The Role of Radiation Therapy in Pediatric Keloid Management

Case Series and Systematic Review

Allison C. Hu, MD, Isabel A. Ryan, BS, Philip D. Tolley, MD, Nicholas A. Han, BSE, Jesse A. Taylor, MD, David W. Low, MD, Jordan W. Swanson, MD, MSc, and Scott P. Bartlett, MD

Background: Radiation therapy following surgical excision is an effective strategy for recurrent keloids in adults. However, concerns about radiation-induced malignancy in children have limited its use and study in younger populations. This study aimed to assess clinical outcomes of postoperative radiation for recurrent pediatric keloids through a pooled literature analysis and review of our institutional experience.

Methods: A retrospective review was conducted of all pediatric patients treated at the Children's Hospital of Philadelphia from 2000 to 2024 who underwent reexcision followed by postoperative radiation for recurrent keloids. Recurrence was defined as clinical evidence of regrowth beyond scar borders. A systematic review was also performed in March 2025 in accordance with PRISMA guidelines, using terms related to "keloid," "radiation," and "pediatric." Studies' eligibility criteria were assessed for quality using the Oxford Levels of Evidence.

Results: Five published studies and 1 institutional series comprising 60 patients and 85 keloids were included (mean age, 14.4 ± 3.5 years). Most lesions were on the earlobes (38.3%). Brachytherapy (53.3%) and external beam radiation (46.7%), most commonly at 12 Gy in 3 fractions, were the primary modalities, typically delivered within 24 hours postoperatively. Adjunctive treatments included corticosteroids (21.7%) and compression therapy (20.0%). Overall recurrence was 22.4%. Hyperpigmentation (53.3%) and transient pruritus (15.0%) were common side effects. No cases of secondary malignancy or growth disturbance were observed (mean follow-up, 32.3 ± 24.0 months).

Conclusion: Postoperative radiation following reexcision may serve as an effective treatment for recurrent pediatric keloids. Further long-term prospective studies are warranted to evaluate durability and oncologic safety in the long term.

Key Words: keloid, radiation, recurrence

(*Ann Plast Surg* 2026;96: 233–240)

Keloids are benign fibroproliferative lesions that result from dysregulated wound healing, characterized by excessive collagen deposition extending beyond the boundaries of the original injury. Although histologically nonmalignant, they frequently cause significant physical symptoms and psychosocial distress, particularly when they are large, symptomatic, or located in cosmetically sensitive areas.[1–3] In pediatric patients, keloids pose distinct challenges. Their incidence increases during adolescence and is disproportionately higher among individuals with darker skin phototypes, a positive family history, or injuries to high-tension anatomical areas such as the earlobes and anterior chest.[4–6] Treatment of pediatric keloids is often extrapolated from adult protocols and lacks standardization. Conservative options such as corticosteroid injections, massage, pressure therapy, silicone sheeting, and cryotherapy are commonly used but demonstrate limited efficacy, particularly for recurrent lesions.[7–10]

Surgical excision is the cornerstone for treatment of symptomatic or disfiguring keloids, yet recurrence rates after excision alone can exceed 70%.[9,11,12] Consequently, there is growing interest in multimodal approaches, particularly the use of adjuvant radiation therapy to improve local control.[13,14] Meta-analyses suggest that the addition of radiation to surgery reduces recurrence more effectively than dual therapy with corticosteroids alone.[15] Triple therapy, such as surgery plus radiation and a third modality like triamcinolone, has been associated with the lowest recurrence rates.[15] Radiation modalities, including superficial radiation therapy, high–dose-rate (HDR) brachytherapy, and intraoperative radiation therapy, have demonstrated recurrence rates as low as 10%–20% when delivered within 24 to 48 hours postoperatively.[3,13,15] These techniques limit penetration depth and minimize exposure to adjacent growing tissues, thereby addressing long-standing concerns regarding growth disturbance and radiation-induced malignancy in children. Despite the demonstrated efficacy of radiation, its use in children remains controversial due to concerns over growth impairment and carcinogenic risk. However, the evidence supporting these concerns is limited. A review of over a century of radiation literature found only 5 case reports of secondary malignancies possibly linked to keloid radiation, often with unclear dosing and protection protocols.[16] Furthermore, in a national survey of radiation oncologists, although concern about secondary malignancy remained high, the actual incidence of malignancy attributed to keloid-directed radiation was extremely low.[17] Of 101 respondents, only 3 reported observing a secondary malignancy attributable to keloid-directed radiation: 1 melanoma, 1 sarcoma, and 1 nonmelanoma skin cancer.[17] Recent pediatric series, including those using HDR brachytherapy and superficial radiation therapy, have reported favorable outcomes with minimal short-term toxicities.[5,18]

Although these findings are promising, pediatric-specific data remain sparse and heterogeneous. Most studies are retrospective and underpowered, and lack standardized outcome measures. Factors such as lesion location, prior treatment history, and timing of radiation may critically influence outcomes but are inconsistently reported.[2,4] Given the clinical and psychosocial burden of pediatric keloids and the evolving role of radiation therapy in their management, further evaluation of pediatric-specific outcomes is needed. In this study, we present a systematic review of the literature on combined surgical excision and adjuvant radiation therapy in children and adolescents with keloids. We assess treatment outcomes, recurrence rates, and complications and additionally contribute a case series from our institution to better inform clinical decision-making in this population.

