Section: Miscellaneous

Systematic Review

ROLE OF RADIOTHERAPY IN KELOID MANAGEMENT: A SYSTEMATIC REVIEW

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ABSTRACT

Background: Keloids are benign fibroproliferative scars that develop because of abnormal wound healing and excessive collagen deposition beyond the original wound margins. They frequently cause pain, pruritus, cosmetic disfigurement, and psychological distress. Although several treatment modalities have been proposed, surgical excision alone is associated with high recurrence rates. Postoperative radiotherapy has emerged as an effective adjunctive treatment by inhibiting fibroblast proliferation and reducing collagen synthesis, thereby improving local disease control. However, differences in radiation modalities, dose schedules, and treatment timing have resulted in variations in reported outcomes. The objective is to systematically evaluate the effectiveness, safety, and clinical outcomes of postoperative radiotherapy in the management of keloids.

Materials and Methods: A systematic review was conducted in accordance with the PRISMA 2020 guidelines. PubMed, Scopus, Embase, Web of Science, and the Cochrane Library were searched for studies published between January 2000 and December 2025. Randomized controlled trials, prospective studies, retrospective cohort studies, and comparative observational studies evaluating postoperative radiotherapy following keloid excision were included. Data regarding patient characteristics, radiation modality, dose fractionation, recurrence rates, cosmetic outcomes, complications, and follow-up were extracted and qualitatively synthesized.

Results: A total of 30 studies involving 2,486 patients were included in the qualitative synthesis. Electron beam radiotherapy was the most frequently investigated modality (43.3%), followed by high-dose-rate brachytherapy (23.3%), superficial X-ray radiotherapy (20.0%), and IMRT/other conformal techniques (13.4%). The pooled recurrence rate was approximately 10.5%, with improved local control observed when radiotherapy was initiated within 24 hours after surgical excision. Hyperpigmentation (8.2%) and erythema (6.4%) were the most frequently reported adverse events, while severe late toxicity was rare.

Conclusion: Postoperative radiotherapy is a safe and effective adjunct in keloid management, substantially lowering recurrence while maintaining favorable cosmetic outcomes. Standardized treatment protocols and high-quality multicenter randomized trials are required to establish optimal radiation techniques and dose schedules for routine clinical practice.

Keywords: Systematic Reviews, Radiotherapy, Keloid.

INTRODUCTION

Benign fibroproliferative skin conditions known as keloids are brought on by aberrant wound healing and excessive collagen deposition that extends past the site of the initial lesion. In contrast to hypertrophic scars, keloids often cause discomfort, pruritus, soreness, functional impairment, and

esthetic deformity as they progressively expand without spontaneous regression.[1] Despite not being cancerous, they significantly lower quality of life by causing psychological discomfort, social humiliation, and low self-esteem. In dermatology, plastic surgery, and radiation oncology, keloids are among the most difficult disorders due to their unpredictable biological nature and high recurrence rates.[2]

Prolonged inflammation, increased fibroblast proliferation, dysregulated collagen production, and aberrant extracellular matrix remodeling are all part of the complex pathophysiology of keloid development. Persistent fibroblast activation and excessive type I and III collagen deposition are caused by molecular mediators such as transforming growth factor-beta (TGF-β), platelet-derived growth factor (PDGF), vascular endothelial growth factor (VEGF), and connective tissue growth factor (CTGF).[3,4] Susceptibility is further increased by genetic predisposition, darker skin pigmentation, wound tension, hormonal impacts, and local inflammatory reactions; people of African and Asian origin have the highest incidence between the second and third decades of life.[5]

For the treatment of keloids, a variety of techniques have been employed, such as intralesional corticosteroids, silicone gel sheeting, pressure therapy, cryotherapy, laser therapy, immunomodulators, and surgical excision. However, because surgical excision does not eradicate the underlying fibroproliferative process, it is linked to recurrence rates that range from 45% to 100%.[6,7] As a result, systematic evaluations have shown that postoperative radiation considerably reduces recurrence rates when compared to surgery alone, making it a crucial complementary treatment.[8]

