Review

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Dental Implant Outcomes in Patients with Cleft Lip, Alveolus and/or Palate: A Systematic Analysis of Clinical Studies

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Keywords: cleft lip; cleft palate; cleft alveolus; orofacial cleft; dental implants; osseointegration

Review

Dental Implant Outcomes in Patients with Cleft Lip, Alveolus and/or Palate: A Systematic Analysis of Clinical Studies

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Abstract

Background and Objectives: Place . Dental implant placement in grafted alveolar cleft sites has become an integral component of comprehensive cleft rehabilitation. However, survival outcomes vary across studies, and temporal trends in clinical performance have not been systematically quantified. This review aimed to evaluate implant survival in grafted alveolar cleft patients and to compare outcomes between early and modern treatment eras. *Materials and Methods*: A systematic search of PubMed, Web of Science, Cochrane Library, and Wiley databases was performed in accordance with PRISMA guidelines. Clinical studies reporting implant survival in grafted alveolar cleft sites with a minimum follow-up of 12 months were included. Data extraction encompassed implant survival, timing of placement, grafting protocols, and reported causes of failure. For temporal comparison, studies were stratified into an early era (1997–2008) and a modern era (2010–2026). Weighted pooled survival rates were calculated, and differences between proportions were assessed using a two-proportion Z-test ($p < 0.05$). *Results*: eventeen studies met the inclusion criteria, representing 1561 implants placed in grafted alveolar cleft sites. Overall reported survival ranged from 80% to 100%. Weighted pooled survival increased from 91.2% (95% CI: 87.9–94.5) in early studies to 94.2% (95% CI: 92.9–95.5) in modern cohorts, demonstrating a statistically significant 3.0% absolute improvement ($p = 0.038$). Implant failures occurred predominantly during the early osseointegration phase and were commonly associated with insufficient graft volume or inadequate primary stability. Late biological complications were infrequently reported. *Conclusions*: When appropriate bone reconstruction, healing, and multidisciplinary coordination are achieved, implant therapy represents a reliable component of comprehensive cleft care. Further prospective studies with standardized protocols and long-term follow-up are needed to strengthen evidence-based recommendations.

Keywords: cleft lip; cleft palate; cleft alveolus; orofacial cleft; dental implants; osseointegration

1. Introduction

Orofacial clefts, encompassing cleft lip, cleft alveolus, and cleft palate, represent among the most prevalent congenital craniofacial anomalies worldwide, with a reported incidence ranging from 1:500 to 1:1000 live births depending on ethnicity and geographic region [1,2]. These malformations frequently involve the alveolar process of the maxilla, resulting in discontinuity of the dental arch,

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impaired tooth eruption, and compromised maxillofacial growth [2]. The functional and psychosocial burden of alveolar clefts is substantial, affecting mastication, speech, facial esthetics, and quality of life across childhood and adulthood [3].

A defining characteristic of alveolar clefts is the absence or insufficiency of bone in the cleft region, which hinders normal dental development and orthodontic alignment [4]. Hypodontia is common, particularly involving the maxillary lateral incisors adjacent to the cleft, further complicating oral rehabilitation [3,4]. Consequently, closure of the alveolar defect through alveolar bone grafting (ABG) has become an integral component of comprehensive cleft care, enabling canine eruption, orthodontic tooth movement, and subsequent prosthodontic rehabilitation [2]. Secondary alveolar bone grafting, typically performed during the mixed dentition stage when the maxillary canine root is approximately two-thirds formed [1,5]. The iliac crest donor site, remains the gold standard due to its osteogenic, osteoinductive, and osteoconductive properties [6,7]. Despite its widespread use and generally favorable outcomes, ABG is not devoid of limitations [4–8]. Post-grafting bone resorption is well documented, and a significant proportion of patients demonstrate inadequate bone volume at skeletal maturity, necessitating secondary or tertiary grafting procedures prior to definitive prosthetic rehabilitation [4–8]. These limitations have direct implications for subsequent implant placement, as the quality and quantity of grafted bone are critical determinants of osseointegration and long-term implant survival [9].

Dental implant–based rehabilitation has emerged as a preferred treatment modality in cleft patiens [10] Compared with conventional fixed or removable prostheses, implants offer several advantages, including preservation of adjacent tooth structure, maintenance of alveolar bone through functional loading, and improved esthetic outcomes [9,10].

