

Clinical Survival and Failure Patterns of Stainless Steel Crowns Under General Anesthesia in Pediatric Dentistry: A Systematic Review

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Abstract

Comprehensive dental rehabilitation under general anesthesia (GA) is often needed for young children with extensive caries, and failed restorations can mean repeat anesthesia. Stainless steel crowns (SSCs) are widely used for primary molars in this setting, but evidence on their survival and failure under GA is limited. This review evaluated SSC survival and failure patterns after placement under GA and the factors associated with failure.

The review followed Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) guidance; the protocol was not registered. PubMed/MEDLINE, ScienceDirect, Web of Science, the Cochrane Library, and Google Scholar were searched from inception to January 31, 2026. Eligible studies enrolled children aged 16 years or younger who received SSCs under GA and reported survival or failure outcomes. Two reviewers independently selected studies, extracted data, and appraised the risk of bias with the Newcastle-Ottawa Scale. Because outcome definitions, units of analysis, and follow-up differed, results were not pooled; each estimate is reported with its own definition, follow-up, and 95% confidence interval (CI). A post hoc sensitivity analysis excluded studies that did not fully meet the age or GA criteria.

Eight retrospective studies (2,797 children) were included. Seven reported SSC-level data, covering 7,256 SSCs placed under GA. Study-level survival or success ranged from 89.3% (5-year service time, Schüller) to 99.93% (12-month Kaplan-Meier estimate); examples are 97.2% (95% CI 96.6-97.7) at three years, 91.7% (89.5-93.5) free of retreatment at a second GA, and 89.7% (86.0-92.5) at two years. Reported failures included crown loss or debonding, open margins, recurrent caries, recementation, replacement, extraction, and perforation. SSCs had lower failure or retreatment rates than composite resins in four studies. Evidence against amalgam was inconsistent: Tate found significantly lower SSC failure, whereas Amin found no significant difference. Younger age and poor oral hygiene were associated with higher failure rates of dental procedures overall in one study, not SSC failure specifically. Pulpotomy did not significantly change two-year SSC survival ($p = 0.283$).

SSCs placed under GA generally show favorable survival and lower failure rates than composite resin in retrospective studies with up to seven years of follow-up. Heterogeneous definitions, substantial loss to follow-up, and mostly non-SSC-specific risk-factor data prevent a pooled estimate or firm claims of superiority. Prospective studies with standardized SSC-specific outcomes are needed.

Categories: Dentistry

Keywords: clinical pediatric dentistry, clinical survival, dental rehabilitation, general anesthesia, stainless steel crowns

Introduction And Background

Dental caries remains one of the most prevalent chronic diseases in childhood, often leading to extensive destruction of primary teeth that necessitates comprehensive restorative treatment [1]. In children who are behaviorally uncooperative, very young, or medically complex, conventional behavior management techniques may be insufficient, and dental rehabilitation under general anesthesia (GA) is frequently indicated to complete all necessary procedures safely in a single visit. The prevalence of early childhood caries and the associated treatment burden have led clinicians to prioritize durable restorative options in these high-risk populations because failed restorations can necessitate repeat anesthesia exposure, which carries additional medical and psychological risks for the child [2].

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Stainless steel crowns (SSCs) have long been widely used as full-coverage restorations for extensively decayed or structurally compromised primary molars due to their strength, ease of placement, and long-term clinical performance compared with intracoronal materials such as composite resins or amalgam [3]. In retrospective analyses of pediatric dental records, SSCs placed under GA demonstrated superior survival. For example, in a large cohort of children treated under GA for severe early childhood caries, primary molars restored with SSCs exhibited a survival probability of 98% at up to 84 months post-treatment, significantly outperforming other restorative modalities such as composites and sealants in the same setting [4]. Similarly, Patel et al. reported that only 8% of SSCs placed at an initial GA episode required retreatment at a subsequent GA session, whereas a much higher proportion of composite restorations eventually failed and were converted to SSCs on follow-up [5].

Although SSCs are widely used in pediatric restorative dentistry, the evidence specifically evaluating their clinical performance when placed during dental rehabilitation under GA remains limited and heterogeneous. Available studies are predominantly retrospective and differ in follow-up duration, definitions of survival and failure, and units of analysis [6]. Furthermore, evidence from routine pediatric dental care cannot necessarily be assumed to reflect outcomes in children undergoing comprehensive treatment under GA, who may differ in caries severity, treatment needs, behavioral characteristics, and healthcare requirements. Therefore, a focused synthesis of outcomes in the GA setting is warranted.

The present systematic review aimed to evaluate the clinical survival and failure patterns of SSCs placed under GA in pediatric patients and to identify patient- or treatment-related factors associated with restoration failure. By synthesizing the available evidence according to outcome definitions and follow-up periods, this review sought to clarify the reported performance of SSCs in this specific clinical setting and identify areas requiring further prospective research.

Review
Methods

Study Design

This systematic review was conducted in accordance with the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) guidelines. A protocol was developed prior to study initiation; however, it was not registered. The focused research question was formulated using the PICO (Population, Intervention, Comparison, and Outcome) framework (Table 1).

Table with 2 columns: Component, Description. Rows include Population (P), Intervention (I), Comparison (C), and Outcome (O).

TABLE 1: PICO framework of the research question

A comprehensive electronic literature search was performed in PubMed/MEDLINE, ScienceDirect, Web of Science, Cochrane Library, and Google Scholar from database inception to 31 January 2026. To ensure completeness of the evidence, the reference lists of all eligible studies were manually screened for additional relevant publications. The search strategy combined the following Medical Subject Headings (MeSH) and free-text terms: "stainless steel crowns", "preformed metal crowns", "preformed metallic crowns", "pediatric dentistry", "children", "infants", "preschool children", "primary teeth", "deciduous teeth", "primary molars", "early childhood caries", "general anesthesia", "general anaesthesia", "dental general anesthesia", "full-mouth rehabilitation", "dental rehabilitation", "oral rehabilitation", "comprehensive dental treatment", "crown survival", "clinical success", "crown failure". Boolean operators (AND and OR) were used to combine search terms appropriately according to the indexing requirements of each database. A detailed search strategy is included in the Appendices.