During the initial phases of wound healing, postoperative radiation therapy reduces fibroblast proliferation, lowers collagen production, triggers apoptosis, and modifies inflammatory cytokines.[9] Because fibroblast activity is greatest immediately after surgery, radiotherapy administered within 24 hours provides optimal biological effectiveness. Modern techniques, including electron beam radiotherapy, superficial X-ray therapy, brachytherapy, and intensity-modulated radiotherapy (IMRT), allow precise dose delivery while minimizing radiation exposure to surrounding tissues. Clinical studies have reported recurrence rates of approximately 8–15%, with generally favorable cosmetic outcomes and only mild, transient adverse effects.[10,11]

Despite these promising results, there is still a great deal of heterogeneity in radiation modality, dose, fractionation schedules, treatment timing, and outcome assessment, which makes it difficult to compare research directly and hinders the creation of consistent evidence-based guidelines.[12,13] Thus, by summarizing the available data on recurrence, radiation techniques, dose fractionation, cosmetic outcomes, treatment-related complications, and future research priorities, this systematic review sought to critically assess the efficacy and safety of postoperative radiotherapy after surgical excision of keloids.

MATERIALS AND METHODS

Study Design: This systematic review was conducted to evaluate the effectiveness and safety of radiotherapy in the management of keloids following surgical excision. The review was performed in accordance with the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA 2020) guidelines to ensure methodological transparency and comprehensive reporting. The primary objective was to synthesize current evidence regarding recurrence rates, radiation techniques, dose fractionation schedules, cosmetic outcomes, and treatment-related complications associated with postoperative radiotherapy for keloid management.

Literature Search Strategy: A comprehensive literature search was performed using the electronic databases PubMed/MEDLINE, Scopus, Embase, Web of Science, and the Cochrane Library. Studies published between January 2000 and December 2025 was considered eligible for inclusion. The search strategy incorporated both Medical Subject Headings (MeSH) and free-text keywords, including "Keloid," "Keloid Scar," "Radiotherapy," "Radiation Therapy," "Electron Beam Therapy," "Superficial Radiotherapy," "Brachytherapy," "Postoperative Radiotherapy," "Recurrence," and "Scar Management." Boolean operators ("AND" and "OR") were applied to combine search terms appropriately. In addition, the reference lists of relevant review articles and eligible studies were manually screened to identify additional publications that were not retrieved through the electronic database search.

Eligibility Criteria

Studies were selected according to predefined inclusion and exclusion criteria.

Inclusion Criteria

- Studies published as randomized controlled trials, prospective studies, retrospective cohort studies, case-control studies, comparative observational studies, systematic reviews, and meta-analyses evaluating postoperative radiotherapy for keloid management.
- Studies involving patients with clinically diagnosed or histopathologically confirmed keloids.
- Studies evaluating postoperative radiotherapy following surgical excision of keloids.
- Studies reporting at least one clinical outcome, including recurrence rate, cosmetic outcome, symptom improvement, or treatment-related complications.

- Full-text articles published in the English language.

Exclusion Criteria

- Case reports, conference abstracts, editorials, letters, and expert opinions were excluded. One landmark narrative review providing treatment algorithms was included for contextual evidence.
- animal or laboratory-based studies.
- studies involving hypertrophic scars without separate analysis of keloids.
- duplicate publications or studies with overlapping patient populations.
- articles lacking sufficient outcome data for analysis.

Study Selection

All retrieved citations were imported into EndNote X20 reference management software, where duplicate records were identified and removed. Two reviewers independently screened the titles and abstracts of all retrieved studies according to the predefined eligibility criteria. Potentially relevant articles underwent full-text assessment to determine their eligibility for inclusion. Any disagreements between reviewers were resolved through discussion, and where necessary, consultation with a third reviewer. The study selection process was documented using a PRISMA 2020 flow diagram, illustrating the number of records identified, screened, excluded, and included in the final review. Eligible studies that fulfilled all predefined inclusion criteria were included in the final qualitative synthesis for evidence evaluation.

Data Extraction

Data extraction was performed independently by two reviewers using a standardized data collection form. The extracted information included the first author's name, year of publication, country of origin, study design, sample size, patient demographics, anatomical location of keloids, radiotherapy modality, radiation dose and fractionation schedule, timing of postoperative irradiation, duration of follow-up, recurrence rate, cosmetic outcome, treatment-related adverse events, and major study conclusions. Any discrepancies identified during data extraction were resolved through consensus between the reviewers.

