to an increased risk of stem injuries, and urban trees are also vulnerable to vandalism. Such injuries can result in large wounds, leading to reduced water and nutrient transport, taking several years to occlude, and the apparent risk of decay. Covering the wounds with plastic wrapping has been discussed over the years, but the evidence for its efficacy is not complete. During winter 2020/2021 a total of 248 trees were systematically vandalised in Malmö, Sweden. The two organisations responsible for these trees handled the injuries differently; one wrapped the stem wounds with plastic, and the other did not. This provided a rare opportunity to compare the treatment outcomes in urban field conditions. Methods: We studied the effects of plastic wrapping on tree wounds by comparing data from measurements that were performed in 2021 with measurements in 2023. The study focused on 3 genera: maple (*Acer*), birch (*Betula*), and linden (*Tilia*). Results: Tree wounds in both linden and maple wrapped in plastic occluded faster than unwrapped trees, but no benefit of wrapping could be seen in birch. There was an overall difference of occlusion rate between the genera, where the linden trees wrapped in plastic occluded faster than the wrapped trees of maple and birch. Conclusion: Plastic-wrapping can benefit urban trees with stem wounds. However, the effect is at least genera, if not species, specific. This highlights the need for further studies of differences across different genera and species.

Keywords. Compartmentalization; Stem Damage; Stem Injury; Tree Care; Tree Vandalism; Urban Trees; Wound Closure; Wound Occlusion.

INTRODUCTION

Vandalism and collision damages near roads and construction sites can cause severe damage to trees and result in their death. In a review of causes of tree mortality, vandalism was found to be one of the most common human-related factors (Hilbert et al. 2019), but the extent of vandalism varies geographically. Between 1999 and 2001, 30% of newly planted trees in the UK were vandalized, compared to less than 5% in central European countries (Pauleit et al. 2002). Furthermore, single car accidents frequently involve trees (Budzynski et al. 2016; Kocián and Nováček 2023) and can result in substantial stem injuries. Urban densification and construction increase the risk of collision damages. Although research on this issue remains limited, there is an increasing trend of tree protection guidelines during construction, which appears to reduce tree mortality if implemented correctly (Hauer et al. 2020).

Bark represents all tissues outside the vascular cambium and is divided in 2 parts, the outer bark and the inner bark (Angyalossy et al. 2016). The outer bark is a waterproof isolating surface that keeps the moisture inside the tree (Jupa and Pokorná 2024) and protects from fungal and bacterial pathogens. The inner bark, made of secondary phloem, transports carbohydrates and plant hormones and stores e.g., starch and water which can be used to rehydrate injured xylem (Angyalossy et al. 2016; Jupa and Pokorná 2024). The vascular cambium produces secondary xylem towards the tree pith and produces secondary phloem towards the bark. When the bark is damaged, the underlying parts of the phloem become disrupted. Furthermore, the vascular cambium is thin and easily damaged when the bark is injured and consequently loses its capacity to create new phloem and xylem. Collisions can kill large blocks of bark and underlying tissue, which often leads to severe outcomes for the trees.

