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SYSTEMATIC REVIEW

# Narrow Excision Margins for Diverse Histological Subtypes of Cutaneous Melanoma in Children and Adults: A Systematic Review

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## ABSTRACT

***Introduction*:** Wide local excision (WLE) is a standard component of cutaneous melanoma management, although prospective evidence supporting current margin recommendations remains limited. Surgical margins have progressively decreased. However, six randomized clinical trials comparing wider (3–5 cm) vs. narrower (1–2 cm) margins did not demonstrate significant reductions in local recurrence (LR) or survival benefits. Furthermore, wider margins are associated with increased morbidity and healthcare costs.

***Methods*:** We systematically reviewed relevant published studies up to and including December 2025 to compare LR and survival outcomes between standard WLE and no or narrow-margin excisions. The analysis included adult and pediatric cases of superficial spreading, nodular, acral, and desmoplastic cutaneous melanoma; lentigo maligna was excluded.

***Results*:** No prospective studies were found comparing WLE to the omission of WLE for cutaneous melanoma. Two retrospective studies reported no significant differences in LR or overall survival (OS) in patients who did not undergo WLE ($n=453$). Regarding lateral margins, 30 retrospective studies were identified. Collectively, these studies suggest that narrower margins than those currently recommended are not associated with worse LR, disease-free survival, or OS for melanoma in situ and pT1–pT3 tumors (Breslow index ≤ 4 mm). However, findings for pT4 melanomas (Breslow index > 4 mm) remain inconsistent. Analysis of deep margins ($n=5$ retrospective studies) largely supported more superficial excision strategies than current guidelines. Regarding acral melanoma, seven retrospective studies were located, all of which reported that narrower and shallower margins—including the preservation of plantar fat—did not adversely affect LR or survival. Conversely, in cases of desmoplastic melanoma, two retrospective studies were found with conflicting results regarding LR. In the

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pediatric population, evidence remains scarce; two retrospective studies evaluating narrow excision margins revealed no adverse impact on OS. ***Conclusions***: Current evidence suggests that narrower lateral margins and shallower deep excision strategies could be oncologically safe. However, the absence of an observed association with higher rates of LR or worse survival outcome should not be interpreted as proof of non-inferiority to standard WLE, given the predominance of observational data, heterogeneity across studies, and limited statistical power in smaller cohorts. High-quality prospective randomized trials are required. Ongoing randomized trials (MelMART-II, WoW, and ICEMAN) will play a key role in refining future surgical margin recommendations.

**Keywords:** Melanoma; Margins; Survival; Recurrence; Acral melanoma; Pediatric

**Key Summary Points**

Available evidence supporting wide local excision (WLE), particularly lateral margins and deep excision to the muscular fascia, is limited and largely based on retrospective studies and expert consensus rather than robust prospective trials.

Across melanoma in situ and pT1–pT3 invasive melanomas, multiple retrospective studies report no clear association between narrower excision margins—or even omission of WLE—and worse local recurrence or survival outcomes; however, absence of association should not be interpreted as evidence of equivalence or non-inferiority compared with standard WLE.

More conservative deep excision strategies, including the preservation of subcutaneous or plantar fat in acral melanoma, appear oncologically safe in retrospective cohorts and may reduce surgical morbidity and functional impairment.

Evidence heterogeneity, selection bias, and discrepant margin definitions limit the strength of current conclusions, underscoring the need for well-designed prospective randomized trials to define when conservative margin strategies can be safely adopted.

## INTRODUCTION

Despite being deeply embedded in clinical practice, robust prospective evidence supporting the routine performance of wide local excision (WLE) in cutaneous melanoma is lacking [1]. Over the past century, recommended excision margins have progressively decreased from 5 to 1–2 cm for invasive disease. Several randomized controlled trials (RCTs) have shown that margins of 1 cm and 2 cm are safe for melanomas with a Breslow index (BI) < 2 mm [2] and > 2 mm [3, 4], respectively. Current North American and European guidelines recommend margins of 5 mm for melanoma in situ, 1 cm for thin melanoma (BI ≤ 1 mm), 1–2 cm for intermediate-thickness melanoma (BI 1.1– 2 mm), and 2 cm for thick melanoma (BI > 2 mm) [5, 6]. Notably, recommendations for melanoma in situ and thin melanoma are based on expert consensus published in 1992 [7], and the evidence underpinning current guidelines remains limited.

To date, six RCTs evaluating WLE in melanoma have been published (Table 1). However, their comparisons (5 cm vs. 2 cm, 4 cm vs. 2 cm, and 3 cm vs. 1 cm) do not adequately inform modern practice regarding the safety of narrower margins. Meta-analyses of these trials have consistently failed to demonstrate that wider margins (3 cm–5 cm) reduce local recurrence or improve disease-free survival compared with narrower margins (1–2 cm) [8–11].

Residual melanoma or microsatellitosis within WLE specimens appears to be uncommon. A retrospective study of 1089 melanomas (excluding lentigo maligna [LM]) reported microsatellitosis in only 0.8% of cases, associated with BI > 2 mm, ulceration, and high mitotic rate, with

**Table 1** Randomized clinical trials on surgical excision margins in cutaneous melanoma and their impact on recurrence or survival

| Status | Trial, authors and year | *N*, characteristics | Breslow index | Intervention | Median follow-up | Impact on local recurrence | Impact on survival |
|---|---|---|---|---|---|---|---|
| Completed* | UK MSG Trial<br>Thomas et al., 2004 [78]<br>Hayes et al., 2016 [79] | 900 melanomas of the trunk and extremities | > 2 mm | 1 cm vs. 3 cm | 8.8 years | Trend toward higher LR with narrower margins (HR 1.26; 95% CI 1.00–1.59; $p = 0.05$) [78] | No differences in OS. Slight, non-significant increase in MFS (HR 1.24; 95% CI 1.01–1.53; $p = 0.041$) [79] |
| | Swedish Trial II<br>Gillgren et al., 2011 [4]<br>Utjes et al., 2019 [3] | 936 melanomas of the trunk and extremities | ≥ 2 mm | 2 cm vs. 4 cm | 19.6 years | No significant differences [80] | No significant differences in MFS or OS [3] |
| | Intergroup Trial<br>Balch et al., 2001 [81] | 468 melanomas of the trunk and extremities | 1 to 4 mm | 2 cm vs. 4 cm | 10 years | No significant differences | No significant differences |
| | Swedish Trial I<br>Cohn-Cedermark et al., 2000 [82] | 989 melanomas of the trunk and extremities | 0.8–2 mm | 2 cm vs. 5 cm | 11 years | No significant differences | No significant differences |
| | European Trial<br>Khayat et al., 2003 [83] | 337 melanomas not located in acral sites | ≤ 2 mm | 2 cm vs. 5 cm | 16 years | No significant differences | No significant differences |

**Table 1** continued

| Status | Trial, authors and year | *N*, characteristics | Breslow index | Intervention | Median follow-up | Impact on local recurrence | Impact on survival |
|---|---|---|---|---|---|---|---|
| | WHO Trial<br>Veronesi et al., 1991 [2]<br>Cascinelli et al., 1998 [84] | 612 melanomas not located on the face or acral sites | < 2 mm | 1 cm vs. 3 cm | 7.5 years | No significant differences | No significant differences |
| Ongoing | ICEMAN trial<br>Bichajkian et al., 2025 [77] | Melanomas of the face, trunk, extremities, and acral sites | AJCC stage I (pT1a, pT1b, pT2a) | Mohs surgery/ excision margin of 0.5 cm vs. 1–2 cm | – | – | – |
| | WoW trial<br>Wennberg et al., 2025 [76] | Melanomas of the face, trunk, and extremities | BI ≤ 1 mm | 1 cm vs. no margin extension (melanomas excised with histologic margins ≥ 1.5 mm) | – | – | – |
| | Melmart-II<br>Rossi et al., 2022 [75] | Melanomas of the trunk and extremities | AJCC stage II; BI > 2 mm without ulceration or > 1 mm with ulceration | 1 cm vs. 2 cm | – | – | – |

*AJCC* American Joint Committee on Cancer, *BI* Breslow index, *HR* hazard ratio, *LR* local recurrence, *MFS* melanoma-free survival, *N* number of patients, *OS* overall survival

*Across these six randomized clinical trials, a total of 8 acral melanomas were included [59]

no subcutaneous involvement identified [12]. Other studies have reported residual melanoma rates ranging from 0 to 4% [13–17]. The largest study to date ($n$=44,628) reported a residual melanoma rate of 2%, and <3% in melanomas with BI≤2 mm [18]. A recent immunohistochemistry-enhanced study reported a residual melanoma rate of 3.4% in melanomas with BI<1 mm [19]. Importantly, the presence of residual melanoma at WLE has not been linked to worse recurrence-free outcomes [20]. In a recent retrospective study by Nacchiero et al. ($n$=460) [20] BI was the only factor associated with residual melanoma, with a proposed cutoff of 2.3 mm, suggesting that WLE might be omitted in selected cases.