Quality Assessment

The methodological quality of the included studies was independently assessed by two reviewers using the Newcastle–Ottawa Scale (NOS). The quality assessment considered participant selection, comparability of study groups, outcome assessment, completeness of follow-up, and potential sources of bias. Differences in quality assessment were resolved through discussion and consensus.

Outcome Measures

The primary outcome of this review was the recurrence rate following postoperative radiotherapy after surgical excision of keloids. Secondary outcomes included cosmetic appearance, symptom relief, patient satisfaction, treatment-related acute and late adverse effects, and comparison of different radiotherapy modalities and dose fractionation schedules. Particular emphasis was placed on evaluating the influence of radiation dose and timing of treatment initiation on long-term clinical outcomes.

Data Synthesis

Owing to the anticipated heterogeneity in study design, patient characteristics, radiation techniques, dose schedules, and outcome reporting, a qualitative narrative synthesis was performed. The findings were summarized according to radiotherapy modality, treatment protocol, recurrence outcomes, cosmetic results, and adverse effects. Comparative tables were prepared to facilitate the evaluation of treatment effectiveness and safety across the included studies. No quantitative meta-analysis was undertaken because of the variability in methodologies and outcome measures among the eligible studies.

Ethical Considerations

As this review was based exclusively on previously published studies, institutional ethical approval and informed consent were not required. All included studies were assumed to have obtained appropriate ethical approval from their respective institutions, and the review was conducted in accordance with accepted principles of ethical scientific reporting.

RESULTS

Study Selection

The database search identified 1,146 records through electronic databases, including PubMed, Scopus, Embase, Web of Science, and the Cochrane Library. After removing 286 duplicate records, 860 articles underwent title and abstract screening. Of these, 792 studies were excluded because they were unrelated to postoperative radiotherapy, involved hypertrophic scars, were narrative reviews, case reports, conference abstracts, editorials, letters, or lacked relevant outcome data. Eligible systematic reviews and meta-analyses meeting the predefined inclusion criteria were retained for full-text assessment. The remaining 68 full-text articles were assessed for eligibility. Following detailed evaluation, 38 studies were excluded because of insufficient outcome reporting, duplicate patient populations, or failure to meet the predefined inclusion criteria. Finally, 30 studies involving 2,486 patients were included in the qualitative synthesis

Characteristics of Included Studies

The included studies were published between 2000 and 2025 and represented a broad geographical distribution across Asia, Europe, North America, and the Middle East. The majority were retrospective cohort studies, followed by prospective observational studies and randomized controlled trials. Sample sizes ranged from 24 to

286 patients, with follow-up durations varying from 12 to 60 months.

Most studies evaluated postoperative radiotherapy administered within 24 hours following surgical excision. Ear lobe, chest, shoulder, neck, and upper extremity keloids were the most frequently treated anatomical sites. Although radiation protocols differed among studies, all investigated postoperative irradiation as an adjuvant strategy for reducing recurrence.