METHODS

Study Sources and Search Strategy

A systematic review was performed in March 2025 using the Preferred Reporting Items for Systematic reviews and Meta-Analyses (PRISMA 2020) statement guidelines (Fig. 1).[19] We queried the PubMed, Cochrane Library, and ISI Web of Science databases.

Received August 10, 2025, and accepted for publication, after revision December 14, 2025.
From the Division of Plastic, Reconstructive, and Oral Surgery, Children's Hospital of Philadelphia, Pennsylvania, PA.
Conflicts of interest and sources of funding: none declared.
Allison C. Hu and Isabel A. Ryan are co-first authors.
Reprints: Scott P. Bartlett, MD, Children's Hospital of Philadelphia, Perelman School of Medicine, University of Pennsylvania, 3401 Civic Center Blvd, Philadelphia, PA 19104. E-mail: bartletts@chop.edu.
Copyright © 2026 Wolters Kluwer Health, Inc. All rights reserved.
ISSN: 1536-3708/26/9603–0233
DOI: 10.1097/SAP.0000000000004629

Copyright © 2026 Wolters Kluwer Health, Inc. All rights reserved.

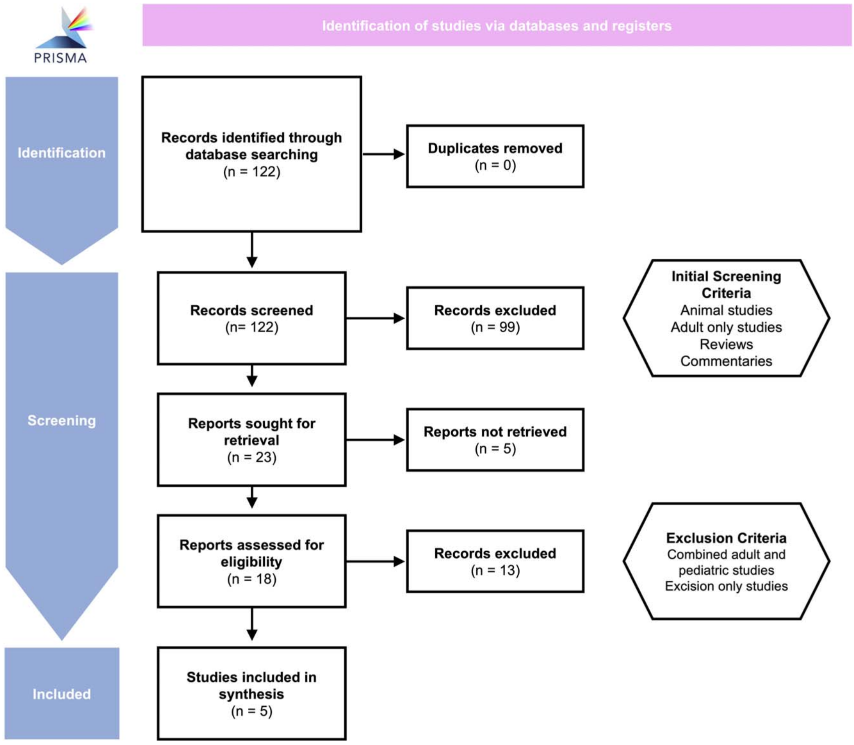

FIGURE 1. Preferred Reporting Items for Systematic reviews and Meta-Analyses (PRISMA) flowchart of selected studies for inclusion in systematic review.

Searches were limited to the English language without date restrictions. The following Boolean term was used: (keloid) AND (radiation OR brachytherapy OR x-ray OR electron) AND (pediatric OR paediatric OR child). The search terms were adapted for use in other bibliographic databases. Article abstracts and full texts were screened to identify relevant reports. The references of articles that met inclusion criteria were also reviewed to identify additional pertinent articles not captured in our initial search.

All criteria for inclusion and exclusion were determined in advance. Studies were included if they described combined surgical management and radiation of difficult keloids in pediatric patients. Studies describing management of keloids in adults were excluded. All basic science articles, abstracts, presentations, reviews, and commentaries were excluded. Studies in a foreign language or those that did not clearly delineate outcomes were also excluded. If an article only had a subset of patients in their entire study population that met our inclusion criteria, that subset, rather than the entire patient cohort, was extracted and included in this study for analysis. Finally, we noted a wide variability in available data among the included studies, which precluded us from performing an in-depth quantitative analysis of risk factors and outcomes.