Eligibility Criteria

Studies were considered eligible for inclusion if they involved pediatric patients aged 16 years or younger who received SSCs under GA. Eligible study designs included randomized controlled trials, prospective or retrospective cohort studies, case-control studies, and observational studies. Included studies were required to report clinical outcomes related to survival rates, longevity, or failure patterns of SSCs. Only articles published in English were considered. Studies were excluded if they were case reports, case series including fewer than 10 participants, narrative reviews, in vitro or laboratory-based investigations, animal studies, or conference abstracts without available full texts. Additionally, studies that did not clearly specify that the SSCs were placed under GA were excluded.

Studies involving mixed populations or treatment settings were retained when the majority of the study population was consistent with the predefined eligibility criteria and the relevant outcomes could not be extracted separately for the eligible subgroup. Specifically, studies with an upper age limit exceeding 16 years or in which SSCs were not exclusively placed under GA were retained in the primary qualitative synthesis because subgroup-specific outcome data were unavailable. To assess the potential influence of these deviations on the findings, a post hoc sensitivity analysis was conducted after peer review, excluding studies with either of these characteristics.

Study Selection

All records retrieved from the electronic searches were exported into Zotero reference management software (Corporation for Digital Scholarship, Vienna, Virginia), where duplicate records, non-peer-reviewed records or links, posters, and conference abstracts were identified and removed. Two reviewers independently screened the titles and abstracts of all retrieved articles for potential eligibility. Full-text articles of potentially relevant studies were subsequently assessed independently according to the predefined inclusion and exclusion criteria. Any disagreements during the screening process were resolved through discussion, and when consensus could not be achieved, a third reviewer was consulted.

Data Extraction

Data extraction was independently performed by two reviewers using a standardized and pilot-tested data extraction form. Extracted information included the first author's name, year of publication, country of origin, study design, sample size, participant characteristics, number of SSCs evaluated, follow-up duration, clinical survival or success rates, reported failure patterns, comparative outcomes, and factors associated with restoration failure. Any discrepancies identified during data extraction were resolved through discussion until consensus was reached.

Outcome Measures

The primary outcome of interest was the clinical survival of SSCs placed under GA, defined as the restoration remaining functional throughout the follow-up period without requiring replacement or extraction. Secondary outcomes included restoration failure patterns such as loss of crown retention, crown perforation, recurrent caries, marginal defects, pulpal pathology, tooth extraction, and retreatment, as well as patient- or treatment-related factors associated with restoration failure.

Risk of Bias Assessment

The methodological quality of the included studies was independently assessed by two reviewers using the Newcastle-Ottawa Scale (NOS), as all eligible studies were observational in design. The NOS evaluates studies across three domains: selection of study participants, comparability of study groups, and assessment of outcomes. Studies scoring seven to nine stars were considered high quality, those scoring five to six stars were considered moderate quality, and studies scoring four stars or fewer were considered low quality. Any disagreements in quality assessment were resolved through discussion until consensus was achieved.

Data Synthesis and Analysis

A qualitative synthesis of the included studies was undertaken because quantitative meta-analysis was considered inappropriate due to clinical and methodological heterogeneity. Outcomes were recorded as reported in each study, including the unit of analysis (tooth, child, or retreatment at a subsequent GA session), the definition of clinical success or failure, and the follow-up duration. Where event counts were available, 95% confidence intervals (CIs) for proportions were calculated using the Wilson score method based on tooth-level counts, without adjustment for clustering of multiple teeth within individual children. When only percentages were reported, corresponding event counts were derived where feasible and identified as derived estimates. Kaplan-Meier survival estimates were reported as published, and no confidence intervals were imputed when these were not reported by the original studies. Estimates based on different outcome definitions, units of analysis, and follow-up periods were not pooled.

The cumulative number of SSCs was calculated using studies that reported an SSC-specific denominator

with extractable outcome data. Studies reporting outcomes only at the patient level, without a separately extractable SSC denominator, contributed to the qualitative synthesis and overall patient count but were excluded from the cumulative SSC total. Accordingly, a narrative synthesis was performed to summarize clinical survival, failure patterns, comparative findings, and factors associated with SSC failure under GA.

Results

A total of 616 records were identified through database searching from inception to January 2026. Before screening, 192 records were removed: 89 duplicates and 103 records that were not peer-reviewed full-text publications. The remaining 424 records were screened by title and abstract, and 384 were excluded. Of the 40 reports sought for retrieval, five could not be obtained, and 35 were assessed in full text. Following the exclusion of 27 studies (nine were not original studies and 18 did not report the studied outcomes), eight studies met the inclusion criteria and were included in this systematic review (Figure 1) [4-11].