As the damage exposes underlying wood, there is an increased risk of long-term negative effects. When trees are injured, by accident or pruning, there is a high risk of discolouration of the wood (Schmidt 2006b). Discoloured wood may result from the tree's internal chemical reaction, much like when it transforms to heartwood, or from the invasion of bacteria, microorganisms, and/or fungi (Schmidt 2006a, 2006b). As a defence mechanism, trees reduce the negative consequences of damage in a process that has been schematically described as the Compartmentalization of Decay/Damage in Trees (CODIT) model. The CODIT model illustrates how trees react to injuries by compartmentalizing exposed wood (Shigo and Marx 1977; Smith 2006). Morris et al. (2016) describes the internal processes of this model partly as anatomical, with sections that work as a physical defence and partly by the reaction of the ray parenchyma and axial parenchyma, forming boundaries in different ways when injury occurs. The abundance and patterns of ray parenchyma and axial parenchyma differ greatly depending on species (Morris et al. 2016). The external process of the model is called occlusion, which is defined as, "The continued radial growth of new wood, including wound wood, which gradually grows over wounds to the woody parts of trees" (Wilson 2021), or used as a broader term that includes callus tissue as well (O'Hara 2007; Ow et al. 2013; Slater and Ennos 2015). Wound closure is also commonly used to describe the same process, however we will use the term occlusion in this article. This should not be confused with vessel occlusion, which is when tyloses or gums plugs vessels to form heartwood or as an internal wound reaction (de Micco et al. 2016). Wound wood is callus tissue that has become lignified. Angiosperms can create both wound surface callus produced by undifferentiated callus and lateral callus produced by the cambium (Stobbe et al. 2002b; Chano et al. 2015). Gymnosperms, in contrast, can create lateral callus but no surface callus since they ooze resins, another kind of defence against fungal spores (Chano et al. 2015).

With slow occlusion and widespread discoloration comes the risk colonization by e.g., fungi, insects, and bacteria. Fungal spores travel through the air by water or soil splashing and can easily attach to exposed wood, but fungi can also be found inside healthy living wood. Parfitt et al. (2010) found latent propagules of fungi within living wood that may awaken upon injury, triggered by oxygen entering the wood.

Over the decades, various ideas have emerged regarding how to manage tree wounds after pruning. Different kinds of chemicals and paint (hereafter referred to as wound dressings) have been used in arboriculture with the intention of preventing fungi from establishing. However, Shigo and Shortle (1983) tested 13 different wound dressings and found that none of them helped the trees compartmentalise damages. Whether wound dressings prevent spores from entering via external sources is largely unknown.

Today, tree care professionals generally do not treat exposed wood with wound dressings, but in recent years, dark plastic wrapping has re-emerged as a potentially beneficial method for protecting stem bark injuries and promoting occlusion in urban trees. The practice was first proposed in 1958 (Leiser 1958) in a small-scale study and has since been revisited in a few experimental settings and observational studies. Blanchette and Sharon (1975) investigated the effect of plastic wrapping and inoculation of a bacteria (*Agrobacterium tumefaciens*) on yellow birch (*Betula alleghaniensis* Britton) and found both treatments to enhance occlusion. Shortle and Shigo (1978) tested the use of black plastic, transparent plastic, and no plastic on red maple wounds (*Acer rubrum* L.) and found that black plastic accelerated the occlusion but only when applied directly after wounding. No effect was seen if the plastic was applied 2 weeks after wounding. While internal compartmentalisation remained unaffected, a reduction in decay fungi in discoloured wood was noted. McDougall and Blanchette (1996) statistically demonstrated that plastic wrapping significantly reduced wound size and resulted in less dieback in American aspen (*Populus tremuloides* Minchx) and red maple, though no significant effect was observed in paper birch (*B. papyrifera* Marsh). The timing of the application was again demonstrated: plastic applied on the day of injury was effective, while a one-week delay nullified the benefits.

In line with the step-by-step abandonment of wound dressings, a German case study compared traditional wound dressings with plastic wrapping (Dujesiefken et al. 2001). In comparisons of stem damages either treated with black plastic or lac balsam in a forest environment, they observed higher stem callus formation for the plastic wrapping for European beech (*Fagus sylvatica* L.), European aspen (*P. tremula* L.), European ash (*Fraxinus excelsior* L.) and European hornbeam (*Carpinus betulus* L.). However, no control or statistical testing was included, reducing the possibility to draw firm conclusions about the treatments' actual effect in comparison to no treatment and the trend seen of different species reactions. Similarly, Stobbe et al. (2002a) observed plastic wrapping to outperform wound dressings in young (10 to 15 years) vital trees of willows (*Salix* spp.), pedunculate oak (*Quercus robur* L.), maples (*Acer* spp.), cherries (*Prunus* spp.), and black alder (*Alnus glutinosa* [L.] Gaertn.) irrespective of season and species. However, also here the lack of control treatment and statistical tests induced uncertainties. Lastly, in a forest environment Gaiser et al. (2006) compared both plastic wrapping and chemical wound dressing with control in stem damages inflected during the winter season on Douglas fir (*Pseudotsuga menziesii* [Mirb] Franco), Norway spruce (*Picea abies* [L.] H.Karst.), Scots pine (*Pinus sylvestris* L.), silver fir (*Abies alba* Mill.), pedunculate oak, European ash, and beech. Given the lack of statistical testing, the trend observed was differences between species in surface callus formation, with a positive response of plastic wrapping in all deciduous species both against control and chemical wound dressings.