Data Collection, Data Synthesis, and Quality Assessment

A data-charting form was developed by 2 authors (A.C.H and I. A.R.) to determine relevant variables to extract. Data collection sheets using Excel (Microsoft Corp, Redmond, WA) were utilized to extract variables for analysis, including author, publication year, country of origin, study design, number of patients with sex breakdown, age, surgical details, diagnosis, indications, treatment, outcome, recurrence, and follow-up time. The quality of evidence for each study was assessed using the Oxford Centre for Evidence-Based Medicine Levels of Evidence Scale.[18]

Institutional Study Population

A retrospective review was performed of all children and adolescents with keloids who underwent surgical excision followed by postoperative radiation from 2000 to 2024 at Children's Hospital of Philadelphia. Inclusion criteria were as follows: (1) clinical diagnosis of keloid confirmed by physical examination and/or histopathology and (2) at least 1 postoperative follow-up. Demographic data, clinical characteristics, operative details, and treatment outcomes were collected. Recurrence was defined as clinical evidence of regrowth, such as a palpable mass beyond scar borders or visible reappearance of the lesion. Outcomes were categorized as recurrence or nonrecurrence. Postoperative complications and treatment-related side effects were also recorded.

Statistical Analysis

All data were analyzed using SPSS software version 25 (IBM, Chicago, IL) or JASP (version 0.18.1, JASP Team, 2023) with significance set at $P < 0.05$. Descriptive statistics were performed for demographic variables. For subgroup analyses, chi-square test was performed for categorical variables and t test was performed for continuous variables. A significance level of 0.05 for 2-sided tests was used. Given the rarity of the condition of interest and subsequent limited sample size, any further subgroup analyses were not performed.

RESULTS

Article Search

The initial search identified 122 articles. Following title screening, there were 23 articles remaining. Abstracts were reviewed to identify studies that reported combined surgical treatment of keloids with surgical excision and radiation therapy in pediatric patients, yielding a total of 18 articles to be assessed for eligibility. Articles where adult and pediatric patients were combined and unable to be analyzed

© 2026 Wolters Kluwer Health, Inc. All rights reserved.

Copyright © 2026 Wolters Kluwer Health, Inc. All rights reserved.

separately were excluded. After full-text screening and application of exclusion criteria, a total of 5 articles were included for analysis (Fig. 1).[3,4,7,13,20]

A total of 6 sources were included in this systematic review: 5 previously published studies and 1 retrospective cohort from our institution. Collectively, the review encompasses 60 pediatric patients and 85 keloid lesions that underwent surgical excision followed by adjuvant radiation therapy. These studies varied in radiation modality, dosing, adjunctive treatments, and follow-up duration, limiting meta-analytic synthesis but allowing for narrative approach.

Study details such as year of publication, country of origin, study design, number of patients, and quality of evidence are presented in Table 1. All studies were either case reports (n = 1, 20.0%), case series (n = 2, 40.0%), or cohort studies (n = 2, 40.0%). There were no prospective studies or randomized controlled trials. Most studies were performed in the United States (n = 2, 40.0%) or Spain (n = 2, 40.0%).

Patient Demographics

Individual patient clinical characteristics are detailed in Table 2. Across all included patients, the mean age was 14.4 ± 3.5 years (Table 3). Of the 60 patients, 11 (18.3%) were male and 12 (20.0%) were female; sex was not reported in 37 patients (61.7%). Laterality was bilateral in 7 (11.7%), left-sided in 11 (18.3%), right-sided in 5 (8.3%), and not reported in 37 (61.7%). The most common keloid location was the earlobe (n = 23, 38.3%; Fig. 2), followed by the helix and retroauricular region (n = 4 each, 6.7%), with scattered involvement of the preauricular area, back, jaw, and sternum (n = 1 each, 1.7%; Fig. 3). The average lesion size was 5.1 ± 3.7 cm, and 44 patients (73.3%) had previously undergone at least 1 surgery prior to the index intervention.

Radiation Modality and Protocols

Radiation was delivered using either external beam techniques (n = 28 lesions, 46.7%) or brachytherapy (n = 32 lesions, 53.3%) (Table 4). The most frequently employed regimen was 12 Gy in 3 fractions (n = 28, 46.7%). Other common protocols included 20 Gy in 5 fractions (n = 7, 11.7%), 10–12.5 Gy in 2 fractions (n = 7, 11.7%), and 20 Gy in 3 fractions (n = 4, 6.7%). The average time from surgery to radiation initiation was 0.8 ± 0.6 days, consistent with evidence favoring early postoperative dosing.

Adjunctive Treatments

Adjunctive therapies were frequently utilized, with steroid injections in 13 patients (21.7%), compression therapy in 12 (20.0%), and 5-fluorouracil (5-FU) in 1 case (1.7%) (Table 4). Many patients received multiple adjuncts, particularly those treated at our institution. The concurrent use of steroids and compression therapy was common in protocols associated with low recurrence rates.