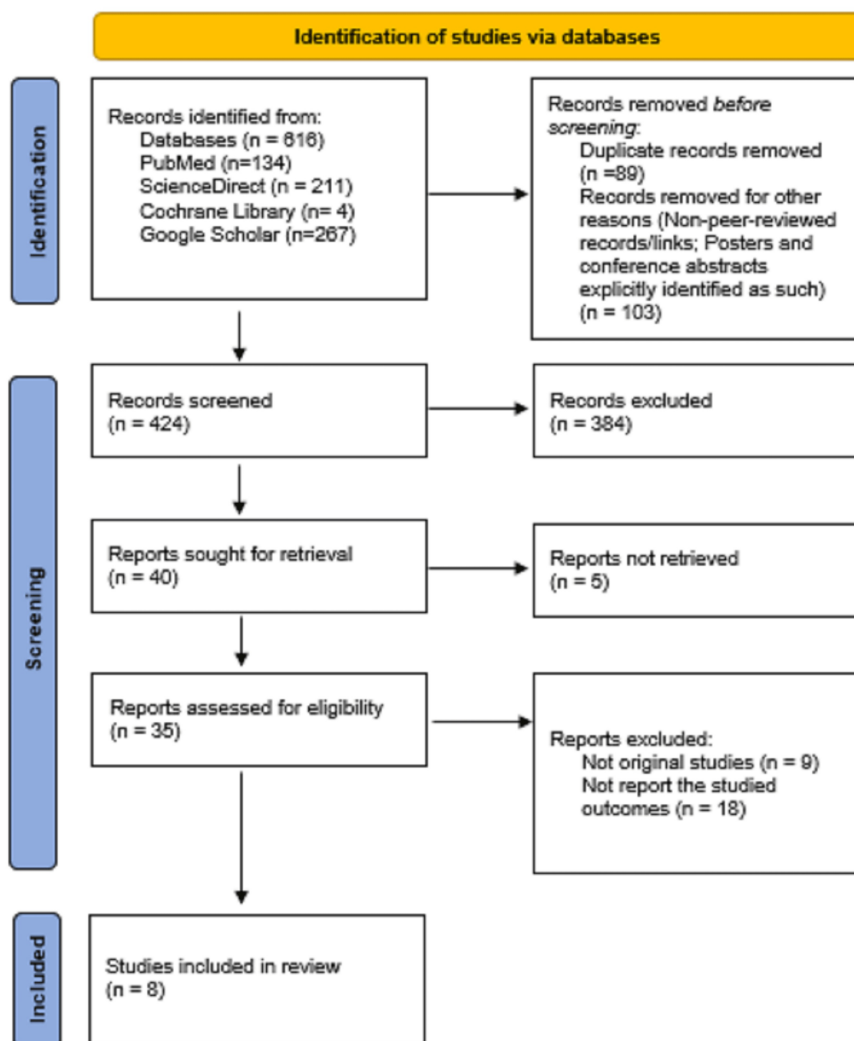


FIGURE 1: PRISMA flowchart showing the study selection process

PRISMA: Preferred Reporting Items for Systematic Reviews and Meta-Analyses.

The reasons for exclusion at the full-text stage included failure to specify that SSCs were placed under GA, case series with fewer than 10 participants, and studies that did not report clinical outcomes related to survival or failure patterns.

Risk-of-bias assessment

The methodological quality of the included studies was assessed using the NOS for observational studies. This is shown in Table 2.

Study	Selection (max 4)	Comparability (max 2)	Outcome (max 3)	Total /9	Overall assessment
Al-Eheideb & Herman (2003) [9]	★★★	★	★★	6/9	Moderate
Rao Tate et al. (2002) [7]	★★★	★	★★	6/9	Moderate
Schüler et al. (2014) [6]	★★★★	★	★★	7/9	High
AlMotawah et al. (2020) [10]	★★★★	★	★★	7/9	High
Patel et al. (2021) [5]	★★★★	★	★★	7/9	High
Elkhodary et al. (2022) [8]	★★★★	★★	★★	8/9	High
Amin et al. (2016) [11]	★★★★	★★	★★	8/9	High
Azadani et al. (2020) [4]	★★★★	★★	★★	8/9	High

TABLE 2: Newcastle-Ottawa scale assessment of included retrospective studies

The eight included studies demonstrated moderate to high methodological quality, with scores ranging from 6 to 8 out of a possible 9 stars. Common strengths across studies included the selection of representative cohorts, adequate sample sizes, and clear definitions of outcome measures. Common limitations included the retrospective design inherent to all studies, which introduces potential selection bias and reliance on the accuracy of medical and dental records. Loss to follow-up was a concern in several studies. In Tate et al. [7], only 241 of 504 reviewed records (48%) had follow-up of at least six months. Elkhodary et al. [8] included 221 of 634 treated children (35%) and reported 51% attrition as their main limitation, despite telephone recall and scheduled appointments. AlMotawah et al. [10] analyzed 131 of 372 screened records because 241 lacked two-year follow-up. Azadani et al. [4] analyzed 865 of 2,018 children; 967 (48%) never returned, and inclusion required a recall visit within 18 months. Amin et al. [11] included only children who completed three years of follow-up. Survival estimates are therefore conditional on returning for follow-up and may be biased in either direction. The lack of blinding of outcome assessors was a potential source of detection bias in most studies, although several attempted to standardize assessments through single-examiner protocols and calibration exercises. The heterogeneity in follow-up durations and definitions of failure across studies precluded meta-analysis but was appropriately addressed through qualitative synthesis in all included reports.

Study Characteristics

The eight included studies were published between 2002 and 2025, reflecting nearly two and a half decades of research on SSCs placed under GA. All studies employed retrospective designs, with three cohort studies, three chart or record reviews, one recall study, and one observational follow-up study. No randomized trials were found. No randomized controlled trials were identified that met the inclusion criteria, highlighting the predominance of observational evidence in this field.

The geographic distribution of the studies included four from the United States, two from Saudi Arabia, one from Canada, and one from Germany. Sample sizes ranged from 54 to 865 pediatric patients, with a total of 2,797 participants across all studies. Mean age at treatment, where reported, ranged from 3.2 to 5.2 years; Tate et al. [7] included participants up to 22.8 years (mean 4.25 years), and all other studies enrolled children aged 12 years or younger. Follow-up periods varied considerably, ranging from a minimum of six months to a maximum of 89 months, with most studies reporting outcomes at two years post-treatment.