These studies and observations together suggest that, during favourable conditions, cell proliferation and tissue regeneration enhances, stem occlusion can begin rapidly, and that such favourable conditions seem to be enhanced by plastic wrapping. However, several limitations persist. The technique has only been statistically tested during the growing season and seems to require immediate application, likely due to problems with tissue desiccation and UV damages. Additionally, the favourable conditions needed might not be common within urban field settings, and the treatment effect seem to be genera- or species-specific. Despite these constraints, plastic wrapping is recommended in several arboricultural guidelines and technical standards, including the Swedish reference manual for building products and processes (Svensk Byggtjänst 2023), indicating cautious yet increasing support for its practical application.

In November 2020 to January 2021, the city of Malmö, situated in Southern Sweden, was targeted by a vandal causing large injuries to 248 trees. The replacement cost of the wounded trees was calculated to €2,027,643, or $2,446,940 USD (Östberg and Rowicki 2022a, 2022b), and reactions from the public were huge (e.g., Andersson 2021). As in most countries and municipalities, tree ownership is divided between different management organisations, and in this case, two organisations were affected by the vandalism: the streets and parks department in Malmö and the Malmö cemetery administration. The two organisations choose to handle the vandalism differently. The streets and parks department wrapped plastic around the damaged trees, and the cemetery administration did not.

To the best of our knowledge, no previous studies have systematically evaluated the effects of different wound treatments in real urban contexts. While experimental studies under controlled conditions have provided valuable insights, they often focus on artificially induced wounds in nonurban environments. The vandalism incident in Malmö, where 248 trees were deliberately wounded using a drawknife during the winter months of 2020 to 2021, presents a rare opportunity to investigate wound responses under authentic urban field conditions. This includes factors such as mechanical bark removal with sharp tools, varied site characteristics, and treatment with plastic wrapping.

Thus, the purpose of this study was to, in existing urban field conditions, examine how wrapping plastic over tree wounds during the dormant winter season affects occlusion.

MATERIALS AND METHODS

Malmö is located in Southern Sweden and has a population of 365,843 inhabitants (SCB 2025). From November 2020 to January 2021, 248 tree stems were vandalised with a drawknife. The trees were assessed soon after vandalization, meaning that most damages were assessed within days or at most weeks after the damage had occurred (Östberg and Rowicki 2022a, 2022b).

Treatments

The streets and parks department covered the injuries with black or blue plastic garbage bags and fastened them with duct tape as soon as detected, normally within 24 hours after the damage was detected, and the wrapping was left for one year. The cemetery administration did not use any wrapping. These

Figure 1. The photos (A) and (B) show trees located in the cemeteries with no plastic wrap. Here you can also see how the injuries typically looked. The photos (C) and (D) show trees located in the municipality with plastic wrap.

Table 1. Summary of selected tree species, grouped by genera and source of management.

Genera and species	Cemetery/no plastic	Municipality/plastic	Total
Acer campestre L.		1	1
Acer platanoides L.	11	2	13
Total *Acer*	11	3	14
Betula ermanii Cham.	10		10
Betula pendula Roth		7	7
Betula pubescens Ehrh.		1	1
Betula utilis ssp. *albosinensis* (Burkill) Ashburner & McAll.		3	3
Total *Betula*	10	11	21
Tilia cordata Mill.	11	17	28
Tilia × *europea* L.	18	28	46
Tilia tomentosa Moench	1	2	3
Total *Tilia*	30	47	77
Trees in total	51	61	112

different ways of handling the damages thereby resulted in two different treatments (Figure 1).