Outcomes and Recurrence Rates

Of the 85 treated keloids, 19 (22.4%) experienced recurrence during the follow-up period (Table 5). When specified, recurrence was defined as redevelopment of any clinically apparent keloid at the treated site, including visible regrowth or palpable mass documented on follow-up examination.[7,20] Institutional recurrence rate was notably lower, with only 3 of 18 lesions (16.7%) recurring, albeit a shorter follow-up time. Follow-up durations ranged from 1 to 120 months, with a mean of 32.3 ± 24.0 months. Recurrence rates were higher in cohorts lacking adjunctive therapy, but this was not statistically significant (25.4% vs 13.6%, $P > 0.05$).

Adverse Events and Safety

Adverse effects were minimal. Complications were reported in a subset of patients, with hyperpigmentation being the most common (n = 32, 53.3%), followed by transient pruritis (n = 9, 15.0%), hypertrophic scarring (n = 8, 11.7%), and hypopigmentation (n = 6, 10.0%) (Table 5). A Vancouver Scar Scale score of ≥5 was observed in 4 cases (6.7%). There were no reported cases of pain or erythema. Across all studies, no cases of radiation-induced malignancy or growth disturbances were reported within the available follow-up periods. Most radiation modalities used in pediatric patients, such as superficial X-rays or HDR brachytherapy, were selected to minimize systemic exposure, although long-term surveillance remains essential.

DISCUSSION

This systematic review and institutional case series supports the growing consensus that surgical excision followed by adjuvant radiation is a viable treatment strategy for pediatric keloids. Our pooled recurrence rate of 22.4% is markedly lower than the >70% recurrence commonly cited for excision alone, reinforcing the role of radiation in achieving local control. Although pediatric-specific concerns, especially regarding growth inhibition and long-term carcinogenic risk, have historically limited adoption, our findings align with emerging evidence that superficial and localized modalities such as HDR brachytherapy and low-energy X-ray therapy can potentially mitigate these risks when used judiciously.

Our single-center experience, involving 11 pediatric patients with 18 recurrent keloids, appears consistent with trends reported in the existing literature. We observed a recurrence rate of 16.7% over a mean follow-up of more than 12 months, with no long-term complications identified during that period. These preliminary findings suggest that postoperative radiation, when initiated within 24–48 hours after reexcision, may be both effective and well tolerated in select cases. All patients had previously failed other therapies, highlighting the potential utility of radiation in refractory disease. The radiation protocol used in our cohort, 20 Gy delivered in 3–5 fractions, was somewhat higher than the dosing regimens in some published reports (eg, 12–14 Gy), although this aligns with literature proposing a possible dose-response effect.[9] Additionally, radiation was delivered in conjunction with intraoperative corticosteroid injections, a combination that has been described to offer additive benefit, although this remains to be formally evaluated.[15]

TABLE 1. Summary of the 5 Studies That Met Inclusion Criteria

Study	Year	Country	Study Design	No. Patients	No. Keloids	Grade
Bradshaw et al[20]	2020	USA	Cohort	28	44	4
Khan et al[4]	2020	USA	Cohort	9	9	3
Proaño Landázuri et al[13]	2022	Spain	Case series	4	5	4
Sicre et al[3]	2024	Spain	Case report	1	1	4
Stahl et al[7]	2010	Israel	Case series	7	8	4

No., number; USA, United States of America.

© 2026 Wolters Kluwer Health, Inc. All rights reserved.

Copyright © 2026 Wolters Kluwer Health, Inc. All rights reserved.