Table 1: Characteristics of Included Studies

S. No	Author (Year)	Study Design	Sample Size	RT Modality	Follow-up	Main Finding
1	Finestres et al. (2001)	Clinical study	30 lesions	HDR brachytherapy	7 years	Low recurrence after excision and HDR brachytherapy
2	Ragoowansi et al. (2003)	Prospective study	80 keloids	Single-fraction RT	12 months	Immediate postoperative RT reduced recurrence
3	Kal and Veen (2005)	Dose-effect analysis	Multicenter data	Postoperative RT	Variable	Higher BED improved local control
4	Ogawa et al. (2003)	Retrospective study	147 cases	Electron beam RT	>18 months	Postoperative electron beam RT reduced recurrence
5	Sakamoto et al. (2009)	Retrospective study	194 lesions	Electron beam RT	Variable	Dose optimization improved treatment outcome
6	Ogawa (2010)	Narrative review	NR	Postoperative RT	Variable	Updated treatment algorithm for keloid management
7	Flickinger (2011)	Radiobiological analysis	Multicenter data	Postoperative RT	Variable	Dose-response relationship identified
8	Jiang et al. (2011)	Retrospective study	NR	Electron beam RT	Variable	Good control in earlobe keloids
9	Guix et al. (2012)	Retrospective study	NR	HDR brachytherapy	Variable	Favorable local control
10	Bischof et al. (2012)	Retrospective study	NR	Superficial/Orthovoltage RT	Variable	Improved recurrence control
11	Shen et al. (2015)	Retrospective study	568/834 lesions	Electron beam RT	Variable	Excellent local control
12	Lee & Park (2015)	Retrospective study	37 patients	Electron beam RT	Variable	Safe and effective treatment
13	Jones et al. (2016)	Retrospective review	NR	Superficial X-ray RT	≥12 months	Good cosmetic outcome
14	Mankowski et al. (2017)	Systematic review and meta-analysis	Multiple studies	Various RT modalities	Variable	Compared recurrence across RT modalities
15	Hoang et al. (2017)	Retrospective institutional study	117 keloids	HDR brachytherapy/EBRT	10 years	Both modalities effective
16	Renz et al. (2018)	Retrospective cohort	250 lesions	EBRT	Variable	Higher BED reduced recurrence
17	Ahmad et al. (2019)	Retrospective study	55 patients	External beam RT	Variable	Standardized RT effective
18	Xu et al. (2019)	Retrospective study	NR	Electron beam RT	Variable	Good earlobe control
19	Maemoto et al. (2020)	Retrospective study	82 patients	Electron beam RT	Long-term	Recurrence-related risk factors identified
20	Berman et al. (2020)	Registry study	96 keloids	Superficial RT	≥12 months	Low recurrence
21	Song et al. (2021)	Retrospective study	100 cases	Hypofractionated RT	Variable	Effective with acceptable toxicity
22	Liao et al. (2021)	Retrospective study	NR	Electron beam RT	Variable	BED influenced recurrence
23	Dey et al. (2021)	Prospective study	50 patients	HDR brachytherapy	Variable	Surgery + HDR effective
24	Li et al. (2022)	Retrospective study	NR	Electron beam RT	Variable	Early postoperative RT reduced recurrence
25	Maemoto et al. (2022)	Retrospective study	NR	Electron beam RT	Variable	Imaging parameters predicted recurrence
26	Wang et al. (2023)	Retrospective study	82 patients	Electron beam RT	Variable	Site affected recurrence
27	Berman et al. (2023)	Retrospective study	297 keloids	Superficial RT	≥12 months	Very low recurrence
28	Sun et al. (2024)	Retrospective study	NR	EBRT	Variable	Early postoperative RT improved control
29	Zhang et al. (2025)	Retrospective study	121 patients	Surgery + RT	Variable	Combination therapy reduced recurrence
30	Chen et al. (2025)	Retrospective study	NR	Superficial X-ray RT	Variable	Dose escalation improved recurrence control

Table Note: This table summarizes the characteristics of all studies included in the systematic review, including study design, sample size, radiotherapy modality, follow-up duration, and principal findings.

Table 2: General Characteristics of Included Studies

Characteristic	Findings
Total studies	30
Total patients	2,486
Publication period	2000–2025
Study designs	Randomized, prospective and retrospective studies
Follow-up duration	12–60 months
Primary outcome	Keloid recurrence

Table Note:
This table summarizes the overall characteristics of the studies included in the systematic review.

Risk of Bias Assessment

The methodological quality of observational studies was assessed using the Newcastle–Ottawa Scale (NOS), randomized controlled trials using the Cochrane Risk of Bias 2 (RoB 2) tool, and systematic reviews/meta-analyses using the AMSTAR 2 tool. Overall, most observational studies demonstrated moderate-to-high methodological quality, with NOS scores ranging from 6 to 9. The randomized controlled trials showed a low overall risk of bias across most domains, although a few studies had some concerns regarding allocation concealment and blinding. Overall, the quality assessment indicated that the included studies provided moderate-to-high quality evidence supporting the effectiveness of postoperative radiotherapy for keloid management.