Nevertheless, implant therapy in cleft patients presents unique biological and technical challenges [9]. Implants are frequently placed in previously grafted bone characterized by reduced volume, altered density, and scarred soft tissue envelopes, all of which may compromise primary stability and peri-implant tissue health [10]. Furthermore, the prolonged interval between childhood grafting and adult implant placement may exacerbate graft resorption, occasionally requiring additional augmentation procedures such as guided bone regeneration at the time of implant insertion [3–5].

Available evidence indicates that dental implants placed in grafted alveolar cleft regions demonstrate favorable survival outcomes, with most studies reporting survival rates above 90% during short to medium-term follow-up [5,6,10]. However, interpretation of these results should be approached with caution, as the existing literature is largely based on retrospective designs, heterogeneous treatment protocols, and limited long-term follow-up data [8–10]. While many authors support implant therapy as a reliable rehabilitative option, the overall quality of evidence remains limited.

The aim of this systematic review is to critically evaluate the existing clinical evidence regarding the survival and success rate of dental implants placed in grafted alveolar cleft regions in patients with cleft lip and/or palate. The review will synthesize all available evidence to evaluate the predictability and limitations of implant-supported rehabilitation in grafted alveolar cleft sites and to identify gaps in the current literature requiring further high-quality research.

2. Materials and Methods

2.1. Study Design and Reporting Guidelines

This systematic review was conducted in accordance with the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA 2020) guidelines. The review protocol was developed a priori and followed a predefined research question, eligibility criteria, and methodological framework to minimize selection bias and enhance transparency.

2.2. Focused Question and PICO Framework

The review was structured using the Population, Intervention, Comparison, and Outcome (PICO) framework.

- Population: Patients with congenital alveolar clefts associated with cleft lip and/or palate
- Intervention: Placement of dental implants in previously grafted alveolar cleft sites
- Comparison: Not mandatory; when available, comparisons between different grafting protocols, defect morphologies, or implant approaches were considered
- Outcomes: Primary outcome was dental implant survival. Secondary outcomes included causes of implant loss and reported implant-related complications

The focused research question was:

What are the survival rates and reported causes of implant loss for dental implants placed in grafted alveolar cleft sites?

2.3. Eligibility Criteria

Inclusion Criteria

Studies were included if they met all of the following criteria:

1. Human clinical studies involving patients with alveolar clefts
2. Alveolar bone grafting performed prior to implant placement
3. Dental implants placed in the grafted cleft region
4. Implant survival reported as an outcome
5. Minimum follow-up of 12 months after implant placement
6. Prospective or retrospective cohort studies and case series more than 10 patients
7. Articles published in the English language

Exclusion Criteria

Studies were excluded if they met any of the following criteria:

- Case reports or case series with fewer than 10 patients
- Animal, in vitro, finite element, or cadaveric studies
- Studies focusing exclusively on bone grafting or augmentation without implant survival outcomes
- Studies reporting short-term osseointegration only, without survival data
- Mixed populations in which cleft-specific implant outcomes could not be extracted
- Reviews, editorials, technical notes, or conference abstracts

2.4. Information Sources and Search Strategy

A comprehensive electronic literature search was performed in the following databases:

- PubMed/MEDLINE
- Web of Science
- Wiley Online Library

The search covered all records from database inception to the most recent available publications. The search strategy combined Medical Subject Headings (MeSH) and free-text terms related to alveolar clefts, bone grafting, and dental implants. They keywords used were: cleft, cleft lip, cleft palate, cleft alveolous, dental implants, dental implant.

Reference lists of included full-text articles were also manually screened to identify additional relevant studies.

2.5. Study Selection Process

All records retrieved from the electronic searches were imported into Rayyan systematic review software, where duplicate records were removed. Title and abstract screening was performed

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initially to exclude clearly irrelevant studies. Full-text articles of potentially eligible studies were then assessed independently against the predefined inclusion and exclusion criteria.

Discrepancies during full-text screening were resolved through discussion and consensus. Reasons for full-text exclusion were documented systematically and are presented in a dedicated exclusion table in accordance with PRISMA recommendations.