TABLE 2. Individual Patient Characteristics

Patient No.	Sex	Age (Years)	Laterality	No. Keloids	Location	Largest Dimension (cm)	Prior Treatment	Treatment	Time to Radiation (Days)	Radiation Dose	Posttreatment	Sequelae	No. Recurrence	Follow-up (Months)
Institution														
1	F	16	BL	2	Earlobe	11	Surgical resection + triamcinolone	Resection + radiation	1	20 Gy/3 fractions	Triamcinolone, compression	Hyperpigmentation	0	3
2	F	9	R	1	Helix	8	Surgical resection + triamcinolone	Resection + radiation	0	20 Gy/3 fractions	Compression	None	0	6
3	F	9	L	1	Earlobe	2	Surgical resection + triamcinolone	Resection + radiation	0	20 Gy/5 fractions	Triamcinolone, compression	Hypertrophic scar	0	8
4	F	17	R	1	Earlobe	3.5	Surgical resection + triamcinolone	Resection + radiation	0	20 Gy/3 fractions	Compression	None	0	1
5	M	13	L	1	Earlobe	3	Surgical resection + triamcinolone	Resection + radiation	0	20 Gy/5 fractions	Triamcinolone, compression	Hypertrophic scar	0	8
6	F	15	L	1	Earlobe	7	Surgical resection + triamcinolone	Resection + radiation	2	20 Gy/3 fractions	Triamcinolone, compression	None	0	34
7	F	17	BL	4	Earlobe	3.5	Surgical resection + triamcinolone	Resection + radiation	0	20 Gy/5 fractions	Triamcinolone, compression	None	0	6
8	F	18	L	1	Earlobe	3.5	Surgical resection + triamcinolone	Resection + radiation	1	20 Gy/5 fractions	Triamcinolone, compression	None	0	9
9	F	19	BL	2	Helix	1.5	Surgical resection + triamcinolone	Resection + radiation	0	20 Gy/5 fractions	Triamcinolone, compression	None	0	15
10	M	19	BL	3	Back and Jaw	10	Surgical resection + triamcinolone	Resection + radiation	1	20 Gy/5 fractions	Triamcinolone, compression	Recurrence	3	37
11	F	20	BL	1	Sternum	7.5	Surgical resection + triamcinolone	Resection + radiation	1	20 Gy/5 fractions	Triamcinolone, compression	None	0	9
Proaño Landázuri et al[13]														
12	M	15	L	1	Retroauricular	NA	Surgical resection + verapamil	Resection + brachytherapy	NA	12 Gy/2 fractions	Triamcinolone ×1	Hypertrophic scar	0	21
13	M	9	L	1	Preauricular	NA	None	Resection + brachytherapy	NA	12 Gy/2 fractions	Triamcinolone ×3	Hypertrophic scar	0	12
14	M	17	BL	2	Retroauricular	NA	Triamcinolone, surgical resection, verapamil ×4	Resection + brachytherapy	NA	14 Gy/2 fractions	None	Hypertrophic scar	0	12
15	F	15	R	1	Retroauricular	NA	Surgical resection + verapamil, triamcinolone	Resection + brachytherapy	NA	12 Gy/2 fractions	Triamcinolone	Hypertrophic scar	0	18
Sicre et al[3]														
16	M	9	R	1	Retroauricular	13.5	Surgical resection ×2, triamcinolone injection	Resection + superficial radiotherapy	1	12 Gy/1 fraction	Triamcinolone, 5-FU injections, compression therapy	Hypertrophic scar	0	14
Stahl et al[7]														
17	M	16	L	1	Earlobe	NA	None	Resection + preoperative and postoperative radiotherapy	1	10–12.5 Gy/2 fractions (preoperation and postoperation)	NA	NA	0	NA
18	M	10	R	1	Earlobe	3.5	None	Resection + preoperative and postoperative radiotherapy	1	10–12.5 Gy/2 fractions (preoperation and postoperation)	NA	Recurrence	1	24
19	M	13	L	1	Earlobe	1.5	None	Resection + preoperative and postoperative radiotherapy	1	10–12.5 Gy/2 fractions (preoperation and postoperation)	NA	5 Vancouver Scar Scale	0	48
20	F	14	BL	2	Earlobe	1	None	Resection + preoperative and postoperative radiotherapy	1	10–12.5 Gy/2 fractions (preoperation and postoperation)	NA	6 Vancouver Scar Scale	0	36

© 2026 Wolters Kluwer Health, Inc. All rights reserved.
Copyright © 2026 Wolters Kluwer Health, Inc. All rights reserved.

21	M	13	L	1	Earlobe	1	None	Resection + preoperative and postoperative radiotherapy	1	10–12.5 Gy/2 fractions (preoperation and postoperation)	NA	10 Vancouver Scar Scale	0	84
22	M	12	L	1	Earlobe	5	Resection	Resection + preoperative and postoperative radiotherapy	1	10–12.5 Gy/2 fractions (preoperation and postoperation)	NA	Recurrence	1	60
23	F	17	L	1	Earlobe	NA	NA	Resection + preoperative and postoperative radiotherapy	1	10–12. 5 Gy/2 fractions (preoperation and postoperation)	NA	6 Vancouver Scar Scale	0	120
Kahn[4]														
All patients (9)	NA	NA	NA	9	Earlobe	NA	NA	Resection + radiation	NA	NA	NA	Recurrence	n = 4 (44%)	Mean, 70
Bradshaw et al[20]														
All patients (28)	NA	Median, 16.5 (5–25)	NA	44	Earlobe (50%) Pinna (11%) Neck (11%) Postauricular (7%) Face (7%) Chest (5%) Suprapubic (5%) Back (2%) Extremities (2%)	Mean, 5 (1–25)	Resection (90%), resection + adjuvant therapy (70%)	Resection + brachytherapy	1	12 Gy/3 fractions	NA	Hyperpigmentation (70%) Hypopigmentation (14%) Transient pruritus (20%)	n = 10 (23%)	Mean, 25 (3–37)

BL, bilateral; F, female; L, left; M, male; NA, not available; R, right

TABLE 3. Summary of Demographics

	n (%) or Mean ± SD
No. patients	60
No. keloids	85
Age (years)	14.4 ± 3.5
Sex	
M	11 (18.3)
F	12 (20.0)
NA	37 (61.7)
Laterality	
Right	5 (8.3)
Left	11 (18.3)
Bilateral	7 (11.7)
NA	37 (61.7)
Location	
Earlobe	23 (38.3)
Helix	4 (6.7)
Retroauricular	4 (6.7)
Preauricular	1 (1.7)
Back	1 (1.7)
Jaw	1 (1.7)
Sternum	1 (1.7)
NA	28 (46.7)
Average size (cm)	5.1 ± 3.7
Secondary surgery	44 (73.3)