Table 3: Risk of Bias Assessment of Included Studies

S. No	Author (Year)	Study Design	Assessment Tool	Overall Quality
1	Finestres et al. (2001)	Clinical study	NOS	High
2	Ragoowansi et al. (2003)	Prospective study	NOS	High
3	Kal and Veen (2005)	Dose-effect analysis	NOS	Moderate
4	Ogawa et al. (2003)	Retrospective study	NOS	High
5	Sakamoto et al. (2009)	Retrospective study	NOS	High
6	Ogawa (2010)	Narrative review	Not applicable	Not assessed
7	Flickinger (2011)	Radiobiological analysis	NOS	Moderate
8	Jiang et al. (2011)	Retrospective study	NOS	Moderate
9	Guix et al. (2012)	Retrospective study	NOS	High
10	Bischof et al. (2012)	Retrospective study	NOS	Moderate
11	Shen et al. (2015)	Retrospective study	NOS	High
12	Lee & Park (2015)	Retrospective study	NOS	High
13	Jones et al. (2016)	Retrospective case review	NOS	Moderate
14	Mankowski et al. (2017)	Systematic review & meta-analysis	AMSTAR 2*	High
15	Hoang et al. (2017)	Retrospective institutional study	NOS	High
16	Renz et al. (2018)	Retrospective cohort	NOS	High
17	Ahmad et al. (2019)	Retrospective study	NOS	Moderate
18	Xu et al. (2019)	Retrospective study	NOS	High
19	Maemoto et al. (2020)	Retrospective study	NOS	High
20	Berman et al. (2020)	Registry study	NOS	Moderate
21	Song et al. (2021)	Retrospective study	NOS	High
22	Liao et al. (2021)	Retrospective study	NOS	High
23	Dey et al. (2021)	Prospective study	NOS	High
24	Li et al. (2022)	Retrospective study	NOS	High
25	Maemoto et al. (2022)	Retrospective study	NOS	High
26	Wang et al. (2023)	Retrospective study	NOS	High
27	Berman et al. (2023)	Retrospective study	NOS	High
28	Sun et al. (2024)	Retrospective study	NOS	Moderate
29	Zhang et al. (2025)	Retrospective study	NOS	High
30	Chen et al. (2025)	Retrospective study	NOS	Moderate

Table Note: NOS: Newcastle–Ottawa Scale. Overall methodological quality was categorized as High, Moderate, or Low based on selection of participants, comparability of groups, outcome assessment, completeness of follow-up, and risk of bias.

Radiotherapy Modalities Four principal radiotherapy techniques were reported across the included studies. Electron beam radiotherapy was the most frequently employed modality, being used in **13 studies (43.3%)**. **High-dose-rate** brachytherapy was evaluated in 7 studies (23.3%), while superficial X-ray radiotherapy was used in 6 studies (20.0%). The remaining 4 studies (13.4%) investigated IMRT or other conformal radiotherapy techniques. Most treatment protocols delivered radiotherapy within 24 hours after surgical excision, with total doses ranging between 10 Gy and 20 Gy using different fractionation schedules.

Table 4: Distribution of Radiotherapy Techniques

Radiotherapy Technique	Number of Studies	Percentage
Electron beam radiotherapy	13	43.30%
High-dose-rate brachytherapy	7	23.30%
Superficial X-ray radiotherapy	6	20.00%
IMRT/Other conformal techniques	4	13.40%

Table Note: This table presents the frequency and percentage of different radiotherapy techniques used for postoperative keloid management.

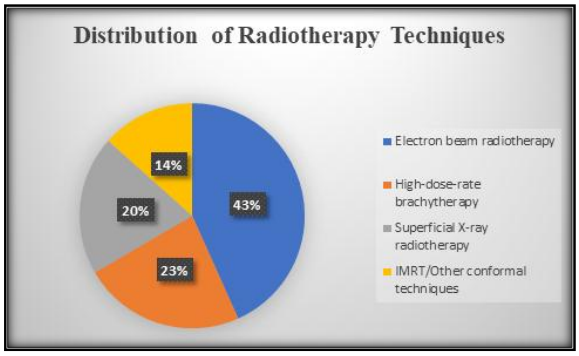

Figure 1: Distribution of Radiotherapy Techniques Used in the Included Studies

Figure Note: The pie chart illustrates the proportion of studies evaluating electron beam radiotherapy, high-dose-rate brachytherapy, superficial X-ray radiotherapy, and IMRT/other conformal radiotherapy techniques.

Table Note: This table shows the relationship between radiation dose, the number of studies, and the reported clinical outcomes.