SSC-level data were available for seven studies, covering 7,256 SSCs placed under GA. This total is 7,293 evaluated SSCs minus 37 of Schüler’s crowns that were placed under local anesthesia, with or without sedation, rather than GA. It excludes Elkhodary et al. [8], who reported only the mean number of SSCs per child. Their mean of 4.18 per child implies about 924 SSCs, but their own subgroup means (4.94 and 4.41) imply a different overall figure, so no crown total is stated for this study. Azadani et al. [4] evaluated primary second molars only. Without Tate et al. [7], the total is 6,394 SSCs. Detailed characteristics of each study are presented in Table 3.

Study	Design	Country	Children	Age	SSCs (GA)	Follow-up
Al-Eheideb and Herman (2003) [9]	Retrospective recall study	USA	54	Mean 4.5 y; 63% aged 3-5 y	111	6-27 mo (mean 16.5)
Tate et al. (2002) [7]	Retrospective record review	USA	241 of 504 reviewed	Mean 51 mo (17-274 mo)	862	At least 6 mo
Schüler et al. (2014) [6]	Retrospective observational follow-up	Germany	171	1.1-8.6 y	428 evaluated; 391 under GA	Service time 1, 3, or 5 y (different crowns)
AlMotawah et al. (2020) [10]	Retrospective cohort	Saudi Arabia	131	2-8 y	340	2 y
Patel et al. (2021) [5]	Retrospective chart review	USA	296	0-6 y at first GA (mean 3.4)	747	Mean 2.0 y to second GA
Elkhodary et al. (2022) [8]	Retrospective cohort	Saudi Arabia	221 of 634 treated	2-12 y (mean 4.92)	Not reported [†]	2 y
Amin et al. (2016) [11]	Retrospective cohort	Canada	818	19-71 mo (mean 46.2)	3,198	3 y
Azadani et al. (2020) [4]	Retrospective chart review	USA	865	24-48 mo	1,607 (second molars)	6-89 mo

TABLE 3: General characteristics of included studies

[†]The number of SSCs evaluated was not reported separately by Elkhodary et al.; therefore, this study was not included in the total SSC-specific denominator. In Schüler et al., 91.6% of SSCs were placed under general anesthesia, while the remaining crowns were placed without GA.

SSC, stainless steel crown; GA, general anesthesia; ECC, early childhood caries; SHCN, special healthcare needs.

Survival Rates of SSCs

Study-level survival or success ranged from 89.3% to 99.93%, but definitions, units of analysis, and follow-up differ, so no single range or pooled figure is reported. Table 4 gives each estimate with its own definition.

Study	Unit and definition of failure	Follow-up	Failures / n	Survival or success (95% CI)
Al-Eheideb and Herman (2003) [9]	SSCs; open margin, perforated or missing crown, tooth lost to pathology, or recurrent caries.	Mean 16.5 mo (6–27)	5 / 111	95.5% (89.9–98.1)
Tate et al. (2002) [7]	SSCs; replacement for structural breakdown, pulpal or dentoalveolar infection, or recurrent decay.	At least 6 mo; mean not reported	About 69 / 862 (derived from 8%)	92.0% (90.0–93.6), derived
Schüler et al. (2014) [6]	SSCs; crown loss, perforation, or pathological tooth mobility. Different crowns examined at each service time.	1 y (n = 215)	3 / 215	98.6% (96.0–99.5)
		3 y (n = 157)	3 / 157	98.1% (94.5–99.3)
		5 y (n = 56)	6 / 56	89.3% (78.5–95.0)
		All service times	12 / 428	97.2% (95.2–98.4)
AlMotawah et al. (2020) [10]	Teeth; clinical failure (n = 29) or clinical plus radiographic failure (n = 6), mostly crown debonding.	2 y, children with complete 2-year recall	35 / 340	89.7% (86.0–92.5)
Patel et al. (2021) [5]	Teeth; any retreatment (new SSC or extraction) at a second GA, in children who had repeat GA.	Mean 2.0 y	62 / 747	91.7% (89.5–93.5)
Amin et al. (2016) [11]	Teeth; any new treatment after the 1-month visit, including recementation.	3 y, children completing follow-up	89 / 3,198	97.2% (96.6–97.7)
Azadani et al. (2020) [4]	Primary second molars; new treatment planned for SSC loss or damage, restoration failure, or new or recurrent caries; Kaplan-Meier analysis.	12 mo	Not reported	99.93%
		24 / 36 / 48 mo	Not reported	99.61% / 99.11% / 98.78%
		60 / 72 / 84 mo	Not reported	98.27% / 98.01% / 98.01% (CI not reported)
Elkhodary et al. (2022) [8]	Not estimable: failures reported as per-child means without an SSC denominator.	2 y	Not reported	Not reported

TABLE 4: Survival or success of stainless steel crowns (SSCs) placed under general anesthesia, by study, with each study's own outcome definition, follow-up and 95% confidence interval

Survival or success is the proportion of SSCs (or teeth, where stated) without failure, as defined by each study. Definitions, units of analysis, and follow-up differ between studies, so estimates are not directly comparable and were not pooled. The 95% CIs are Wilson score intervals calculated from reported tooth-level counts; they do not account for clustering of teeth within children and may therefore underestimate uncertainty. The Tate et al. figures are derived from the reported 8% failure rate (about 69 of 862 SSCs). Schüler et al. examined different crowns at each service time (one, three, and five years), so these are not repeated measures. AlMotawah et al. counted clinical and clinical-plus-radiographic failures. Patel et al. counted retreatment only in children who returned for a second GA. Amin et al. counted any new treatment after the one-month visit, including recementation. Azadani et al. (primary second molars only) reported Kaplan-Meier estimates as published, without CIs. An SSC-specific survival estimate could not be calculated from Elkhodary et al. because failures were reported as per-child means without an SSC denominator.