The opportunistic nature of this study means that treatment could not be controlled and randomized beforehand, and tree species could not be selected, even though species react differently to damage (Dănescu et al. 2015; Lund et al. 2023). We aimed for as balanced a dataset as possible by only choosing tree genera occurring in both management organisations. As such 112 individual trees were included, of which 14 were maples (*Acer*), 21 birch (*Betula*), and 77 linden (*Tilia*)(Table 1). Of these, 51 trees grew on the streets and park departments land, and 61 trees grew on the cemetery administration land (Figure 2).

Data Collected

During the initial inventory conducted in 2020 to 2021, a standardized set of parameters was recorded for each vandalized tree to enable later comparison and analysis:

- Stem circumference at 1 m above ground level (in cm, with 0.5 precision).

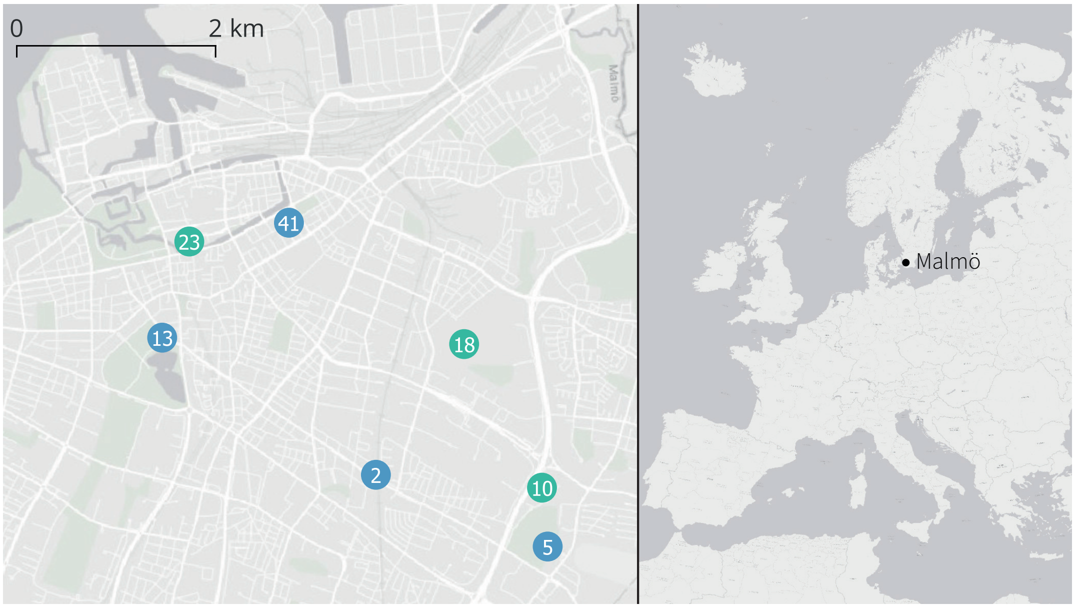

Figure 2. To the right, a map that points out Malmö in the South of Sweden. To the left, the locations of the vandalised trees in Malmö that were included in the study. The green circles represent the cemetery managed sites where trees were not wrapped with plastic, and the blue circles represents the streets and parks department managed sites with trees that were wrapped with plastic. The number inside the circles shows how many trees per site. Esri Gray Light was used as a background map (ESRI 2025).

- Stem circumference where the damage had its greatest circumference spread.
- Horizontal length of the damage (in cm, with 0.5 precision).
- Vertical width of the damage (in cm, with 0.5 precision)
- Soil conditions, visually estimated as growing in hardscape or not hardscape.
- Vitality according to Roloff (2001), but with the adjustment that highest vitality was rated as 4 and lowest as 1.