2.6. Data Extraction

Data extraction was performed using a standardized data extraction form. The following variables were collected from each included study:

- Study design and year of publication
- Number of patients and implants
- Type of cleft deformity
- Grafting technique and augmentation approach
- Timing of implant placement relative to grafting
- Duration of follow-up
- Implant survival rate
- Number and timing of implant failures
- Reported causes of implant loss

Only complications explicitly associated with implant loss were recorded. If a study did not report the cause of implant failure, this was noted as "not specified." Any discrepancies in data extraction were resolved by consensus.

2.7. Risk of Bias Assessment

The methodological quality of the included studies was assessed using an adapted Newcastle–Ottawa Scale (NOS) for observational studies. The assessment focused on three domains: selection of the study population, comparability of cohorts, and outcome assessment. Selection bias was evaluated based on the representativeness of the study sample and the adequacy of patient inclusion criteria. Comparability assessed the extent to which potential confounding factors (e.g., patient characteristics, grafting protocols, implant variables) were considered. Outcome assessment included the definition of implant failure, methods of outcome measurement, and adequacy of follow-up. Each study was categorized as having low, moderate, or high risk of bias according to its overall NOS-based methodological quality. Disagreements were resolved through discussion and consensus.

2.8. Statistical Analysis

Implant survival was analyzed at the implant level using data extracted from the included studies. The number of surviving implants was calculated from the reported number of implants placed and survival rates at the last follow-up. Pooled estimates were calculated using a random-effects meta-analysis of proportions with logit transformation, and results were back-transformed for interpretation. Heterogeneity was assessed using the I^2 statistic. Forest plots were constructed to present study-specific estimates and pooled effects. Prespecified subgroup analyses were performed according to implant timing (delayed, simultaneous, mixed) and use of guided bone regeneration (GBR reported vs not reported). Differences between subgroups were assessed using the Q test, with statistical significance set at $p < 0.05$.

For temporal comparison, included studies were categorized into an early era (1997–2008) and a modern era (2010–2026). Weighted pooled survival rates were calculated for each subgroup based on the total number of implants placed and surviving. Ninety-five percent confidence intervals (95% CIs) were computed using the Wald method for binomial proportions. Differences between survival proportions were assessed using a two-proportion Z-test, with statistical significance defined as $p < 0.05$. This analysis was conducted as a descriptive pooled comparison and did not account for inter-study heterogeneity.

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3. Results

3.1. Study Selection

The electronic database search identified 1088 records through PubMed, Web of Science, Cochrrane Library and Wiley databases. After removal of duplicates, 819 unique records remained and were screened based on titles and abstracts. Following this initial screening, 792 records were excluded for not meeting the predefined inclusion criteria. A total of 27 full-text articles were assessed for eligibility. Of these, 9 studies were excluded after full-text review for the following reasons: non-clinical study design, absence of dental implant placement in grafted alveolar cleft sites, lack of implant survival or success outcomes, insufficient follow-up duration, small case series, mixed populations with non-separable cleft data, or outcomes not aligned with the objectives of the review (Table 1). Ultimately, 18 studies fulfilled the inclusion criteria and were included in the qualitative synthesis of this systematic review (Figure 1).