GA, general anesthesia; CI, confidence interval; SSC, stainless steel crown.

The survival and success rates of SSCs placed under GA were generally high across the included studies, although reported estimates varied according to the outcome definition and follow-up duration. Al-Eheideb and Herman [9] reported a 95.5% success rate (106/111; 95% CI 89.9–98.1) for SSCs over a mean follow-up of 16.5 months (range 6–27), with failure defined as an open margin, a perforated or missing crown, loss of the tooth to pathology, or recurrent caries. Tate et al. [7] reported a lower SSC failure rate of 8% among 862 crowns (92% success; derived 95% CI 90.0–93.6) over a minimum follow-up of six months, significantly outperforming amalgam (79% success), composite resins (70% success), and composite strip crowns (49% success).

Patel et al. [5] examined retreatment at a second dental rehabilitation under GA. They found that 91.7% of SSCs (685/747; 95% CI 89.5-93.5) placed at the first GA encounter did not require retreatment at the second encounter, at a mean interval of 2.0 years. Only 8.3% of crowns required intervention, with 2.0% needing replacement with a new crown and 6.3% requiring extraction [5]; this applies only to children who returned for a second GA.

Schüler et al. [6] evaluated SSCs that had been in service for one, three, and five years in a high caries-risk population, examining different crowns at each service time. The overall success rate was 97.2% (416/428; 95% CI 95.2-98.4), with success rates of 98.6% at one year, 98.1% at three years, and 89.3% at five years. Notably, 91.6% of the crowns in this study were placed under GA [6].

Amin et al. [11] reported a 97.2% SSC success rate (3,109/3,198 crowns; 95% CI 96.6-97.7) over three years. Azadani et al. [4], who studied primary second molars, reported a Kaplan-Meier SSC survival probability of 98.0% at 84 months, with estimates of 99.93% at 12 months, 99.61% at 24 months, 99.11% at 36 months, 98.78% at 48 months, 98.27% at 60 months, and 98.01% at 72 and 84 months; no confidence intervals were reported. These estimates were derived using different outcome definitions and analytical approaches and were therefore not pooled.

AlMotawah et al. [10] examined whether pulp therapy influenced the survival of SSCs placed for moderate proximal caries. The overall success rate was 89.7% (305/340; 95% CI 86.0-92.5) at two years. The mean survival time within the 24-month window was 22.68 months for crowns placed without pulpotomy, compared with 22.91 months for crowns placed with pulpotomy, a difference that was not statistically significant ($p = 0.283$) [10].

Failure Patterns of SSCs

The failure patterns of SSCs varied across studies, with the most commonly reported failures including loss of retention, open margins, recurrent caries, and the need for extraction. Elkhodary et al. [8] provided the most detailed analysis of failure types, reporting that recurrent decay was the most common failure detected at the two-year follow-up (mean 2.68 per child), followed by SSC open margins (mean 0.69 per child). Dislodged restorations and loose crowns were reported less frequently [8].

Schüler et al. [6] reported a clinical failure rate of 2.8%, with specific failures including loss of the crown (1.9%), pathological tooth mobility (0.7%), and crown perforation (0.2%). Importantly, this study did not detect any cases of secondary caries beneath the SSCs, even in cases where marginal adaptation was not fully sealed [6].

Patel et al. [5] found that when SSCs did fail, extraction (6.3%) was more than three times as common as recementation or replacement with a new crown (2.0%). Amin et al. [11] reported 89 SSC failures among 3,198 crowns; 36.0% were recemented, 20.2% were replaced, and 43.8% were extracted. Azadani et al. [4] defined failure events as SSC loss or damage, restoration failure, or new/recurrent caries.

Al-Eheideb and Herman [9] reported that for anterior teeth restored with strip crowns under GA, the failure rate was 30%, comparable to the 29% failure rate for Class III, IV, and V composite resin restorations. This highlights a distinct difference in outcomes between posterior SSCs and anterior aesthetic restorations in the GA setting.

Factors Associated With Failure

Several patient-level and treatment-level factors were identified as being associated with SSC failure. Age at the time of treatment emerged as a significant factor in multiple studies. Elkhodary et al. [8] found a statistically significant negative correlation between age and failure rates ($r = -0.202$, $p < 0.01$), indicating that younger children at the time of treatment under GA experienced higher overall failure rates of dental procedures, including SSCs. Children younger than six years had significantly higher rates of recurrent decay ($p = 0.003$) and required more extractions of teeth previously treated under GA ($p = 0.039$) compared to older children.

Patel et al. [5] similarly observed that children younger than the mean age of 3.4 years at the first GA were more likely to require retreatment of molars initially restored with composite resins, although overall treatment outcomes between younger and older children were not significantly different for SSCs specifically ($p = 0.582$).

Oral hygiene status at follow-up was strongly associated with failure rates. Elkhodary et al. [8] reported that children with poor oral hygiene at the two-year follow-up had the highest mean number of failed procedures (8.28, SD 3.38), which was significantly higher than that of children with fair (6.53, SD 3.07) or good oral hygiene (3.56, SD 2.01) ($p < 0.001$). Conversely, children with good oral hygiene had the highest number of successful procedures ($p = 0.032$) [8].

Schüler et al. [6] conducted a comprehensive analysis of factors associated with gingival bleeding around SSCs, which can be considered a proxy for periodontal health and potentially a precursor to failure. Gingival bleeding was observed in 72.1% of SSCs at follow-up. Binary logistic regression revealed that the presence of plaque on the crown was significantly associated with gingival bleeding (OR 0.29, 95% CI: 0.18–0.47), while each unit increase in baseline dmft (decayed, missing, filled teeth) increased the odds of gingivitis by approximately 10% (OR 1.108, 95% CI: 1.03–1.19). Notably, clinical factors related to crown quality, such as marginal adaptation, extension, and proximal contacts, did not significantly influence the occurrence of gingival bleeding.