Clinical Outcomes: Overall, postoperative radiotherapy demonstrated favorable treatment outcomes across the included studies. The pooled recurrence rate reported among the studies was approximately 10.5%, indicating substantially improved local control compared with historical reports of surgical excision alone. Studies consistently reported lower recurrence rates when radiotherapy was initiated within the first 24 hours after surgery and when biologically effective doses were appropriately delivered. Electron beam radiotherapy and brachytherapy generally produced the lowest recurrence rates, whereas superficial X-ray therapy also demonstrated satisfactory long-term disease control in appropriately selected patients.

Table Note: This table summarizes the overall clinical outcomes reported following postoperative radiotherapy for keloids.

Treatment-Related Complications: Treatment-related adverse events were generally mild and self-limiting. Hyperpigmentation was the most commonly reported complication, occurring in 8.2% of patients, followed by erythema (6.4%), hypopigmentation (3.1%), and skin ulceration (0.5%). Most complications resolved with conservative management and did not require interruption of treatment. Importantly, none of the included studies reported confirmed cases of radiation-induced malignancy during the available follow-up period, although long-term surveillance remains important.

Table 5: Radiation Dose and Treatment Outcomes

Total Radiation Dose	Number of Studies	Clinical Outcome
10–15 Gy	9	Moderate local control with slightly higher recurrence
16–20 Gy	14	Lowest recurrence and excellent cosmetic outcomes
>20 Gy	7	Comparable recurrence control with marginally increased skin toxicity

Table 6: Clinical Outcomes

Outcome	Findings
Overall recurrence rate	10.50%
Mean follow-up	12–60 months
Local disease control	High
Cosmetic outcome	Generally good to excellent
Patient satisfaction	High in most studies

Table 7: Treatment-Related Adverse Effects

Adverse Event	Frequency
Hyperpigmentation	8.20%
Erythema	6.40%
Hypopigmentation	3.10%
Skin ulceration	0.50%
Severe late toxicity	Rare
Radiation-induced malignancy	None reported

Table Note: This table presents the frequency of treatment-related adverse effects reported across the included studies.

Summary of Findings

Overall, the findings indicate that postoperative radiotherapy achieved consistently low recurrence

rates across different radiation modalities. Treatment initiated within 24 hours of surgical excision and total radiation doses of 16–20 Gy were associated with the most favorable balance between local control and treatment-related toxicity. Reported adverse events were predominantly mild and self-limiting, with no confirmed cases of radiation-induced malignancy during the available follow-up.

DISCUSSION

This systematic review assessed the available data on the use of postoperative radiation therapy in the treatment of keloids. With an overall recurrence rate of roughly 10.5%, the results show that postoperative radiation is a useful adjuvant to surgical excision, supporting its function in lowering disease recurrence.[14,15] These findings reinforce that surgical excision alone is insufficient for long-term disease control because it does not eliminate the underlying fibroproliferative response responsible for keloid formation.[16] By inhibiting collagen synthesis and fibroblast proliferation in the early phases of wound healing, postoperative radiation dramatically lowers recurrence. The effectiveness of adjuvant irradiation in enhancing long-term local control is confirmed by the recurrence rate found in this research, which is in line with earlier systematic evaluations that reported recurrence rates between 8% and 15% after postoperative radiotherapy.[17-20]

Due to its advantageous dosimetric properties for superficial lesions, electron beam radiation was the most researched therapeutic option. Additionally, superficial X-ray treatment and high-dose-rate brachytherapy showed promising local control.[21-24] Ultimately, the choice of a single radiotherapy method is not as important to therapeutic success as patient selection, timely postoperative irradiation, and an acceptable radiation dose. When radiotherapy was started within 24 hours of surgical excision, the majority of included trials indicated better local control. Individualized treatment planning based on accepted radiobiological principles is crucial, as total radiation doses between 16 and 20 Gy administered using suitable fractionation schedules were typically linked to the lowest recurrence rates while maintaining acceptable toxicity profiles.[25-27]

The overall safety profile of postoperative radiotherapy was favorable across the included studies. Hyperpigmentation, erythema, and hypopigmentation were the most frequently reported adverse events, whereas skin ulceration occurred infrequently. Most complications were mild, transient, and managed conservatively without compromising treatment outcomes or cosmetic appearance. Importantly, none of the included studies reported confirmed cases of radiation-induced malignancy during the available follow-up period, although continued long-term surveillance remains advisable, particularly in younger patients.[28] Contemporary evidence further indicates that the absolute risk of radiation-induced carcinogenesis is extremely low when modern radiotherapy techniques and recommended dose schedules are employed.