According to the Swedish tree terminology standard SS990000:2025, vitality is defined as a trees' life force (SIS 2025). Rating of vitality often focuses on crown structure, with consideration to species, by examining crown size and crown density (Östberg et al. 2021). There are different methods to measure vitality, and studies have shown that visual examination is practically efficient (Johnstone et al. 2013; Callow et al. 2018). During the re-inventory in February 2023, we remeasured the above listed parameters for all injuries that had not fully occluded.

Statistics

We measured the injuries in horizontal and vertical direction in 2021 and 2023. However, the injuries were seldom a clear rectangle but had more of an elliptical shape. To attain a more correct measurement, we calculated the elliptic area (area = π × length radius × width radius) from the measurements done in 2021 and 2023. Based on this, we calculated the percentage of occluded area and used it as the main response variable for the statistical analyses, since this standardizes the data across different tree and wound sizes.

All statistical analyses were executed with R (version R-4.4.1; R Foundation, Vienna, Austria) and R Studio (version 2024.12.0; Posit Software, PBC, Boston, MA, USA) together with the following support packages: readxl (Wickham and Bryan 2025), tidyverse (Wickham et al. 2019), extrafont (Chang and Bertrand 2025), and ggplot2 (Wickham 2016).

We used 0.05 as the significance level for all analyses and hence 95% confidence intervals for estimated means. Validation of model assumptions was done by plotting of model residuals and comparison of models was made using AIC and likelihood ratio test together with suitable estimation method for the specific comparisons. The final model presentation was done using REML estimation.

To account for the clustered spatial pattern of the trees and hence spatial autocorrelation between the observations, we used generalized least square model (Pinheiro et al. 2025) together with suitable spatial correlation structures as our modelling approach. To account for heteroskedasticity, i.e., different variance between groups related to the unbalanced design, we also included suitable variance structures. The occluded area of the wound in percentage was used as the response, and genera (3 levels: *Tilia*/*Acer*/*Betula*) and treatment (2 levels: no plastic/plastic), including their interaction, as fixed effects. The variance structure using varIdent was set to allow different variance, one for each level of explanatory factors. We tested 5 different correlation structures (spherical, linear, rational quadratic, gaussian, exponential) for the spatial coordinates of the trees; and based on AIC comparison and variogram, we selected a rational quadratic spatial correlation structure for the final models.

Additionally, we tested the inclusion of baseline measure from 2021 of stem circumference, tree vitality, damage width, damage area, and damage length as explanatory variables (covariates) in the model above and compared them using AIC, likelihood ratio test, and verification of model assumptions through residual plotting and control of VIF values. The final most parsimony model selected was then tested using type II ANOVA due to the unbalanced design, using the car package (Fox and Weisberg 2018). The most parsimony model was with damage height included as covariate; no other covariate had a significant effect on the model performance. Post hoc test of significant effects was done as pairwise comparison of estimated marginal means and compact letter display (Hothorn et al. 2008a; Graves et al. 2024; Lenth and Piaskowski 2025) with Tukey Dunn-Sidak adjustment for multiple testing, which a flexible but conservative approach reducing false discovery rates. Due to the model complexity, degrees of freedom for the post-hoc test were the error degrees of freedom for the model, minus the number of extra random effects estimated. To test the independence of the individual covariates with treatment that is confounded with the main sites (municipal vs. cemetery), we used permutation-based independence test in the coin package (Hothorn et al. 2008b).