Operator experience and the setting of treatment were consistent across most studies, with SSCs placed by pediatric dental residents or specialists under the supervision of attending faculty. Al-Eheideb and Herman [9] specifically evaluated outcomes of procedures performed by postgraduate students, finding that SSC success rates remained high (95.5%) despite the training setting. Rao Tate et al. [7] similarly reported outcomes from resident-provided care at two academic institutions. Detailed outcomes and results of the included studies are shown in Table 5.

Author (year)	Primary outcome (SSC survival/success)	Key failure patterns for SSCs	Comparative findings	Factors associated with failure
Al-Eheideb and Herman (2003) [9]	95.5% success (106/111; 95% CI 89.9–98.1) over a mean follow-up of 16.5 months (range 6–27)	Failure defined as open margin, perforated or missing crown, tooth lost to pathology, or recurrent caries. SSC-specific failure types not reported	SSC failure 4.5% vs 50% for Class II amalgam or composite (8 teeth; no statistical test reported)	No factors analyzed for SSCs
AlMotawah et al. (2020) [10]	89.7% success (305/340; 95% CI 86.0–92.5) at 2 years. Restricted mean survival 22.68 months without pulpotomy vs 22.91 months with pulpotomy ($p = 0.283$)	29 clinical failures and 6 clinical plus radiographic failures (35/340). Clinical failures: 17 without pulpotomy vs 12 with; most failures were debonding. Difference not significant ($p = 0.499$)	SSC alone vs pulpotomy plus SSC: no significant difference in survival	Neither pulpotomy ($p = 0.675$) nor tooth type, first vs second molar ($p = 0.982$), predicted failure
Elkhodary et al. (2022) [8]	SSC failure rate not estimable: failures reported as per-child means without an SSC denominator. 211 of 221 children (95.5%) received at least one SSC (mean 4.18 per child)	SSC open margin (mean 0.69 per child) was the most common SSC failure, followed by lost SSC (0.14) and loose SSC (0.05). Recurrent decay (2.68 per child) was the most common failure overall	No comparator	Younger age ($r = -0.202$, $p < 0.01$) and poor oral hygiene ($p < 0.001$) were associated with more failed procedures overall, not SSC failures specifically
Patel et al. (2021) [5]	91.7% (685/747; 95% CI 89.5–93.5) needed no retreatment at the second GA, at a mean of 2.0 years; 8.3% were retreated	Of the 8.3% retreated: 2.0% needed a new SSC and 6.3% extraction; 23 extractions were in pulpotomized teeth (3.2% excluding them)	Lower retreatment than composite: OR for composite vs SSC 4.45 (one-surface) and 4.46 (two-surface); overall 4.48 (95% CI 3.36–5.97), $p < 0.001$	Restoration material was the factor assessed. For retreated SSCs, extraction was more common than replacement. Counts only children who had a second GA
Tate et al. (2002) [7]	8% failure (92% success; about 69/862, derived 95% CI 90.0–93.6) at a minimum follow-up of 6 months	Failure defined as replacement for structural breakdown, pulpal or dentoalveolar infection, or recurrent decay. SSC-specific failure types not reported	Significantly lower failure than amalgam (21%), composite (30%), and composite strip crowns (51%), each $p < 0.001$	Failure appeared related to follow-up length. Sample included participants up to 22.8 years
Schüler et al. (2014) [6]	97.2% overall (416/428; 95% CI 95.2–98.4). Different crowns examined at 1, 3, and 5 years: 98.6%, 98.1%, and 89.3%. 91.6% of crowns placed under GA	Loss of SSC 8 (1.9%), pathological tooth mobility 3 (0.7%), perforation 1 (0.2%). No secondary caries	No comparator. Success did not differ by pulp treatment ($p = 0.741$) or extent of caries ($p = 0.794$)	Gingival bleeding (72.1%): plaque-free crowns had lower odds (OR 0.29, 95% CI 0.18–0.47); higher baseline dmft raised the odds (OR 1.108). Marginal defects were not associated
		89 failures: 36.0% recemented,	Significantly higher survival than Class II composite (HR 4.76, 3.45–6.63) and	No significant difference in

Amin et al. (2016) [11]	97.2% success (3,109/3,198; 95% CI 96.6–97.7) over 3 years	20.2% replaced, and 43.8% extracted; some extractions may reflect failed pulp therapy	multisurface composite (HR 3.95, 2.28–6.80). No significant difference vs amalgam (p = 0.136 and 0.121)	SSC success by arch (p = 0.082) or first vs second primary molar (p = 0.359)
Azadani et al. (2020) [4]	Kaplan-Meier survival: 98.0% at 84 months (primary second molars). 99.93% at 12, 99.61% at 24, 99.11% at 36, 98.78% at 48, 98.27% at 60, and 98.01% at 72 and 84 months; no CIs reported	Events were SSC loss or damage, restoration failure, and new or recurrent caries	Hazard of new treatment vs SSC: sealant 51.9 (27.9–96.5), composite 78.4 (41.3–148.8), not erupted 143.7, fluoride 111.2; all p < 0.0001	The model accounted for clustering of teeth within children and adjusted for age, sex, language, and number of teeth; restoration type was the main determinant

TABLE 5: Outcome data and results related to stainless steel crowns

SSC: stainless steel crown; GA1: first dental rehabilitation under general anesthesia; GA2: second dental rehabilitation under general anesthesia; OR: odds ratio; SHCN: special health care needs; CR: composite resin; dmft: decayed, missing, and filled teeth.