WLE may be associated with relevant morbidity. Margins≥2 cm substantially increase the need for complex reconstructions compared with 1 cm margins [21, 22], and may significantly raise healthcare costs [23]. Even in T1a melanomas, a 1-cm WLE can result in physical and psychological morbidity [24].

In this article, we review the impact of narrower and more superficial lateral as well as less margin depth WLE than those recommended by North American or European guidelines—or omission of WLE—across different types of cutaneous melanoma (excluding LM) focusing on objective outcomes such as local recurrence (LR) rate, overall survival (OS), disease-free survival (DFS), and melanoma-specific survival (MSS).

## METHODS

This systematic review was conducted in accordance with the Preferred Reporting Items for Systematic Reviews and Meta-analysis (PRISMA) guidelines and was registered through PROSPERO (CRD420251271424). This article is based on previously conducted studies and does not contain any new studies with human participants or animals performed by any of the authors.

### Eligibility Criteria

Original studies published in English were eligible if they included patients of any age with histologically confirmed primary cutaneous melanoma undergoing surgical excision and evaluated lateral excision margins and/or deep excision margin depth. Mohs micrographic surgery (MMS) represents a distinct surgical strategy that differs fundamentally from conventional excision with predefined lateral margins. Margin control during MMS is achieved through complete peripheral and deep margin assessment rather than predefined metric distances, and margin widths cannot be directly compared with those used in standard excision. Accordingly, studies evaluating MMS were not included.

Studies were required to report at least one oncologic outcome, including LR, locoregional recurrence (LRR), MSS, DFS, or OS. Prospective studies, retrospective observational studies, and RCTs including more than 30 patients were considered. Studies focusing exclusively on lentigo maligna were excluded because of its distinct biological behavior and management [25]. Melanomas of mucosal origin were not included, as the present review focused exclusively on primary cutaneous melanoma.

### Information Sources and Search Strategy

A systematic literature search was performed in MEDLINE (via PubMed) and the Cochrane Library (CENTRAL) from inception up to December 2025. The search combined free-text terms and controlled vocabulary related to cutaneous melanoma, surgical excision margins (lateral and/or deep), and oncologic outcomes. Searches were limited to English-language publications. Full search strategies are provided in Supplementary Material 1.

### Study Selection and Data Collection Process

Titles and abstracts were screened independently by two reviewers (PBS and MMP) followed by full-text assessment of potentially eligible studies. Data extraction was performed independently using a standardized form, aggregating information on study design, patient and tumor characteristics, surgical margins, follow-up duration, and reported oncologic outcomes. Disagreements were resolved by consensus or by a third reviewer (DMC). The study selection process is summarized in the PRISMA flow diagram (Fig. 1).

### Risk of Bias

Risk of bias was assessed independently by two reviewers (PBS and MMP) using the Cochrane Risk of Bias tool (RoB 2) for randomized trials and the Risk of Bias In Non-randomized Studies of Interventions (ROBINS-I) tool for non-randomized studies (Supplementary Material 2). Domains assessed included confounding, participant selection, intervention classification, deviations from intended interventions, missing data, outcome measurement, and selective reporting. Risk of bias judgments were considered in the interpretation of results.

### Data Synthesis and Analysis

Given the heterogeneity in study design, surgical approaches, and outcome definitions, a descriptive synthesis was performed. Across the included studies, excision margins were variably reported as clinical (surgical) margins or histological (pathological) margins. Given the heterogeneity in reporting and the known impact of tissue shrinkage on histological measurements, no systematic conversion between clinical and histological margins was performed, and margins were analyzed as reported in the original studies.

In the review of retrospective studies, outcomes analyzed via multivariable models were prioritized, as this approach minimizes the impact of confounding factors.

## RESULTS

### Study Selection

A total of 261 records were identified through the database searches. After removal of duplicates, 234 titles and abstracts were screened

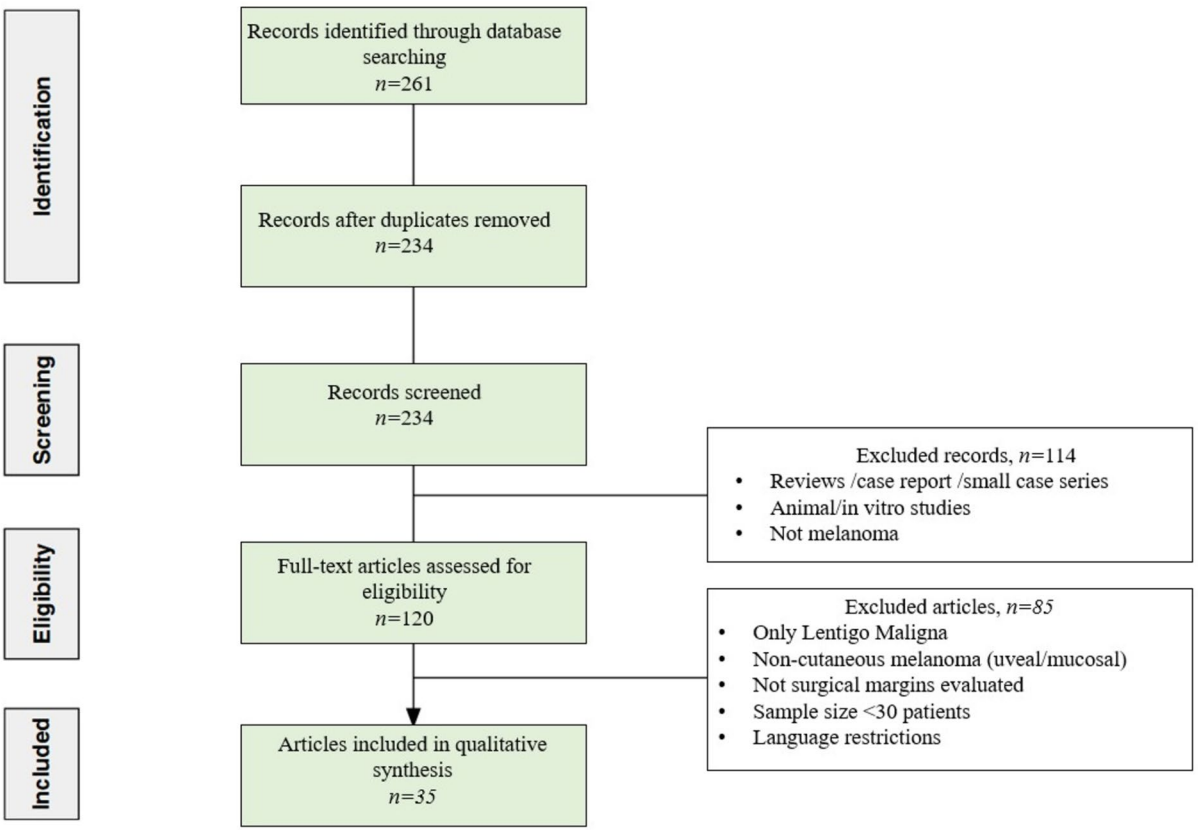


**Fig. 1** PRISMA flow diagram of study selection

for relevance, and 120 full-text articles were assessed for eligibility. Following the full-text review, 35 studies met the predefined inclusion criteria and were included in the final qualitative synthesis. The study selection process is summarized in the PRISMA flow diagram (Fig. 1).