RESULTS

The trees had slightly unbalanced distribution (Z = 1.932, P-value = 0.0534) in stem circumference between the municipality (median = 45 cm, mean = 46.2 cm) and the cemeteries (median = 40 cm, mean = 54.7 cm)(Table S1). More clear differences were seen for the vertical damage height (Z = 2.522, P-value = 0.0117), where the cemetery had slightly larger damage (median = 41 cm, mean = 42.6 cm) than the streets and parks department (median = 40 cm, mean = 38 cm) as well as for the damage width (Z = 3.1712, P-value = 0.0015). The percent damage of the stem circumference however only differed marginally (Z = 1.359, P-value = 0.174) in the cemeteries (median = 19.5%, mean = 19.1%) towards the municipality (median = 17.3%, mean = 17.2%), supporting the robustness of using percentage of occlusion as the main response variable for statistic modelling.

There was a significant difference (Z = 4.852, P-value < 0.001) in tree vitality between cemeteries (median = 4, mean = 3.8) and municipality (median = 3, mean = 3.2), indicating that the trees overall had good vitality when the vandalism occurred, but this was even better in the cemeteries.

The ANOVA type II test of the model for percentage of occlusion showed significant main effects for treatment, genera, damage height in 2021, and the interaction between treatment and genera (Table 2). Damage height (i.e., the vertical length of the damage) was the only covariate that had a significant effect of those tested, confirming its necessity in relation to overall model parsimony.

Both treatment and genera had clear significant effects on the occlusion, with an overall pattern of higher occlusion for plastic wrapping and with *Tilia* occluded to a higher extent, followed by *Acer* and then *Betula*. However, given the significant interaction effect and related post-hoc test, the treatment effect clearly is genera dependent (Figure 3). There was a significant treatment effect for both *Tilia* and *Acer*, but none for *Betula* (Figure 3). The differences between genera were not significant for the treatment

Table 2. ANOVA type II test of occluded area per treatment, genera, and damage height.

	Degrees of freedom	Chi-square	*P*-value
Treatment	1	43.1010	< 0.001
Genera	2	17.9477	< 0.001
Damage height 2021	1	10.8405	< 0.001
Treatment:Genera	2	8.7419	0.0126

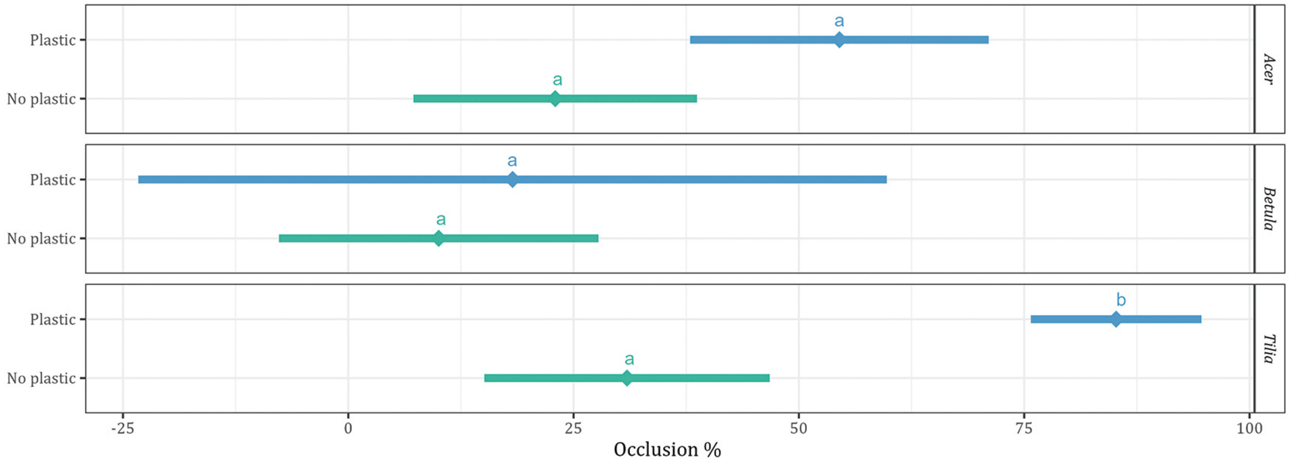

Figure 3. Estimated mean occlusion with 95% confidence intervals for each genus and treatment using estimated marginal means. Treatment within genera not sharing the same letter are significantly different from each other.

without plastic wrapping, indicating that the natural occlusion does not differ wildly for the included genera, but the benefits of plastic wrapping clearly do.