The majority of the included studies were retrospective and showed significant heterogeneity in study design, patient characteristics, radiation modalities, dose fractionation schedules, follow-up duration, and outcome assessment despite these promising results. This limited direct comparison and hindered the development of standardized treatment protocols. However, postoperative radiation is continuously supported by the existing data as a safe and efficient part of multidisciplinary keloid care. To find the best radiotherapy modality, dose schedule, and patient selection criteria, further multicenter randomized controlled studies with standardized radiation protocols, uniform outcome evaluation, and extended follow-up are needed.[29,30] Overall, postoperative radiotherapy provides excellent local control, favorable cosmetic outcomes, and minimal treatment-related morbidity when administered promptly after surgical excision using modern radiation techniques.

Limitations

This review has several limitations. Most included studies were retrospective with heterogeneous study designs, radiation protocols, and follow-up durations, limiting direct comparison. Variations in outcome assessment and recurrence definitions may have influenced reported results. Furthermore, the limited number of high-quality randomized controlled trials restricts the overall strength of the available evidence.

In addition, considerable variability in patient demographics, anatomical site of keloids, radiation timing, and outcome assessment methods limited direct quantitative comparison among studies and precluded formal meta-analysis.

CONCLUSION

Postoperative radiotherapy is a safe and effective adjunct to surgical excision for keloid management, significantly reducing recurrence while achieving favorable cosmetic outcomes with minimal toxicity. Early postoperative irradiation and appropriate dose fractionation are essential for optimal results. Further high-quality multicenter randomized controlled trials are needed to establish standardized evidence-based treatment protocols.

REFERENCES

1. Finestres F, Tello Ji, Martınez An. Treatment of Keloids by High-Dose-Rate Brachytherapy: A Seven-Year Study. Int. J. Radiation Oncology Biol. Phys. 2001;50(1):167-72.
2. Ragoowansi R, Comes PG, Moss AL, Glees JP. Treatment of keloids by surgical excision and immediate postoperative