## Study Characteristics

The included studies were published between 1998 and 2025 and were conducted in several countries. Overall, 35 studies (Tables 2, 3, 4, 5, 6, 7, 8) were included in the review: all were retrospective studies. No RCTs evaluating the use of narrower lateral margins or reduced deep excision margins compared with current international guideline recommendations, or omission of re-excision, were identified for cutaneous melanoma.

## Risk of Bias in Included Studies

According to ROBINS-I, most included studies were judged to have an overall serious risk of bias, with a minority rated as moderate. The main factors were serious risk of confounding across most studies and moderate to serious risk related to participant selection and missing data. In contrast, risk of bias due to intervention classification, deviations from intended interventions, outcome measurement, and selective reporting was generally low to moderate. These limitations, inherent to the predominantly observational design, were taken into account when interpreting the results.

## Results of Individual Studies

### *Adults*

***Omission of Wide Local Excision (WLE)*** We identified two retrospective studies including 453 patients without re-excision. No significant association with adverse outcomes was reported in this group. Both studies were conducted in the Netherlands and compared the performance of WLE to omission of WLE. The study by Haniff et al. [26] ($n=454$) reported no significant differences in OS between the group that underwent the recommended WLE ($n=272$; median BI, 1.8 mm) and the group without WLE ($n=182$; median BI, 1.8 mm). In multivariable analysis, omission of WLE was not associated with worse MSS. LR rates were not reported. A second study by Stekelenburg et al. [14] ($n=5918$) included 271 melanomas with no subsequent WLE (median BI = 0.9 mm; 59 with BI 1.1–2 mm; 70 with BI < 2 mm). The median distance to surgical margins in this subgroup was 2.8 mm. LR rates were 7.6% in the WLE group and 10.3% in the non-WLE group ($p=0.10$). In multivariable analysis, WLE was not associated with recurrence-free survival (HR 0.94; 95% CI 0.62–1.41; $p=0.76$.

### *Narrower Lateral Excision Margins*

***Melanoma in Situ*** There is very limited evidence regarding the appropriate excision margins for melanoma in situ (MIS) when LM is excluded. We identified four retrospective studies including 191 patients with narrower margins (< 5 mm) (Table 2). No significant association with worse outcomes was reported. A recent retrospective study by Dessinioti et at. ($n=403$) [27] reported only one LR (0.2%), corresponding to a patient with positive margins who did not undergo WLE. In 30 MIS with clear margins after diagnostic excision, no WLE was performed, and no recurrences were detected after a median follow-up of 8 years. In an additional 23 patients, a narrower WLE was performed, with a mean margin of 3.6 mm, and no LRs were observed after a median follow-up of 4 years. No patient developed metastases or melanoma-related mortality. In another retrospective study (Smith et al.) [28] including 250 MIS, 46 completely excised MIS did not undergo WLE, and 20 underwent a WLE < 5 mm. None of these cases developed LR or metastases after a mean follow-up of 30 months. Previously, Akhtar et al. [29] conducted a retrospective study of 192 MIS (62% non-LM). Only two LRs were observed among completely excised MIS, both corresponding to LM. Additionally, the authors reported 72 MIS with margins < 2 mm. After a

**Table 2** Published studies on the impact of narrower excision margins in melanoma in situ (non-lentigo maligna)

| Authors, year | Study design | Type of margin reported | *N* | Main findings |
|---|---|---|---|---|
| Dessinioti et al., 2025 [27] | Retrospective | Both (clinical margins; histological clearance assessed) | 30 patients without EM* and 23 patients with EM < 5 mm;<br>348 patients with EM of 5 mm | Median follow-up of 8 and 4 years, respectively. No LR, metastasis, or melanoma-related death observed<br>Median follow-up of 5 years. No LR, metastasis, or melanoma-related death observed |
| Sun et al., 2024 [30] | Retrospective | Clinical margins | 292 patients;<br>351 MIS < 10 mm located outside the head and neck (SSM 50%; LM 31%; lentiginous MIS 19%)<br>EM of 5 mm | Median follow-up of 7 years. LR rate of 0.9%. No nodal or distant metastases observed |
| Smith et al., 2023 [28] | Retrospective | Histological (pathological) margins | 234 MIS with clear margins; 46 MIS without EM; 20 MIS with EM < 5 mm | Median follow-up of 30 months. No LR, metastasis, or melanoma-related death observed |
| Akhtar et al., 2014 [29] | Retrospective | Histological (pathological) margins | 192 MIS (117 non-LM MIS); 72 MIS with margins < 2 mm | Four LRs occurred (all in situ, all LM). No LR, metastasis, or melanoma-related death were observed in non-LM MIS excised with > 1 mm lateral margins. One LR (LM) after a median follow-up of 30 months |

*BI* Breslow index, *EM* excision margin, *LM* lentigo maligna, *LR* local recurrence, *MIS* melanoma in situ, *N* number of patients, *SSM* superficial spreading melanoma

*Patients with clear margins at diagnostic excision. One LR (1/403) occurred (BI 0.8 mm) in a patient with involved margins in whom margin extension could not be performed

**Table 3** Published studies on narrower excision margin size in thin melanoma (pT1, Breslow index ≤ 1 mm)

| Authors, year | Study design | Type of margin reported | *N* | Intervention | Main outcomes |
|---|---|---|---|---|---|
| Rajeh et al., 2025 [42] | Retrospective | Clinical (surgical) margins | 1825 patients with melanoma (111 with narrow excision margins) (61% SSM; 19% NOS melanoma) | Among 1039 melanomas with BI ≤ 1 mm: excision margins of approximately 5 mm ($n = 68$) vs. 10 mm ($n = 971$). Median follow-up 6 years | No significant differences in LR or OS |
| Buja et al., 2025 [35] | Retrospective | Histological (pathological) margins | 2698 melanomas; 2218 pT1 (BI ≤ 1 mm) | Histologic margins < 0.8 cm (surgical margin < 1 cm) ($n = 671$) vs. ≥ 0.8 cm (surgical margin ~ 1 cm) ($n = 1547$). Follow-up 3 years | In pT1 melanomas, narrow margins were not associated with worse OS or MSS |
| Maurichi et al., 2023 [31] | Retrospective | Clinical (surgical) margins | 610 patients with head and neck pT1 melanoma (79% SSM; mean BI 0.3 mm) | Excision margins of 5 mm ($n = 295$) vs. 10 mm ($n = 219$) | No significant differences in LR, OS, or 10-year DFS. Two distant metastases and two melanoma-related deaths occurred, all in the 10-mm group |
| Maurichi et al., 2023 [32] | Retrospective | Clinical (surgical) margins | 1179 pT1a melanomas in critical areas (median BI 0.5 mm); 72.5% SSM; 16.4% LM melanoma; 6.9% AM | Excision margins of 10 mm ($n = 626$) vs. 5 mm ($n = 553$). Median follow-up 112 months | Univariate and multivariate analyses showed no significant associations between narrow margins and higher rates of LR, MSS, DFS, or OS. LMM and AM were associated with higher LR |