F, female; M, male; NA, not available

Across all included studies, recurrence rates ranged from 0% to 44.0%, with our institutional data (16.7%) falling within this spectrum. This reinforces the conclusion that timely radiation postexcision plays an integral role in in reducing the high rates of keloid recurrence commonly observed with surgery alone, which can exceed 50% within 1 year. Although protocols varied, early administration of radiation, ideally within 24 hours postoperatively, was a common feature among successful treatment plans. This is likely due to targeting fibroblasts during the proliferative phase of wound healing.[9,14,21] This aligns with existing adult literature that emphasizes the importance of minimizing the interval between excision and radiation to target proliferative fibroblasts during the early phases of wound healing.[9] The use of intraoperative radiation therapy in adult patients, as described by Tresoldi et al,[8] exemplifies a strategic evolution in this regard. Intraoperative radiation therapy allows for immediate application of collimated electron beam therapy directly to the wound bed, achieving a recurrence rate below 10% and demonstrating statistically significant improvements in scar assessment scores across multiple validated instruments. Although this study focused on adults, the technique holds promise for select pediatric patients, particularly in tertiary centers with appropriate infrastructure.

Adjunctive treatments such as steroid injections, 5-FU, and compression therapy were commonly employed across studies and likely contributed to outcomes. Sicre et al[3] reported a 14-month recurrence-free outcome in a pediatric patient with a large retroauricular keloid after combining surgery, superficial radiotherapy, and multiple 5-FU/Triamcinolone Acetonide (TAC) injections. Evidence from in vitro studies supports a potentiated antifibrotic effect of these agents when combined by more effectively inhibiting keloid fibroblast proliferation and collagen synthesis than either agent alone.[22] In addition, compression garments and silicone sheeting were frequently used as part of postoperative care, although adherence and independent efficacy are difficult to quantify. Interestingly, Lawera et al[23] found that adjunctive therapies

© 2026 Wolters Kluwer Health, Inc. All rights reserved.

Copyright © 2026 Wolters Kluwer Health, Inc. All rights reserved.

FIGURE 2. An 8-year-old female with a refractory keloid of the right helical rim (preoperative, left; recurrence following prior excision, center). She underwent reexcision followed by immediate postoperative radiation therapy (20 Gy in 3 fractions). Six-month postoperative image (right) demonstrates durable contour restoration without clinical evidence of recurrence.

including steroids, radiation, cryotherapy, and pressure therapy did not significantly alter recurrence outcomes when combined with keloids treated with intralesional excision, which preserves a rim of keloid tissue to minimize trauma to adjacent skin. This raises important questions about which interventions provide additive benefit versus those that reflect institutional practice variation.

A major barrier to the widespread use of radiation in pediatric patients has been concern about long-term risks, particularly radiation-induced malignancy and effects on local growth. None of the studies in this review reported such complications within their follow-up periods (up to 120 months), and any adverse events were generally mild and self-limited. Superficial radiation techniques (eg, low-energy X-rays) and brachytherapy protocols tailored to low-penetration dosing were employed specifically to minimize systemic exposure. Nevertheless, these findings should be interpreted with caution. The relatively short follow-up durations (mean, 34 months) across studies, including ours, preclude definitive statements about long-term oncologic safety that can span decades, especially given the increased radiosensitivity of pediatric tissues.

The importance of this limitation is underscored by a recent case reported by Walker Wadsworth et al[24] who described the development of a high-grade pleomorphic sarcoma in the postauricular region of a young adult who had undergone 2 courses of postoperative radiation for a recurrent keloid during adolescence. Although this represents an isolated case, and causality cannot be definitively established, especially given the patient's possible environmental exposures during military deployment, the localization of the malignancy to the irradiated keloid bed raises serious concerns about cumulative dose and long-term surveillance. Similarly, Seo et al[25] reported a malignant peripheral nerve sheath tumor in a 35-year-old woman who presented with a rapidly enlarging, erosive 7 × 9-cm shoulder mass 11 years after postoperative radiotherapy (20 Gy), followed by a second course (25 Gy) for keloid recurrence. The lesion's rapid enlargement, erosive changes, and

FIGURE 3. An 18-year-old male with refractory bilateral mandibular keloids (preoperative, top right and left) underwent surgical excision followed by immediate postoperative radiation therapy (20 Gy in 5 fractions). One-year postoperative images (bottom right and left) demonstrate sustained resolution without clinical recurrence.

 © 2026 Wolters Kluwer Health, Inc. All rights reserved.

Copyright © 2026 Wolters Kluwer Health, Inc. All rights reserved.