DISCUSSION

Tilia spp. showed the most significant results in our study, where the injuries that were wrapped in plastic had a markedly faster occlusion than those left untreated. A similar, although less pronounced, pattern was observed for *Acer* spp. However, the data for *Acer* spp. were the least balanced, with only 3 wrapped trees compared to 11 unwrapped. In contrast, *Betula* spp. showed no significant treatment effect, aligning with previous findings on paper birch (*B. papyrifera*) indicating limited or no response to plastic wrapping (McDougall and Blanchette 1996). However, Blanchette and Sharon (1975) found contrary results when studying yellow birch (*B. alleghaniensis*), which suggests that wound reaction for this genus is species-specific. They observed increased callus formation on trees with plastic wrap compared to unwrapped trees and even more callus formation on trees inoculated with the bacteria *Agrobacterium tumefaciens* and plastic wrap. The use of certain bacteria to promote callus formation is an interesting and understudied idea and should be further explored. Our findings corroborate earlier studies by Shortle and Shigo (1978), who observed accelerated occlusion in red maple (*A. rubrum*) when plastic was applied immediately after wounding. Likewise, McDougall and Blanchette (1996) found beneficial effects of plastic wrapping on American aspen (*P. tremuloides*) and red maple (*A. rubrum*), but not on paper birch (*B. papyrifera*). Stobbe et al. (2002b) saw clear formation of stem surface callus under plastic wrapping when studying *Tilia* spp. However, no control without plastic was used for comparison in that study. These species-specific responses raise important questions about which underlying physiological or anatomical factors determine the efficacy of such treatments.

A critical distinction between our study and previous research lies in the timing of the injuries. Earlier studies using statistical testing were conducted during the growing season, whereas the damage in our study occurred during the trees' dormant period in winter. Despite reduced physiological activity during this phase, we observed clear occlusion benefits from plastic wrapping. To our knowledge, this is the first study to statistically verify a positive effect of plastic wrapping during the dormant season, suggesting that immediate post-injury protection may benefit trees even when metabolic activity is low. This verifies the observations made by Stobbe et al. (2002a) where plastic wrapping promoted stem callus formation equally between active and dormant season. In addition, Gaiser et al. (2006) also observed higher stem callus under plastic wrapping for dormant stem injuries compared to untreated control. Since neither the current study nor Gaiser et al. (2006) include the possibility to explore the interaction between nontreatment of wounds and plastic wrapping in relation to seasons, this remains for future research.

Another difference between studies relates to the type of injury. In our study, the damage was inflicted using a drawknife, resulting in the complete removal of bark down to the cambium and relatively large injuries compared to other studies using smaller and controlled stem damages. However, some urban stem wounds might be crushing injuries leaving some bark tissue intact. This was also reported by Stobbe et al. (2002a) for their stem damage treatments inflicted during the winter, where some inner bark remnants were left after the bark removal. The absence of bark remnants may alter the wound microenvironment, potentially making plastic wrapping more important for initiating callus formation.

It is also important to note that all trees included in the study were relatively small and/or young. Tree age and size are known to influence wound response and regenerative capacity, and it is possible that younger trees may exhibit faster occlusion due to higher physiological plasticity or more active cambial zones. Therefore, caution is needed when extrapolating our findings to older trees, which may respond differently to similar injuries or treatments.