**Table 3** continued

| Authors, year | Study design | Type of margin reported | *N* | Intervention | Main outcomes |
|---|---|---|---|---|---|
| Rawlani et al., 2015 [41] | Retrospective | Clinical (surgical) margins | 79 head and neck melanomas (38 with BI ≤ 1 mm) | Narrow margins ($n = 37$) vs. guideline-recommended margins ($n = 42$). Among BI ≤ 1 mm: 13 received 0.5 cm and 25 received 1 cm margins. Median follow-up 71 months | No significant differences in LR |
| MacKenzie et al., 2016 [34] | Retrospective | Histological (pathological) margins | From 11,290 thin primary pT1 melanomas (≤ 1 mm), 176 cases with LR were identified and 176 controls (without LR) were selected | Histologic excision margin analysis: < 8 mm vs. ≥ 8 mm (approx. < 1 cm vs. ≥ 1 cm clinical). *N* of each group not available | Histologic margins < 8 mm were associated with higher LR risk on univariate analysis; this association did not persist on multivariable analysis |
| Harish et al., 2013 [33] | Retrospective | Both clinical (surgical) and histological (pathological) margins | 24 pT1 eyelid melanomas (≤ 1 mm) within a cohort of 56 invasive eyelid melanomas | Surgical margins available in 35 cases (≤ 5 mm: $n = 19$; > 5 mm: $n = 18$); histological margins available in a subset (in situ ≤ 2 mm: $n = 14$, > 2 mm: $n = 15$; invasive ≤ 2 mm: $n = 9$, > 2 mm: $n = 21$) | In pT1, surgical margins were not significantly associated with LR. A pathologic margin > 2 mm from the in situ component was associated with improved MSS. No additional benefit with wider margins. Lower eyelid melanomas showed higher LR rates regardless of thickness or margins |

*AM* acral melanoma, *BI* Breslow index, *DFS* disease-free survival, *EM* excision margin, *LM* lentigo maligna, *LMM* lentigo maligna melanoma, *LR* local recurrence, *MSS* melanoma-specific survival, *N* number of patients, *NOS* not otherwise specified, *OS* overall survival, *SSM* superficial spreading melanoma

**Table 4** Published studies on narrower excision margin size in intermediate melanoma (pT2; Breslow index 1–2 mm)

| Authors, year | Study design | Type of margin reported | *N* | Intervention | Main outcomes |
|---|---|---|---|---|---|
| Buja et al., 2025 [35] | Retrospective | Histological (pathological) margins | 2698 melanomas; 480 pT2 (BI 1–2 mm) | Histologic margins < 0.8 cm (surgical margin < 1 cm) ($n = 68$) vs. ≥ 0.8 cm (surgical margin ~ 1 cm) ($n = 412$). Follow-up 3 years | In pT2 melanomas, narrow margins were not associated with worse OS or DFS |
| Haydu et al., 2016 [36] | Retrospective | Histological (pathological) margins | 2131 pT2 melanomas | Analysis of lateral and deep histologic margins. Median follow-up 46 months<br>Pathologic margins < 8 mm: $n = 326$; ≥ 8 mm: $n = 1805$ | Multivariable analysis showed no association between narrower lateral margins and LR or MSS |
| Doepker et al. 2016 [37] | Retrospective | Clinical (surgical) margins | 965 pT2 melanomas (BI 1.01–2.0 mm); median BI 1.4 mm (58% SSM, 23% NM, 5% LMM, 3% DM, 2% AM) | Excision margins of 1 cm ($n = 302$) vs. 2 cm ($n = 663$). Median follow-up 15 months | No significant differences in LR or MSS at 5 years |
| Koskivuo et al., 2015 [38] | Retrospective | Clinical (surgical) margins | 160 pT2 melanomas (BI 1.1–2.0 mm) | Excision margins of 1 cm ($n = 80$) vs. 2 cm ($n = 80$). Median follow-up 41 months | No significant differences in LR or MSS |
| Hudson et al., 2013 [39] | Retrospective | Clinical (surgical) margins | 576 patients with melanoma BI 1–2 mm (median BI 1.4 mm) | Excision margins of 1 cm ($n = 224$) vs. 2 cm ($n = 352$). Median follow-up 38 months | On multivariable analysis, a 1-cm margin was not associated with increased LR or worse OS |

**Table 4** continued

| Authors, year | Study design | Type of margin reported | *N* | Intervention | Main outcomes |
|---|---|---|---|---|---|
| McKinnon et al., 2005 [40] | Retrospective | Histological (pathological) margins | 2681 melanomas ≤ 2 mm | Histologic margins < 8 mm: $n = 416$; ≥ 8 mm: $n = 2265$ | Histologic margins were associated with higher LR risk only when < 0.8 cm (approx. < 1 cm clinically). After exclusion of these cases, margin width was no longer predictive of LR. No impact on OS or MSS |

*AM* acral melanoma, *BI* Breslow index, *DFS* disease-free survival, *EM* excision margin, *LM* lentigo maligna, *LMM* lentigo maligna melanoma, *LR* local recurrence, *MSS* melanoma-specific survival, *N* number of patients, *NM* nodular melanoma, *NOS* not otherwise specified, *OS* overall survival, *RCT* randomized clinical trial, *SSM* superficial spreading melanoma

median follow-up of 31 months, only one LR was described, which also corresponded to LM.

More recently, Sun et al. [30] analyzed 351 MIS < 10 mm located outside the head and neck, excised with a 5-mm clinical margin. After a median follow-up of 7 years, the LR rate was remarkably low (0.9%), with no nodal or distant metastases observed.

### *Invasive Melanoma*

***Thin Melanoma (pT1; BI ≤ 1 mm)*** We identified seven studies (all retrospective) including more than 1600 patients with narrower margins (< 1 cm) in pT1 melanoma (Table 3). The multivariate analysis did not detect a significant association between narrower WLE and worse outcomes in this subgroup.

One study including 610 patients (Maurichi et al., 2023) [31] with head and neck pT1 melanoma (79% SSM; mean BI 0.3 mm) compared LR, and 10-year OS and DFS between WLE of 5 mm ($n = 295$) and 10 mm ($n = 219$). After a median follow-up of 88 months in the 5-mm group and 187 months in the 10-mm group, no significant differences were observed between groups. Two distant metastases and two melanoma-related deaths occurred, both in the 10-mm group. Another study by Maurichi et al. [32] ($n = 1179$ pT1a melanomas; median BI 0.5 mm; 72.5% SSM, 16.4% LM melanoma) included melanomas located in critical areas such as the face, scalp, external genitalia, perineal and acral, and compared outcomes of margins of 10 mm ($n = 626$) vs. 5 mm ($n = 553$). Median follow-up was 112 months. Univariate and multivariate analyses showed no significant associations between narrower margins and higher rates of LR, MSS, DFS, or OS. A study carried out in Australia by Harish et al. [33] ($n = 56$) showed no significant association between narrower surgical margins and LR in pT1 tumors. A pathological in situ clearance > 2 mm was sufficient for disease control. A large Australian database study by MacKenzie Ross et al. [34] of 11,290 pT1 primary cutaneous melanomas reported an LR rate of 1.6%. Subsequently, an analysis of 352 patients was conducted (matched case–control subset: 176 LR cases and 176 controls). Narrower histologic excision margins (< 8 mm,

**Table 5** Published studies on narrower excision margin size in thick melanoma (pT3 and pT4; Breslow index > 2 mm)

| Authors, year | Study design | Type of margin reported | *N* | Intervention | Main outcomes |
|---|---|---|---|---|---|
| Buja et al., 2025 [35] | Retrospective | Histological (pathological) margins | 2698 melanomas; 338 pT3 (BI > 2 mm < 4 mm) and 226 pT4 (BI > 4 mm) | Histologic margins < 1.6 cm (surgical margin < 2 cm) ($n = 287$) vs. ≥ 1.6 cm (surgical margin ~ 2 cm) ($n = 277$). Follow-up 3 years | In pT3 melanomas, narrow margins were not associated with worse OS or MSS. In pT4 melanomas, narrow margins were associated with worse OS (HR 1.73; 95% CI 1.01–2.96; $p = 0.047$) and worse MSS (HR 2.55; 95% CI 1.12–5.81; $p = 0.026$) |
| Rajeh et al., 2024 [42] | Retrospective | Clinical (surgical) margins | 1825 patients with melanoma (111 with narrow excision margins) (61% SSM; 19% NOS melanoma) | Among 333 melanomas with BI > 2 mm: excision margins of approximately 1.5 cm ($n = 35$) vs. 2 cm ($n = 298$). Median follow-up 6 years | No significant differences in LR or OS |
| Maurichi et al., 2024 [21] | Retrospective | Clinical (surgical) margins | 736 melanomas with BI > 2 mm (median 3.5 mm); 48% SSM, 30% NM, 16% AM, 5% DM | Excision margins of 1 cm ($n = 471$) vs. 2 cm ($n = 265$). Median follow-up 108 months | No significant differences in LR, DFS, or OS at 10 years. Results were consistent across histologic subtypes. More than twice as many patients in the wide-margin group required complex reconstruction (69% vs. 32%, $p < 0.001$) |