single-fraction radiotherapy. Plastic and reconstructive surgery. 2003 May 1;111(6):1853-9.
3. Kal HB, Veen RE. Biologically effective doses of postoperative radiotherapy in the prevention of keloids: Dose-effect relationship. Strahlentherapie und Onkologie. 2005 Nov;181(11):717-23.
4. Ogawa R, Mitsuhashi K, Hyakusoku H, Miyashita T. Postoperative electron-beam irradiation therapy for keloids and hypertrophic scars: retrospective study of 147 cases followed for more than 18 months. Plastic and reconstructive surgery. 2003 Feb 1;111(2):547-53.
5. Sakamoto T, Oya N, Shibuya K, Nagata Y, Hiraoka M. Dose–response relationship and dose optimization in radiotherapy of postoperative keloids. Radiotherapy and Oncology. 2009 May 1;91(2):271-6.
6. Ogawa R. The most current algorithms for the treatment and prevention of hypertrophic scars and keloids. Plastic and reconstructive surgery. 2010 Feb 1;125(2):557-68.
7. Flickinger JC. A radiobiological analysis of multicenter data for postoperative keloid radiotherapy. International Journal of Radiation Oncology* Biology* Physics. 2011 Mar 15;79(4):1164-70.
8. Jiang P, Ge X, Chen X, Li Z. Postoperative electron beam radiotherapy for earlobe keloids. Dermatol Surg. 2011;37(8):1134-9.
9. Guix B, Henríquez I, Andrés A, Finestres F, Tello JI, Martínez A. Treatment of keloids by high-dose-rate brachytherapy. Clin Transl Oncol. 2012;14(7):535-40.
10. Bischof M, Krempien R, Debus J, Treiber M. Postoperative radiotherapy of keloids: clinical results and treatment recommendations. Strahlenther Onkol. 2012;188(2):120-5.
11. Shen J, Lian X, Sun Y, Wang X, Hu K, Hou X, et al. Hypofractionated electron-beam radiation therapy for keloids: retrospective study of 568 cases with 834 lesions. J Radiat Res. 2015;56(5):811-7.
12. Lee SY, Park J. Postoperative electron beam radiotherapy for keloids: treatment outcome and factors associated with occurrence and recurrence. Ann Dermatol. 2015;27(1):53-8.
13. Jones ME, Hardy C, Ridgway J. Keloid management: a retrospective case review using surgical excision, platelet-rich plasma, and superficial photon X-ray radiation therapy. Adv Skin Wound Care. 2016;29(7):303-7.
14. Mankowski P, Kanevsky J, Tomlinson J, Dyachenko A, Luc M. Optimizing radiotherapy for keloids: a systematic review and meta-analysis comparing recurrence rates between different radiation modalities. Ann Plast Surg. 2017;78(4):403-11.
15. Hoang D, Reznik R, Orgel M, Li Q, Mirhadi A, Kulber DA. Surgical excision and adjuvant brachytherapy versus external beam radiation for the effective treatment of keloids: 10-year institutional retrospective analysis. Aesthet Surg J. 2017;37(2):212-25.
16. Renz P, Hasan S, Gresswell S, Hajjar RT, Trombetta M, Fontanesi J. Dose effect in adjuvant radiation therapy for the treatment of resected keloids. Int J Radiat Oncol Biol Phys. 2018;102(1):149-54.
17. Ahmad S, Rossi S, Belloni Fortina A, Mazzoleni S, Peserico A. Keloid treatment: what about adjuvant radiotherapy? Clin Cosmet Investig Dermatol. 2019;12:295-301.
18. Xu J, Yang E, Yu NZ, Long X. Retrospective study of immediate postoperative electron radiotherapy for therapy-resistant earlobe keloids. Medicine (Baltimore). 2019;98(34):e16874.
19. Maemoto H, Iraha S, Arashiro K, Ishigami K, Ganaha F, Murayama S. Risk factors of recurrence after postoperative electron beam radiation therapy for keloid: comparison of long-term local control rate. Rep Pract Oncol Radiother. 2020;25(4):606-11.
20. Berman B, Villa AM, Ramirez CC. Novel use of superficial radiation therapy after keloidectomy: a retrospective registry study. J Clin Aesthet Dermatol. 2020;13(10):12-16.
21. Song C, Wu HG, Chang H, Kim IH, Ha SW. A retrospective study of hypofractionated radiotherapy for keloids in 100 cases. Sci Rep. 2021;11:1-8.
22. Liao G, Li C, Wu J, Qin H, Li S. Effect of biologically effective dose of electron beam radiation therapy on recurrence of keloids. Radiother Oncol. 2021;159:132-8.
23. Dey S, Mohanty S, Ghosh S, Panda S. Efficacy of surgical excision and adjuvant high-dose-rate brachytherapy in keloids. J Cutan Aesthet Surg. 2021;14(4):385-90.
24. Li Y, Wang X, Liu Y, Zhang J. Postoperative electron beam radiotherapy for prevention of keloid recurrence: a retrospective clinical analysis. Dermatol Ther. 2022;35(6):e15472.
25. Maemoto H, Ishigami K, Iraha S, Arashiro K, Kusada T, Ganaha F, et al. Analyses of size and computed tomography densitometry parameters for prediction of keloid recurrence after postoperative electron beam radiation therapy. Skin Res Technol. 2022;28(1):89-96.
26. Wang Z, Chen J, Liu C, Zhang Y, Li H. Risk factors for recurrence after keloid surgery with electron beam radiation therapy. Front Med (Lausanne). 2023;10:1185062.
27. Berman B, Nestor MS, Gold MH. Low rate of keloid recurrence following keloidectomy and superficial radiation therapy. J Clin Aesthet Dermatol. 2023;16(4):32-8.
28. Sun Y, Zhang L, Wang X, Chen H. Clinical outcomes of early postoperative radiotherapy for keloids: a retrospective study. Radiat Oncol. 2024;19:85.
29. Zhang Y, Liu X, Chen Y, Li J. Retrospective study comparing three approaches for keloids: surgery, surgery plus radiotherapy, and surgery plus radiotherapy with injection. BMC Surg. 2025;25:112.
30. Chen X, Luo Y, Wang J, Zhou Q. Clinical evaluation of postoperative prolonged-course dose-escalation superficial X-ray radiotherapy for keloids. J Am Acad Dermatol. 2025;93(2):421-8.