Sensitivity analysis

Removing Tate et al. [7] (age beyond 16 years) and Schüler et al. [6] (crowns placed without GA) left study-level estimates between 89.7% (AlMotawah et al. [10], two years) and 99.93% (Azadani et al. [4], 12 months). Findings against composite resin were unchanged, since Patel et al. [5], Amin et al. [11], and Azadani et al. [4] remained. Evidence that SSCs fail less than amalgam depended on Tate et al. [7]; Amin et al. [11] found no significant difference, and Al-Eheideb and Herman [9] did not statistically test the comparison. This claim is therefore not supported without Tate et al. [7].

Discussion

This systematic review synthesized available clinical evidence on the survival and failure patterns of SSCs placed in pediatric patients under GA. Overall, SSCs demonstrated consistently high survival rates and low overall failure rates across diverse clinical settings, reinforcing their role as a durable restorative option for primary molars in high-risk pediatric populations. Across eight retrospective studies, SSCs placed under GA showed favorable survival, with study-level estimates between 89.3% and 99.93%, depending on how failure was defined and how long children were followed. The spread should not be read as a typical range. The lowest values came from definitions that count any retreatment or debonding (AlMotawah et al. 89.7% at two years [10], Patel et al. 91.7% at a second GA [5]) or from five-year service time (Schüler et al. 89.3% [6]), while Amin et al. reported 97.2% at three years [11] and Azadani et al. 98.0% at 84 months [4].

The favorable outcomes for SSCs observed in this review align with broader pediatric dentistry literature. Analyses conducted in general clinical environments, outside the GA context, report markedly higher longevity for SSCs compared with multisurface composite restorations, with failure rates for SSCs significantly lower than those for resin-based restorations over three years (1.5% vs. 21%, respectively) and a substantially greater cumulative survival probability [12]. Importantly, similar superiority was demonstrated within the GA setting in the included studies, where four studies found lower failure or retreatment rates for SSCs than for composite resin, and Al-Eheideb and Herman [9] reported a similar direction in a very small sample without testing it. The evidence against amalgam is inconsistent: Tate et al. [7] found significantly lower SSC failure, whereas Amin et al. [11] found no significant difference, and Patel et al. [5] and Azadani et al. [4] did not study amalgam. Full coronal coverage may explain the advantage over adhesive restorations because Schüler et al. [6] found no secondary caries beneath crowns even when margins were open, but this mechanism was not tested. These findings underscore a long-recognized advantage of full-coverage restorations in sealing caries-affected teeth against recurrent decay, a principle that translates well into GA settings where extensive treatment is undertaken in a single sitting.

Retrospective surveys of pediatric dental rehabilitation under GA have also documented lower restorative failure rates for SSCs relative to intracoronal materials. For example, Patel et al. [5] observed that 91.7% of SSCs placed at the first GA session did not require retreatment at a second GA, whereas composite restorations demonstrated significantly higher retreatment odds. Similarly, Tate et al. [7] reported only a 3% failure rate for SSCs compared with substantially higher failure rates for amalgam and composite restorations. Clinical data also indicate that SSCs exhibit one of the lowest failure rates among restorative modalities following comprehensive ECC treatment, with composite restorations tending to fail more frequently within the first year post-treatment [13]. The protective effect of SSCs in high-caries-risk environments may be attributable to their full-coronal coverage, which reduces the risk of microleakage and secondary caries, a common cause of failure in restorations that rely on adhesive bonds alone. This mechanism is supported by Schüler et al. [6], who reported no cases of secondary caries beneath SSCs over

follow-up periods of up to five years, even when marginal discrepancies were present.

The included studies also provide important insight into failure patterns. Crown loss or debonding, open margins, and recurrent caries were the most commonly reported failures. Extraction accounted for 6.3% of SSCs in Patel et al. [5] and 43.8% of failures in Amin et al. [11], but both groups noted that failed pulp therapy may explain part of this. After removing extractions linked to pulpotomy, the extraction rate in Patel et al. [5] fell to 3.2%. The data therefore do not show whether failures start in the crown or in the underlying tooth, and the earlier statement that biological factors outweigh technical ones is not supported.

Patient-level determinants were consistently associated with outcomes across studies. Younger age and poor oral hygiene were associated with more failed procedures in the study by Elkhodary et al. [8], but these counts covered all procedures and not SSCs alone; Patel et al. [5] found no age difference in overall retreatment. Plaque-free crowns had lower odds of gingival bleeding in Schüller et al. [6], while crown quality did not matter. Pulpotomy did not significantly change two-year survival in AlMotawah et al. [10]. These findings are associations from single studies and do not establish risk factors for SSC failure.

These findings are complemented by broader systematic analyses of pediatric crown longevity, which consistently rank SSCs among the most reliable materials for primary teeth. Long-term retention rates for SSCs exceed 95% in multiple review contexts, outperforming many other materials, and they demonstrate acceptable success even when used on permanent molars in older pediatric cohorts [14]. Although esthetic alternatives like zirconia crowns are gaining popularity due to parental preferences and improved gingival outcomes, clinicians must balance these benefits against higher technical demands and increased cost, especially in settings where longevity and minimization of repeat anesthesia are priorities [15].

Importantly, the evidence examined in this review also suggests that failure patterns for SSCs under GA are multifactorial. Mechanical failures, such as loss of retention or marginal discrepancies, are less common than biological failures, such as recurrent caries or gingival inflammation, particularly when oral hygiene is suboptimal. This distribution of failure causes highlights the need for comprehensive postoperative care and preventive strategies to maximize restoration survival.