TABLE 4. Summary of Clinical Details

	n (%) or Mean ± SD
No. patients	60
No. keloids	85
Time to radiation (days)	0.8 ± 0.6
Modality	
Radiation	28 (46.7)
Brachytherapy	32 (53.3)
Radiation dose	
20 Gy / 3 fractions	4 (6.7)
20 Gy / 5 fractions	7 (11.7)
14 Gy / 2 fractions	1 (1.7)
12 Gy / 1 fractions	1 (1.7)
12 Gy / 2 fractions	3 (5.0)
12 Gy / 3 fractions	28 (46.7)
10–12.5 Gy / 2 fractions	7 (11.7)
NA	9 (15.0)
Posttreatment	
Steroids	13 (21.7)
5-FU	1 (1.7)
Compression	12 (20.0)

5-FU, 5-fluorouracil; NA, not available

histologic confirmation of high-grade sarcoma suggest malignant transformation after cumulative radiation exposure, even when individual treatment courses fall within commonly accepted dose ranges. Although secondary sarcoma following keloid irradiation is rare, available data suggest that risk correlates with cumulative dose, peaking around 40 Gy before decreasing as higher doses cause extensive cellular destruction.[26,27]

Both cases underscore that recurrent keloids, particularly those treated repeatedly and without prior histologic evaluation, may harbor malignant potential. Routine pathological assessment of recurrent lesions, especially those with atypical features or prior radiotherapy, may facilitate earlier detection of malignant change. Furthermore, although the intermediate-term safety profile of adjuvant radiation appears acceptable, longitudinal surveillance beyond 10 years is essential, and its use in pediatric and adolescent patients should remain reserved for select high-risk cases. Decisions to pursue radiation must weigh recurrence history, lesion severity, patient age, and alternative treatment failures, ideally within the context of multidisciplinary discussion and informed consent emphasizing both known benefits and uncertain long-term risks.

TABLE 5. Summary of Outcomes

	n (%) or Mean ± SD
No. patients	60
No. keloids	85
Complications	
Hyperpigmentation	32 (53.3)
Transient pruritis	9 (15.0)
Hypertrophic scar	7 (11.7)
Hypopigmentation	6 (10.0)
Vancouver Scar Scale ≥ 5	4 (6.7)
Recurrence (% of no. keloids)	19 (22.4)
Follow-up (months)	32.3 ± 24.0

This updated synthesis reinforces the role of early postoperative radiation as an effective adjunct to surgical excision in pediatric patients with recurrent or treatment-resistant keloids. When integrated into a multimodal approach, adjuvant radiation can achieve durable responses with minimal observed toxicity. Our institutional experience aligns with published data in supporting its safety and efficacy in carefully selected patients. Ideal candidates may include those with large, symptomatic, or recurrent lesions; involvement of cosmetically or functionally critical areas (eg, earlobes, face, chest); or prior failure of conservative or monotherapy regimens. Moving forward, prospective, multicenter studies with standardized protocols are essential to establish definitive clinical guidelines.

This review is subject to several limitations. The current body of evidence is constrained by small sample sizes, with some reports based on single-case experiences, and a lack of randomized controlled trials or prospective studies with no included study meeting level I–III evidence. Second, reporting of key factors such as lesion size, location, Fitzpatrick skin type, and prior treatment history was inconsistent, limiting subgroup analyses that may have identified risk factors for recurrence. Furthermore, the heterogeneity of included studies is considerable, spanning radiation modalities, dosing regimens, adjunctive therapies, surgical techniques, follow-up intervals, and scar assessment methods. Whereas some studies used validated outcome tools such as the Vancouver Scar Scale, others relied solely on descriptive or photographic comparisons, limiting cross-study comparability. These limitations in study design and reporting precluded quantitative synthesis or meta-analysis and increased the potential for type II error in subgroup analyses. Additionally, our own institutional case series is limited by its retrospective nature, small cohort size, and follow-up time. Finally, although we conducted a comprehensive literature search, the possibility remains that some relevant studies were missed. Taken together, these factors underscore the need for cautious interpretation of findings and support the importance of future prospective, multicenter studies to standardize protocols, evaluate long-term safety, compare radiation modalities, assess cost-effectiveness, and incorporate patient-reported outcomes.