**Table 5** continued

| Authors, year | Study design | Type of margin reported | *N* | Intervention | Main outcomes |
|---|---|---|---|---|---|
| Rawlani et al., 2015 [41] | Retrospective | Clinical (surgical) margins | 79 head and neck melanomas (20 with BI > 2 mm) | Narrow excision margins ($n = 37$) vs. guideline-recommended margins ($n = 42$). Median follow-up 71 months | No significant differences in LR |
| Hunger et al., 2015 [47] | Retrospective | Clinical (surgical) margins | 325 melanomas; median BI 4.4 mm (68% NM; 21% SSM) | Excision margins of 1 cm ($n = 228$) vs. 2 cm ($n = 97$). Median follow-up 61 months | No significant differences in LR, DFS, or OS |
| Pasquali et al., 2013 [44] | Retrospective | Both clinical (surgical) and histological (pathological) margins | 632 melanomas with BI > 4 mm (median 5.5 mm); 45% NM, 19% DM, 18% NOS | Excision margins of approximately 2 cm (histologic margin > 16 mm) ($n = 261$) vs. narrower margins ($n = 371$). Median follow-up 37 months | Histologic margins ≤ 16 mm were associated with higher LR and locoregional recurrence |
| Heaton et al., 1998 [45] | Retrospective | Clinical (surgical) margins | 278 melanomas; median BI 6 mm | Excision margins < 2 cm ($n = 26$), 2 cm ($n = 108$), and > 2 cm ($n = 80$). Median follow-up 27 months | Margins ≤ 2 cm were not associated with higher LR or worse DFS or OS |
| Lamboo et al., 2014 [43] | Retrospective | Histological (pathological) margins | 1587 pT3 melanomas (BI 2.01–4.0 mm) | Histologic margins < 8 mm ($n = 246$) vs. ≥ 8 mm (approx. < 1 cm vs. ≥ 1 cm clinically) ($n = 1341$); additional comparison of ~ 1 cm vs. ~ 2 cm | Margins < 8 mm were associated with higher risk of local/in-transit recurrence and worse DFS. No differences were observed between ~ 1 cm and ~ 2 cm margins, and no impact on MSS |

**Table 5** continued

| Authors, year | Study design | Type of margin reported | *N* | Intervention | Main outcomes |
|---|---|---|---|---|---|
| Ruskin et al., 2016 [46] | Retrospective | Histological (pathological) margins | 108 pT4 head and neck melanomas (median BI 6.0 mm) | Excision margins 0–1 cm ($n = 27$) vs. 1–2 cm ($n = 61$) vs. 2–3.5 cm ($n = 20$); median follow-up 40 months | No significant reduction in local or locoregional recurrence with 2 cm margins compared with narrower margins ($p = 0.17$), nor improvement in MSS with wider margins ($p = 0.58$) |

*AM* acral melanoma, *BI* Breslow index, *DFS* disease-free survival, *DM* desmoplastic melanoma, *EM* excision margin, *LM* lentigo maligna, *LMM* lentigo maligna melanoma, *LR* local recurrence, *MSS* melanoma-specific survival, *N* number of patients, *NM* nodular melanoma, *NOS* not otherwise specified, *OS* overall survival, *SSM* superficial spreading melanoma

approximating < 1 cm in vivo) were associated with LR on univariate analyses. However, narrower margins were not a predictor of LR in multivariate analysis.

***Intermediate Melanoma (pT2; BI 1.1–2 mm)*** We identified six retrospective studies including 810 patients with narrower margins (approx. <1 cm) in pT2 melanoma (Table 4). In five studies (Buja et al. [35], Haydu et al. [36], Doepker et al. [37], Koskivuo et al. [38], and Hudson et al. [39]), which included 394 melanomas with narrower WLE, no significant association of narrower margins with adverse outcomes was identified after multivariable adjustment. However, McKinnon et al. [40] described an increased risk of LR in those with histological margins < 0.8 cm.

In a recent study by Buja et al. [35] ($n = 480$ pT2 melanomas), histological margins < 0.8 cm (corresponding to WLE approx. <1 cm) ($n = 68$) were compared with ≥ 0.8 cm (corresponding to WLE approx. ≥ 1 cm) ($n = 412$). No association was found between narrower margins and worse OS or MSS. Similarly, Haydu et al. [36] analyzed 2131 pT2 melanomas and found no association between narrower lateral histologic margins and LR or MSS on multivariable analysis. Three retrospective series directly comparing 1 cm vs. 2 cm excision margins reported concordant results. Doepker et al. [37] ($n = 965$), Koskivuo et al. [38] ($n = 160$), and Hudson et al. [39] ($n = 576$) found no significant differences in LR or MSS, and no increase in LR or worse OS associated with 1 cm margins, even after multivariable adjustment.

An earlier retrospective analysis by McKinnon et al. [40] evaluated 2681 melanomas BI ≤ 2.0 mm (416 with histological margins < 0.8 cm), including a substantial 1–2 mm subgroup, with a median follow-up of 83.8 months. Histopathologic excision margin < 0.8 cm was associated with LR on Cox proportional hazards model. When lesions excised with margins < 0.8 cm in fixed tissue (approx. <1 cm in vivo) were excluded, margin was no longer predictive of LR, suggesting a threshold effect. Margin width did not influence MSS.

***Thick Melanoma (pT3; BI 2.1–4 mm)*** We identified four retrospective studies including

**Table 6** Published studies on the impact of shallower deep margin excision on melanoma prognosis

| Authors, year | Study design | Type of margin reported | *N* | Intervention | Main outcomes |
|---|---|---|---|---|---|
| Burger et al., 2023 [48] | Retrospective | Histological (pathological) margins | 385 pT1–T4 melanomas (61% SSM, 12% NM, 16% NOS, 7% LMM); median BI 0.7 mm | Excision down to the muscular fascia ($n = 218$) vs. excision limited to the subcutaneous tissue (mid or deep) ($n = 144$). Mean follow-up 47 months | Overall, 8% developed LR. Depth of excision was not associated with increased LR |
| Haydu et al., 2016 [36] | Retrospective | Histological (pathological) margins | 2131 pT2 melanomas | Analysis of lateral and deep histologic margins. Median follow-up 46 months. Deep margin recorded in 1691 cases | Significant difference in DFS on univariate ($p < 0.001$) and multivariate analysis ($p = 0.017$) when comparing a deep histologic margin < 8-mm group to the ≥ 8-mm group. Each additional millimeter of deep margin reduced the risk of local/in-transit recurrence by approximately 5% (HR 0.95 per mm; $p = 0.003$). No association was observed between deep margin depth and MSS |
| Lamboo et al., 2014 [43] | Retrospective | Histological (pathological) margins | 1587 T3 melanomas (BI 2.01–4 mm) | Analysis of lateral and deep histologic margins. Deep margin recorded in 1129 cases | Deep margin not associated with outcomes |

*BI* Breslow index, *DFS* disease-free survival, *EM* excision margin, *LITRFS* local and in-transit recurrence–free survival, *LMM* lentigo maligna melanoma, *LR* local recurrence, *MSS* melanoma-specific survival, *N* number of patients, *NM* nodular melanoma, *NOS* not otherwise specified,, *OS* overall survival, *SSM* superficial spreading melanoma