Several limitations should be considered when interpreting the findings of this systematic review. First, all eight included studies were retrospective observational studies, with no randomized controlled trials meeting the eligibility criteria. This limits causal inference and introduces the possibility of selection, information, and attrition bias. Several studies also relied on retrospective dental records, and follow-up completeness varied between cohorts. Second, substantial methodological and clinical heterogeneity was present across the included studies. Definitions of survival and failure differed, follow-up periods ranged from six months to five years, and outcomes were reported at different analytical levels, including per tooth, per child, and retreatment at a subsequent GA session. Consequently, survival estimates from individual studies were not directly comparable, and a meta-analysis was not considered appropriate. Third, SSC-specific outcome reporting was inconsistent. In particular, Elkhodary et al. [8] reported failures at the level of dental procedures rather than providing a separate SSC denominator, limiting the ability to calculate an SSC-specific survival estimate. Similarly, some studies reported overall treatment outcomes or retreatment rather than conventional SSC survival. These differences required cautious interpretation of reported failure rates and associated factors. Fourth, some included populations and treatment characteristics differed from the predefined pediatric population. Tate et al. [7] included participants up to 22.8 years of age, although the cohort was predominantly composed of young children, while Schüller et al. [6] reported that 91.6% of crowns were placed under GA rather than providing outcomes exclusively for the GA subgroup. Similarly, time points reported by Schüller et al. [6] come from different crowns; Patel et al. [5] counted only children who had a second GA; and Azadani et al. [4] covered second molars only. These features may limit the direct generalizability of their findings to the target population. Finally, the review was restricted to English-language publications and searches conducted through January 2026, which may have introduced language and publication bias and may not capture subsequently published evidence. The relatively small number of eligible studies and variation in reporting also limited assessment of potential predictors of SSC-specific failure and prevented meaningful subgroup or sensitivity analyses. Future prospective studies using standardized definitions, SSC-specific denominators, consistent follow-up intervals, and clearly defined failure outcomes are needed to provide more comparable and robust evidence.

Conclusions

This systematic review found that SSCs placed under GA generally demonstrated favorable clinical survival and low failure rates in pediatric patients. In eight retrospective studies, SSCs placed under GA generally showed favorable survival, with study-level estimates ranging from 89.3% to 99.93%, depending on the definition, unit of analysis, and follow-up. SSCs had lower failure or retreatment rates than composite resin in four studies, whereas evidence against amalgam was inconsistent and depended on a single study that included participants older than 16 years. Reported failures included crown loss, open margins, recurrent caries, recementation, replacement, extraction, and perforation. Associations with younger age and poor oral hygiene came from one study of all procedures and are not SSC-specific; pulpotomy did not significantly change two-year survival. Substantial loss to follow-up and heterogeneous definitions prevent a pooled estimate and do not establish superiority in all circumstances. Prospective studies with

standardized definitions, SSC-specific denominators, fixed follow-up intervals, and cluster-adjusted analysis are needed.

Appendices

Database	Controlled vocabulary / indexed terms	Free-text keywords
PubMed/MEDLINE	"Crowns"[MeSH Terms] OR "Stainless Steel"[MeSH Terms] OR "Tooth, Deciduous"[MeSH Terms] OR "Child"[MeSH Terms] OR "Child, Preschool"[MeSH Terms] OR "Anesthesia, General"[MeSH Terms] OR "Treatment Outcome" [MeSH Terms]	"stainless steel crown*" OR "preformed metal crown*" OR "preformed metallic crown*" OR "pediatric dentistry" OR children OR child* OR infant* OR "preschool child*" OR "primary teeth" OR "deciduous teeth" OR "primary molar*" OR "early childhood caries" OR "general anesthesia" OR "general anaesthesia" OR "dental general anesthesia" OR "full-mouth rehabilitation" OR "dental rehabilitation" OR "oral rehabilitation" OR "comprehensive dental treatment" OR "crown survival" OR "clinical success" OR "crown failure"
ScienceDirect	Not applicable; keyword searching used	"stainless steel crown*" OR "preformed metal crown*" OR "preformed metallic crown*" OR "primary molar*" OR "deciduous teeth" OR "primary teeth" AND "general anesthesia" OR "general anaesthesia" OR "dental rehabilitation" OR "full-mouth rehabilitation" AND survival OR success OR failure OR retreatment
Web of Science	Not applicable; Topic (TS) searching used	TS=("stainless steel crown*" OR "preformed metal crown*" OR "preformed metallic crown*") AND TS=(child* OR pediatric OR paediatric OR infant* OR "preschool child*" OR "primary teeth" OR "primary molar*" OR "deciduous teeth") AND TS=("general anesthesia" OR "general anaesthesia" OR "dental rehabilitation" OR "full-mouth rehabilitation" OR "oral rehabilitation") AND TS= ("crown survival" OR "clinical success" OR "crown failure" OR retreatment OR longevity)
Cochrane Library	MeSH terms where available	"stainless steel crown*" OR "preformed metal crown*" OR "preformed metallic crown*" OR "primary molar*" OR "deciduous teeth" OR "primary teeth" OR "early childhood caries" OR "general anesthesia" OR "general anaesthesia" OR "dental rehabilitation" OR "full-mouth rehabilitation" OR "crown survival" OR "clinical success" OR "crown failure"
Google Scholar	Not applicable; free-text search	"stainless steel crowns" "general anesthesia" children; "stainless steel crowns" "dental rehabilitation" pediatric; "preformed metal crowns" "general anesthesia" children; "stainless steel crowns" survival failure pediatric

TABLE 6: Database-specific search strategies, including controlled vocabulary and free-text keywords used to identify studies on the clinical survival and failure patterns of stainless steel crowns placed under general anesthesia in pediatric patients

Additional Information

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All authors have reviewed the final version to be published and agreed to be accountable for all aspects of the work.

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