It is well established that tree species vary in their wound responses, including their capacity for callus formation following pruning (Lund et al. 2023). Both small-leaved linden (*T. cordata* Mill.) and Norway maple (*A. platanoides* L.) have been shown to exhibit moderate occlusion rates compared to slower species such as wild cherry (*P. avium* L.) and the faster pedunculate oak (*Q. robur* L.), suggesting that baseline regenerative capacity plays a role in treatment responsiveness. Species-level differences in the production of phenolic-based secondary metabolites, which are important in defensive responses, may also contribute to these patterns (Morris et al. 2016). Bark structure and residual cambial activity may likewise affect the ability to respond effectively to treatments. Furthermore, anatomical features such as ring-porous xylem structures may influence wound vulnerability and repair capacity, with some studies suggesting greater susceptibility in ring-porous species (Jupa and Pokorná 2024) and others not (Lund et al. 2023). Since our study only included diffuse-porous species, we did not have the opportunity to study any potential differences between ring-porous and diffuse-porous species.

The underlying mechanism by which plastic wrapping facilitates occlusion remains unclear. One hypothesis is that the plastic film retains ethylene gas, a key signalling molecule in wound responses, thereby enhancing the cellular processes that drive callus formation (McDougall and Blanchette 1996). Another plausible explanation is that the plastic conserves moisture at the wound site, reducing desiccation and tissue death and creating favourable conditions for regenerative growth. Regardless of the exact mechanism, the consistent results across studies for certain species suggest that plastic wrapping may offer a simple yet effective intervention, at least under certain conditions.

There are, however, limitations to our study. The research design was opportunistic, not randomized, and the dataset was unbalanced in terms of species distribution and treatment groups. Although great care was taken in incorporating this into the statistical modelling, this still induces some caveats, especially the exactness of degrees of freedom approach possible to use, given that the model complexity can overestimate the degrees for the post-hoc test. This is especially true for *Acer* with its lower number of replicates, which warrants seeing the results for *Acer* more as a trend. But this also emphasizes the soundness for allowing difference in variance within treatment as employed, strengthening the validity in the patterns seen in Figure 3. Additionally, none of the tested covariates except wound length had a significant effect on occlusion, suggesting a true treatment effect. Interestingly, although the plastic-wrapped trees were on average less vital at the time of injury, they still demonstrated better occlusion, indicating that site quality alone (i.e., municipal vs cemetery management) is unlikely to explain the results. These findings support the interpretation that the treatment itself had a genuine, genera-dependent effect.

Further research should explore whether plastic wrapping can support occlusion in other contexts, such as after storm damage or large pruning cuts as well as its practical application and long-term effects. Based on our results and earlier literature, we can recommend plastic wrapping for genera such as *Acer* and *Tilia*. For *Betula*, which showed no response, plastic wrapping does not appear to be effective for faster occlusion; however, the amount of discoloration was not investigated. Shortle and Shigo (1978) studied red maple and found positive effect of plastic wrap by improved compartmentalisation and lower occurrence of fungi, which is why we should not dismiss possible positive effects for *Betula*. Additionally, since Blanchette and Sharon (1975) found positive effect for yellow birch, further research is needed concerning species and genera specific effects. Given the alignment between earlier experimental and observational studies from nonurban field conditions with our study, although the method may not be universally beneficial, it clearly can be an important tool in the everyday practical urban forestry realm.

CONCLUSION

Both linden and maple trees had greater occlusion with plastic wrap on stem injuries, but birch trees did not have the same favourable result. However, since discoloration was not investigated in this study, we don't dismiss the possibility for benefits, even for birch trees.

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Appendix

Table S1. Descriptive statistics of tree size, damage, and vitality. Cemeteries had no plastic treatment, and the streets and parks department had plastic wrapping.

Treatment	Min	1st quarter	Median	Mean	3rd quarter	Max
Stem circumference						
No plastic	25	35	40	54.70588	80	100
Plastic	15	25	45	46.22951	60	105
Vertical damage length						
No plastic	27	35	41	42.64706	50	69
Plastic	15	30	40	38.04918	43	61
Damage % of stem circumference						
No plastic	0.102	0.141	0.195	0.191	0.233	0.303
Plastic	0.051	0.106	0.173	0.172	0.208	0.363
Vitality						
No plastic	2	4	4	3.862	4	4
Plastic	2	3	3	3.245	4	4