**Table 7** Published studies on narrower and/or shallower excision margins in acral melanoma

| Margin | Authors, year | Study design | Type of margin reported | *N* | Intervention | Main outcomes |
|---|---|---|---|---|---|---|
| Lateral | Koizumi et al., 2025 [49, 54] | Retrospective | Clinical (surgical) margins | 336 patients (BI > 2 mm) | Excision margin of 1 cm ($n = 110$) vs. 2 cm ($n = 226$) | No significant differences in OS, MSS, DFS, or LR |
| | Sun et al., 2023 [51] | Retrospective | Clinical (surgical) margins | 207 patients with BI > 2 mm | 43 patients received narrower margins (1–2 cm) and 164 margins ≥ 2 cm | Narrower margins were not associated with worse OS or DSS, nor with higher LR |
| | Lino-Silva et al., 2023 [52] | Retrospective | Clinical (surgical) margins | 306 patients with BI > 2 mm (median BI 6 mm) | Excision margins of 1–2 cm ($n = 69$) vs. > 2 cm ($n = 237$) | No differences in 5-year OS or LR |
| | Ito et al., 2020 [50] | Retrospective | Clinical (surgical) margins | 100 patients, 38% T4 and 16% T3 | NCCN-recommended margins ($n = 35$) vs. narrower margins ($n = 65$): 16 T1 tumors received 5 mm margins; 3 T2 tumors, 5 mm margins; 11 and 2 T3 tumors received 10 and 15 mm margins, respectively; 27 pT4 tumors received margins ≤ 10 mm and 6 received 15 mm margins | Narrow margins were not associated with worse MSS (HR 1.83; 95% CI 0.47–7.14; $p = 0.38$) or worse DFS (HR 1.73; 95% CI 0.60–4.99; $p = 0.30$) |
| | Lee et al., 2016 [53] | Retrospective | Clinical (surgical) margins | 129 patients with primary AM | Thin AM (BI ≤ 1 mm): < 1 cm ($n = 37$) vs. 1 cm ($n = 16$) margins; Thick AM (BI > 1 mm): < 2 cm ($n = 36$) vs. 2 cm ($n = 40$) margins | In thin AM, no recurrences or melanoma-related deaths regardless of margin. In thick AM, a 2-cm margin was associated with lower LR and LITR, without differences in DFS or MSS |

**Table 7** continued

| Margin | Authors, year | Study design | Type of margin reported | *N* | Intervention | Main outcomes |
|---|---|---|---|---|---|---|
| Deep | Koizumi et al., 2025 [54] | Retrospective | Clinical (surgical) margins | 464 patients with plantar AM | Excision down to the muscular fascia ($n=171$) vs. preservation of plantar fat pad ($n=293$) | Multivariable analysis showed that preservation of plantar fat pad was not associated with worse OS, DFS, or 5-year LR |
| | Lee et al., 2025 [55] | Retrospective | Clinical (surgical) margins | 94 patients with T1–T3 AM (median BI 1.7 mm) | Excision down to the muscular fascia ($n=54$) vs. preservation of plantar fat pad ($n=40$) | Preservation of plantar fat pad ($n=40$) was not associated with worse DFS or LR |

*AM* acral melanoma, *BI* Breslow index, *DFS* disease-free survival, *DSS* disease-specific survival, *HR* hazard ratio, *LITR* local and in-transit recurrence, *LR* local recurrence, *MSS* melanoma-specific survival, *N* number of patients, *NCCN* National Comprehensive Cancer Network, *OS* overall survival

more than 800 patients with narrower margins (< 2 cm) in pT3 melanoma (Table 5). In general, no significant association of narrower margins (approx. 1 cm) with adverse outcomes was identified after multivariable adjustment.

A recent study by Maurichi et al. [21] including patients with melanoma with BI > 2 mm ($n=736$; median BI 3.5 mm; 48% SSM, 30% NM, 16% ALM, 5% desmoplastic melanoma) compared WLE of 1 cm ($n=471$) vs. 2 cm ($n=265$). After a median follow-up of 108 months, no significant differences were observed in LR, DFS, or OS at 10 years. No differences were observed when analyzing histological subtypes. A previous study ($n=79$) by Rawlani et al. [41] had reported similar results. Rajeh et al. [42] retrospectively reviewed 333 melanomas with BI > 2 mm. WLE of approximately 1.5 cm ($n=35$) vs. 2 cm ($n=298$) showed no significant differences in LR or OS after a median follow-up of 6 years.

Finally, a large single-center retrospective study by Lamboo et al. [43] ($n=1587$ pT3 melanomas; 246 with histological margins < 0.8 cm; median BI 2.7 mm) showed that histological margins ≥ 8 mm (approx. ≥ 1 cm in vivo) were independently associated with improved local/in-transit RFS (HR 0.54, $p=0.008$) and DFS (HR 0.59, $p=0.001$) compared to < 8 mm. However, the minimum peripheral excision margin as a continuous variable did not influence DFS on univariate or multivariate analysis, and in univariate and multivariate analyses, the minimum peripheral excision margin did not significantly influence MSS. A subgroup analysis comparing ~ 1 cm vs. ~ 2 cm surgical margins ($n=188$ vs. 377) showed no significant differences in LR, in transit recurrence, DFS, or MSS on multivariable analysis.

***Very High-Risk Thick Melanoma (pT4; BI > 4 mm)*** Regarding pT4 melanoma (Table 5), we found five retrospective studies which showed conflicting results: the study by Pasquali et al. [44] including 632 pT4 melanomas (45% NM, 19% DM, 18% not specified) reported higher LR and LRR in patients with histological margins ≤ 16 mm (corresponding to WLE < 2 cm). Recently, a study by Buja et al. [35] ($n=2598$) including 226 melanomas

**Table 8** Narrower excision margin extension in the pediatric melanoma population

| Authors, year | Study design | Type of margin reported | *N* | Intervention | Main outcomes |
|---|---|---|---|---|---|
| Farrow et al., 2025 [57] | Retrospective | Clinical (surgical) margins | 2081 patients (median age 17 years; median BI 1 mm) | Excision margin ≤ 1 cm ($n = 743$) vs. > 1 cm ($n = 1338$). Median follow-up of 4.6 and 5.5 years, respectively | No significant difference in OS between groups. Patients with excision margins ≤ 1 cm showed a trend toward higher OS ($p = 0.053$). Subgroup analysis of children < 12 years ($n = 406$) showed similar results |
| Basta et al., 2022 [74] | Retrospective | Clinical (surgical) margins | 59 patients (median age 13 years) | Excision margin ≤ 2 cm ($n = 36$) vs. > 2 cm ($n = 23$) | No LR or death was observed in either group after a median follow-up of 52 months. AE rates were similar when comparing margins < 2 cm vs. ≥ 2 cm (13.9% vs. 21.7%, $p = 0.433$). Most frequent complications were wound dehiscence (20%), seroma (30%), and infection (10%) |

*AEs* adverse events, *BI* Breslow index, *EM* excision margin, *LR* local recurrence, *N* number of patients, *OS* overall survival

with BI > 4 mm (50% NM, 35% SSM) showed that WLE < 2 cm (histological margins < 1.6 cm) was associated with lower MSS [HR 2.55 (1.12–5.81); $p = 0.026$]. However, the retrospective study by Heaton et al. [45] ($n = 278$; median BI 6 mm) showed that margins ≤ 2 cm were not associated with higher LR or worse OS or DFS compared with margins > 2 cm. In head and neck pT4 melanoma, Ruskin et al. [46] retrospectively analyzed 108 patients (median BI 6.0 mm; median follow-up 40 months) and compared surgical margins of 0–1 cm vs. 1–2 cm vs. 2–3.5 cm and found no significant differences in LR with wider excision margins, and no improvement in MSS with increasing margins ($p = 0.58$). Finally, Hunger et al. [47] ($n = 325$; median BI 4.4 mm; 68% NM; 21% SSM) compared WLE of 1 cm ($n = 228$) vs. 2 cm

($n=97$) and also found no worse outcomes with narrower margins.