REFERENCES

1. Hirsch Y, Waterman CL, Haber R. Pediatric keloids and review of the efficacy of current treatment modalities. *Dermatol Surg*. 2023;49:669–674.
2. Park TH, Chang CH. Location of keloids and its treatment modality may influence the keloid recurrence in children. *J Craniofac Surg*. 2015;26:1355–1357.
3. Sicre JE, Ivars M, Heinz OH, et al. Use of postoperative radiotherapy and multiple adjuvant treatments after surgical removal of a giant retroauricular keloid in a pediatric patient. *Pediatr Dermatol*. 2025;42:677–680.
4. Khan FA, Drucker NA, Larson SD, et al. Pediatric earlobe keloids: outcomes and patterns of recurrence. *J Pediatr Surg*. 2020;55:461–464.
5. Tsai SL, Tsai YC, Weng YT, et al. Keloid excision with primary closure combined with superficial radiation therapy (SRT-100). *Ann Plast Surg*. 2025;94(3S, suppl 1): S18–S23.
6. Arneja JS, Singh GB, Dolynchuk KN, et al. Treatment of recurrent earlobe keloids with surgery and high-dose-rate brachytherapy. *Plast Reconstr Surg*. 2008;121: 95–99.
7. Stahl S, Barnea Y, Weiss J, et al. Treatment of earlobe keloids by extralesional excision combined with preoperative and postoperative "sandwich" radiotherapy. *Plast Reconstr Surg*. 2010;125:135–141.
8. Tresoldi MM, Ivaldi GB, Porcu P, et al. Immediate postoperative treatment of keloids with intraoperative radiation therapy technology: a pilot study. *Plast Reconstr Surg Glob Open*. 2021;9:e3738.
9. Wen P, Wang T, Zhou Y, et al. A retrospective study of hypofractionated radiotherapy for keloids in 100 cases. *Sci Rep*. 2021;11:3598.
10. van Leeuwen MC, Bulstra AE, Ket JC, et al. Intralesional cryotherapy for the treatment of keloid scars: evaluating effectiveness. *Plast Reconstr Surg Glob Open*. 2015;3:e437.
11. Zhou W, Li B, Yin Y, et al. Treatment outcomes of surgery followed by short-course every other day radiotherapy in keloid. *Radiat Oncol*. 2024;19:91.
12. Duan Q, Liu J, Luo Z, et al. Postoperative brachytherapy and electron beam irradiation for keloids: a single institution retrospective analysis. *Mol Clin Oncol*. 2015;3:550–554.

© 2026 Wolters Kluwer Health, Inc. All rights reserved.

Copyright © 2026 Wolters Kluwer Health, Inc. All rights reserved.

13. Proaño Landázuri S, Redondo Sedano J, Martí Carrera E, et al. Initial experience with brachytherapy treatment adjuvant to surgical resection of keloid scars in the pediatric population. *Cir Pediatr*. 2022;35:207–211.
14. Hoang D, Reznik R, Orgel M, et al. Surgical excision and adjuvant brachytherapy vs external beam radiation for the effective treatment of keloids: 10-year institutional retrospective analysis. *Aesthet Surg J*. 2017;37:212–225.
15. Ellis MM, Jones LR, Siddiqui F, et al. The efficacy of surgical excision plus adjuvant multimodal therapies in the treatment of keloids: a systematic review and meta-analysis. *Dermatol Surg*. 2020;46:1054–1059.
16. Ogawa R, Yoshitatsu S, Yoshida K, et al. Is radiation therapy for keloids acceptable? The risk of radiation-induced carcinogenesis. *Plast Reconstr Surg*. 2009; 124:1196–1201.
17. Laspro M, Onuh OC, Cohen RF, et al. The role of radiation therapy in adult and pediatric keloid management: a national survey of radiation oncologists. *Ann Plast Surg*. 2023;91:215–219.
18. Mankowski P, Kanevsky J, Tomlinson J, et al. Optimizing radiotherapy for keloids: a meta-analysis systematic review comparing recurrence rates between different radiation modalities. *Ann Plast Surg*. 2017;78:403–411.
19. Moher D, Shamseer L, Clarke M, et al. Preferred reporting items for systematic review and meta-analysis protocols (PRISMA-P) 2015 statement. *Syst Rev*. 2015;4:1.
20. Bradshaw B, Kumar KA, Derderian CA, et al. Adjuvant radiation therapy with immediate interstitial brachytherapy following surgical excision for pediatric keloid. *Int J Radiat Oncol Biol Phys*. 2020;108:e228.
21. Rödel F, Fournier C, Wiedemann J, et al. Basics of radiation biology when treating hyperproliferative benign diseases. *Front Immunol*. 2017;8:519.
22. Huang L, Cai YJ, Lung I, et al. A study of the combination of triamcinolone and 5-fluorouracil in modulating keloid fibroblasts in vitro. *J Plast Reconstr Aesthet Surg*. 2013;66:e251–e259.
23. Lawera NG, Madzia J, Casey LC, et al. Keloid intralesional excision reduces recurrence: a meta-analytic study of the available literature on 608 keloids. *Plast Reconstr Surg Glob Open*. 2024;12:e5652.
24. Walker Wadsworth E, Duckett KA, Patel KG. High-grade pleomorphic sarcoma in postauricular keloid scar after surgical excision and radiation. *Laryngoscope*. 2024;134:3143–3145.
25. Seo N, Nuri T, Asaka A, et al. Development of malignant peripheral nerve sheath tumor after keloid treatment. *Plast Reconstr Surg Glob Open*. 2025; 13:e6965.
26. Maddams J, Parkin DM, Darby SC. The cancer burden in the United Kingdom in 2007 due to radiotherapy. *Int J Cancer*. 2011;129:2885–2893.
27. Berrington de Gonzalez A, Kutsenko A, Rajaraman P. Sarcoma risk after radiation exposure. *Clin Sarcoma Res*. 2012;2:18.

 © 2026 Wolters Kluwer Health, Inc. All rights reserved.

Copyright © 2026 Wolters Kluwer Health, Inc. All rights reserved.