***Deep Margin*** Three retrospective studies, analyzing a total of 3205 deep margins, were identified to evaluate the impact of reduced deep excision depth (Table 6). Multivariable analysis showed that resection limited to the subcutaneous tissue was not associated with LR or survival. However, one study (Haydu et al. [36]) suggested that a minimum histological margin of 0.8 mm should be maintained.

Burger et al. [48] ($n=385$; median BI 0.7 mm) compared excision down to the muscular fascia ($n=218$) with resection limited to the subcutaneous tissue ($n=144$). On multivariable analysis, excision depth was not associated with an increased risk of LR. In the study by Lamboo et al. [43] (1587 pT3 melanomas), no association was observed between deep margin depth and LR or MSS. Haydu et al. [36] ($n=2131$ pT2 melanomas) reported a significant difference in DFS on both univariate and multivariate analyses when comparing deep histologic margins $<8$ mm with those $\geq 8$ mm. In univariate analysis, each additional millimeter of deep margin reduced the risk of local/in-transit recurrence by approximately 5% (HR $\approx 0.95$ per mm; $p=0.003$). This influence was lost after adjustment in multivariate analysis. A deep margin $<8$ mm was not associated with worse MSS.

### *Acral Melanoma*

***Lateral Margins*** We identified five retrospective studies, including 360 melanomas with narrower lateral margins. Narrower WLE was not associated with LR or survival on multivariate analysis.

A recent multicenter Japanese study by Koizumi et al. [49] including 336 patients with acral melanoma (AM) (BI $>2$ mm) compared excision margins of 1 cm ($n=110$) vs. the recommended 2 cm ($n=226$). After a median follow-up of 43 months, multivariate analysis showed that 1 cm margins were not associated with worse outcomes, with no significant differences in OS, MSS, DFS, or LR. Another Japanese study by Ito et al. [50] ($n=100$; 38% pT4 and 16% pT3) compared NCCN-recommended margins in AM ($n=35$) with narrower margins ($n=65$: 16 patients with pT1 tumors received 5 mm margins; 3 patients with pT2 tumors received 5 mm margins; 11 and 2 patients with pT3 tumors received 10 mm and 15 mm margins, respectively; among pT4 patients, 27 received margins $\leq 10$ mm and 6 received 15 mm margins). Two patients in the narrow-margin group developed LR, whereas none did so in the wide-margin group ($p=0.53$). Mortality rates were similar between groups (1.36 vs. 1.28 per 100 person-years, respectively). However, pT4 patients treated with narrow margins showed higher mortality; notably, these cases had significantly higher BI than those in the wide-margin group. Multivariate analysis showed that narrow margins were not associated with worse MSS (HR 1.83; 95% CI 0.47–7.14; $p=0.3836$) or DFS (HR 1.73; 95% CI 0.60–4.99; $p=0.3092$) (Table 7). A multicenter study carried out in China by Sun et al. [51] included 207 patients with AM and BI $>2$ mm. Forty-three patients (21%) received narrower margins (1–2 cm), while the remainder received margins $\geq 2$ cm. On multivariable analysis, narrower margins were not associated with worse OS or MSS, nor with higher LR. Another multicenter retrospective study performed in Mexico by Lino-Silva et al. [52] including 306 patients with AM and BI $>2$ mm (median BI 6 mm) compared margins of 1–2 cm vs. $>2$ cm. After a median follow-up of 32 months, no differences were observed in 5-year OS or LR.

Regarding AM with lower BI, a retrospective study by Maurichi et al. [32] included 39 pT1a and compared excision margins of 0.5 cm vs. 1 cm. Narrower margins were not associated with worse rates of LR or DFS.

A study in Korea by Lee et al. [53] included 129 patients with primary AM and evaluated oncologic outcomes according to surgical excision margins. Patients were stratified

into thin AM (BI ≤ 1 mm; $n = 53$) and thick AM (BI > 1 mm; $n = 76$). In thin acral melanoma, no local, regional, or distant recurrences, or melanoma-related deaths were observed regardless of whether a 1-cm or > 1-cm margin was used. In contrast, in thick AM, a 2-cm excision margin was independently associated with a lower risk of LR (HR 0.12; $p = 0.023$) and local or in-transit recurrence (HR 0.19; $p = 0.013$) compared with margins < 2 cm. No significant differences were observed in DFS or MSS between margin groups.

***Deep Margin*** Current recommendations advise excision of the entire subcutaneous fat during margin extension in AM. However, this tissue plays a critical role in cushioning and plantar biomechanics.

We found two retrospective studies including 333 acral melanomas with shallower margins. Multivariate analysis revealed that preservation of plantar fat was not associated with worse outcomes.

A multicenter retrospective study by Koizumi et al. [54] including 464 patients with plantar AM and a median follow-up of between 51 and 54 months showed that preservation of plantar fat was not associated with worse OS or DFS, or with higher 5-year LR rates. Another retrospective study by Lee et al. [55] including 94 patients with T1–T3 AM (median BI 1.7 mm) with a median follow-up of 43 months reported similar findings. Preservation of plantar fat ($n = 40$) was not associated with worse DFS or LR, and patients undergoing more conservative excisions showed a trend toward better functional outcomes compared with those undergoing suprafascial excision ($n = 54$).

### *Desmoplastic Melanoma*

We identified two retrospective studies showing conflicting results. Maurichi et al. [56] (2010) analyzed a large retrospective cohort of patients with desmoplastic melanomas (DM) ($n = 242$), showing that the impact of excision margins differed according to subtype. In pure DM ($n = 118$), narrower margins (1 cm; $n = 30$) were associated with a higher risk of LR and MSS compared with 2 cm margins ($n = 88$), whereas in mixed DM, outcomes for patients with narrower margins (1 cm; $n = 34$) were less influenced by margin width and paralleled those of conventional melanoma. However, more recently (2024), the same group [21] included 38 DM with BI > 2 mm. After a median follow-up of 108 months, no differences were observed in LR, OS, or DFS between patients treated with 1 cm margins ($n = 15$) and those treated with 2 cm margins ($n = 23$).

### *Children*

***Pediatric Melanoma*** We did not identify RCTs or prospective studies evaluating WLE in pediatric melanoma (Table 8). Two retrospective studies were found, encompassing more than 750 children treated with narrower WLE. Within this pediatric population, narrower margins were not associated with adverse clinical outcomes.

A retrospective study by Farrow et al. [57] ($n = 2081$; median age 17 years; median BI 1 mm) compared excision margins ≤ 1 cm vs. > 1 cm. No significant difference in OS was observed between groups; in fact, patients treated with margins ≤ 1 cm showed a trend toward higher OS ($p = 0.053$). A subgroup analysis of children younger than 12 years ($n = 406$) yielded similar results. More recently, Basta et al. [58] reported a single-center retrospective cohort of 59 pediatric patients undergoing WLE with excision margins < 2 cm vs. 2 cm. After a median follow-up of 52 months, no LR were observed in either group. Postoperative complication rates did not differ significantly between groups.

## DISCUSSION

### Absence of Excision Margin Extension

We did not identify prospective studies comparing the performance vs. omission of excision margin extension in melanoma. The only available studies addressing this issue were retrospective [14, 26], and neither demonstrated differences in LR or OS. The low rate of residual

melanoma at re-excision, particularly in tumors with BT ≤ 2 mm, suggests that the oncologic benefit of re-excision may be limited in a well-selected subgroup of patients. Omitting excision margin extension could result in savings of hundreds of millions of euros per year in Europe [14]. However, prospective studies are required to support this approach. A relevant consideration is that omission of excision margin extension has mainly been evaluated in selected cohorts with low-risk melanomas and negative initial histologic margins, which limits the extrapolation of these results to thicker melanomas or those with adverse histopathologic features [12, 26]. Furthermore, it is difficult to ascertain whether patients who did not undergo re-excision inherently possessed a more favorable baseline prognosis.

### Lateral Excision Margin Extension in Melanoma in General

The width and depth of excision margin extension in melanoma management will likely decrease in the near future. Most available RCTs have not demonstrated an improvement in survival or a reduction in LR when following current guidelines. Multiple meta-analyses have confirmed these findings [8–11]. The theoretical benefit in reducing long-term adverse events is even more questionable in patients receiving adjuvant or neoadjuvant therapy [11]. Accordingly, interpretation of more recent studies must consider the increasing use of adjuvant and neoadjuvant systemic therapies, particularly immune checkpoint inhibitors in stage II–III melanoma.

In the same way that complete lymph node dissection and sentinel lymph node biopsy have decreased in recent years, wide excision margin extension is also likely to be reduced, particularly in the context of modern systemic therapies. Moreover, our systematic review identified multiple retrospective studies suggesting that narrower and more superficial margins than those currently recommended could be safely used in melanoma in situ (< 5 mm) [27–30], thin melanomas (< 1 cm) [31–35], intermediate-thickness melanomas (≤ 1 cm) [35–39], and thick melanomas (< 2 cm) [21, 41–43]. One possible exception may be pT4 melanomas (BI > 4 mm), for which results remain inconclusive [35, 44–47].

The potential use of narrower excision margins (or omission of margin extension) is particularly relevant in vulnerable populations such as children [57] and older adults, as well as in anatomical locations where cosmetic and/or functional outcomes are critical (face and neck, and acral sites, among others) [21, 32, 59].

### Deep Margin

Current recommendations advise excision of the subcutaneous tissue down to the muscular fascia. Several retrospective studies have shown that excision including the muscular fascia does not result in significant differences in LR, OS, or DFS [60–63], even in melanomas with BI > 2 mm [63]. Notably, fascial excision has been associated with an increased risk of in-transit metastases and higher rates of nodal recurrence [60–63]. It has been hypothesized that resection of the fascia may disrupt lymphatic drainage, allowing superficial drainage to occur through deeper lymphatic channels, thereby potentially facilitating tumor dissemination [60]. Similarly, it appears highly unlikely that complete removal of all subcutaneous tissue down to the muscular fascia is necessary [36, 43, 48, 54, 55]. A more superficial deep margin, limited to the subcutaneous tissue, may facilitate surgical defect closure and reduce postoperative complications.

### Uncommon Histologic Subtypes of Melanoma

Current guidelines recommend excision margins similar to those used for SSM, both laterally and in depth, despite the limited proportion of patients with DM or AM included in the reference studies [59, 64]. Management of these uncommon tumor subtypes should be individualized and discussed by a multidisciplinary tumor board, taking into account their specific tumor characteristics and considering the

possibility of using narrower excision margins than those currently recommended [21, 57, 59].

Several large retrospective studies have shown that MMS is a safe alternative for melanomas of the head and neck [65], AM [66, 67], and DM [68]. A slight survival advantage has even been reported for head and neck melanomas [65]. This technique allows for tissue preservation, limits removal of healthy tissue, and reduces the number of re-excisions and the time to defect reconstruction [66].

AM is infrequent in Caucasian populations, but represents the most frequent melanoma subtype in Asian and African people. Management can be particularly challenging because of its biological characteristics, aggressiveness and poorer prognosis, the functional complexity of the involved anatomical sites, and its relatively limited response to immunotherapy [59, 69]. In light of the retrospective studies included in this systematic review [54, 55], it seems reasonable to consider and discuss with patients the use of narrower excision margins and the preservation of plantar fat in AM, with the aim of reducing morbidity and improving functional outcomes [59]

DM shows a higher prevalence in photoexposed areas such as the head and neck. It is associated with higher rates of LR, lower rates of nodal involvement, and a better prognosis than SSM, as well as an excellent response to immunotherapy [70, 71]. We found very limited evidence to support specific recommendations in this setting.

### Pediatric Melanoma

Melanoma in children is rare, clinical studies are scarce (with a lack of prospective studies), and current recommendations advise following the same clinical guidelines as in adults [72]. However, survival rates are higher in children [73], and in recent years there has been a trend toward the use of narrower excision margins [57]. A recent retrospective study [74] ($n = 59$, median age 13 years) showed a high rate of complications following WLE in children. The most frequent complications were wound dehiscence (20%), seroma (30%), and infection (10%). Given the fragility of this subgroup, the use of narrower excision margins could be considered, based on the results of the study by Farrow et al. [57] including more than 2000 children, without compromising long-term outcomes.

### Ongoing Clinical Trials

Several clinical trials are currently underway. The MelMarT-II trial [75] is comparing the impact of 1 cm vs. 2 cm excision margins on LR, DFS, and OS in patients with stage II melanoma (American Joint Committee on Cancer) (Table 1). The Swedish "WoW" RCT (NCT06363591) [76] is evaluating a 1-cm excision margin vs. no excision margin extension in melanomas with BI ≤ 1 in cases already excised with histologic margins ≥ 1.5 mm. In addition, the ICEMAN RCT is recruiting patients with stage I melanomas (pT1a, pT1b, pT2a) and randomizing them to MMS/5 mm excision margin vs. a 1–2-cm excision margin [77]. Furthermore, the NORMA RCT is currently in the design phase and will evaluate patients with intermediate and thick melanomas in the coming years, comparing WLE plus sentinel lymph node biopsy (SLNB) vs. SLNB alone [14]. The information generated by these studies will be crucial for supporting recommendations for narrower excision margins with a higher level of evidence. In addition, the use of molecular or analytical prognostic biomarkers may help identify patients who require more aggressive interventions (surgical and/or pharmacological) [1].

## LIMITATIONS

This review has several limitations. Most included studies were retrospective observational cohorts and are therefore subject to confounding by indication and selection bias, particularly in analyses evaluating omission of re-excision or use of narrower margins in patients with favorable baseline characteristics. Sample sizes varied widely, and smaller studies may have been underpowered to detect meaningful differences in recurrence or survival outcomes. Accordingly, greater inferential weight

should be attributed to large registry-based studies when interpreting the overall evidence.

Considerable heterogeneity existed in margin reporting, with variable use of clinical vs. histological margins and inconsistent definitions of deep excision, further limiting comparability across studies. Furthermore, histological margins may underestimate clinical margins as a result of tissue shrinkage.

Follow-up duration was often variable or insufficient to capture late local recurrences, particularly in thin melanoma. Several studies included mixed melanoma subtypes without consistent histologic stratification, limiting subtype-specific conclusions.

Finally, evolving staging procedures and treatment paradigms, including sentinel lymph node biopsy and modern systemic therapies such as adjuvant or neoadjuvant immunotherapy, were not uniformly accounted for in older cohorts, which may restrict applicability to contemporary practice. Overall, these limitations highlight the need for adequately powered prospective trials using standardized endpoints to evaluate narrower and/or more superficial excision strategies.

## CONCLUSIONS

While excision margin extension is part of standard practice and is supported by international guidelines, the evidence underpinning its use—particularly for very wide margins and for the deep margin—remains limited and is largely based on retrospective studies and expert consensus. WLE may be associated with relevant morbidity and an increased need for complex reconstructions, with functional, aesthetic, and economic implications.

Overall, the available retrospective studies suggest that, in many clinical scenarios, narrower lateral margins (and a less aggressive deep excision) than those currently recommended would not compromise LR or survival, although the evidence is heterogeneous and results are conflicting in pT4 melanomas. These considerations are particularly important in cosmetically or functionally critical locations (head and neck, acral sites) and in vulnerable populations such as pediatric patients. However, the absence of an observed association between narrower margins and higher rates of LR or worse survival outcome should not be interpreted as proof of non-inferiority to standard WLE, given the predominance of observational data, heterogeneity across studies, and limited statistical power in smaller cohorts. Well-designed prospective trials, with standardized definitions of recurrence and stratification by tumor thickness, histologic subtype, and systemic therapy use, are needed to more precisely define when more conservative margin strategies can be safely adopted. Ongoing randomized trials (MelMART-II, WoW, and ICEMAN) will play a key role in refining future surgical margin recommendations.

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### *Declarations*

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***Ethical Approval.*** This article is based on previously conducted studies and does not

contain any new studies with human participants or animals performed by any of the authors.

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