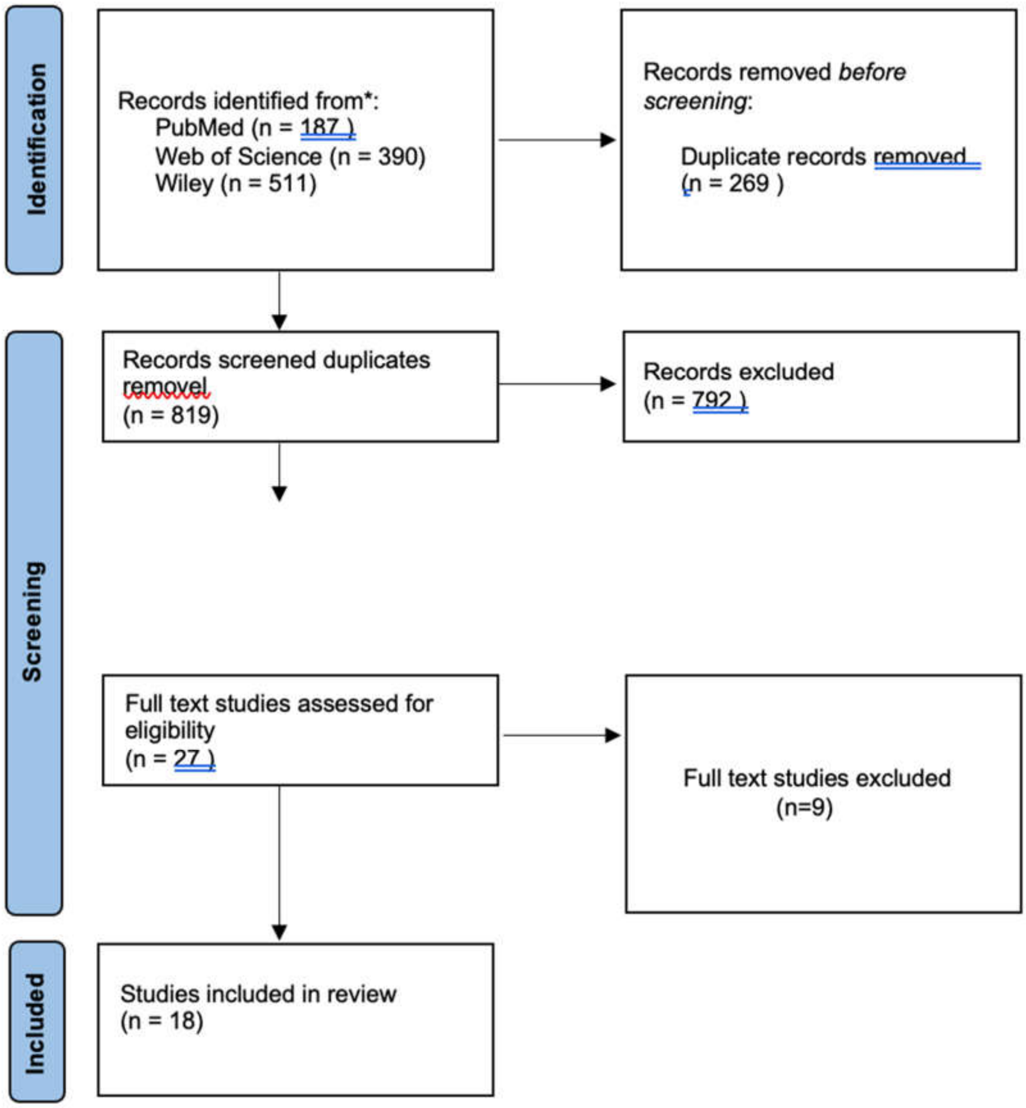

Figure 1. PRISMA flow-chart.

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Table 1. Excluded Full-Text Studies by Reason.

Study	Year	Reason for Exclusion
Esper et al. [11]	2012	No implant survival or success outcomes
Dušková et al. [12]	2007	No implant survival or success outcomes
Dempf et al. [13]	2002	No implant survival or success outcomes
Filho et al. [14]	2013	Outcome focus outside review scope
Sogancı et al. [15]	2016	Non-clinical (finite element analysis)
Dowgierd et al. [16]	2021	Non-comparable intervention (free-flap reconstruction)
Green & Padwa [17]	2021	Implant survival not reported
Green et al. [18]	2024	Primary focus on bone augmentation
Cune et al. [19]	2004	Case series with fewer than 10 patients

3.2. Overall Implant Survival

Across the included studies, implant survival in grafted alveolar cleft sites ranged from 80% to 100%, with the majority of contemporary studies reporting survival rates exceeding 90%.

A total of 18 studies were included in the quantitative synthesis of implant survival (Figure 2A). The pooled survival rate was 92.4% (95% CI: 90.0–94.3), indicating a high probability of implant survival across diverse clinical settings and study designs. Individual study estimates ranged from 80.0% to 100%, with most studies reporting survival above 90%. Several investigations demonstrated survival rates of ≥98%, while a limited number reported lower values (80.0–82.7%). Despite this variability, confidence intervals largely overlapped, and the pooled estimate remained stable, suggesting limited heterogeneity and a consistent treatment effect across the included literature.

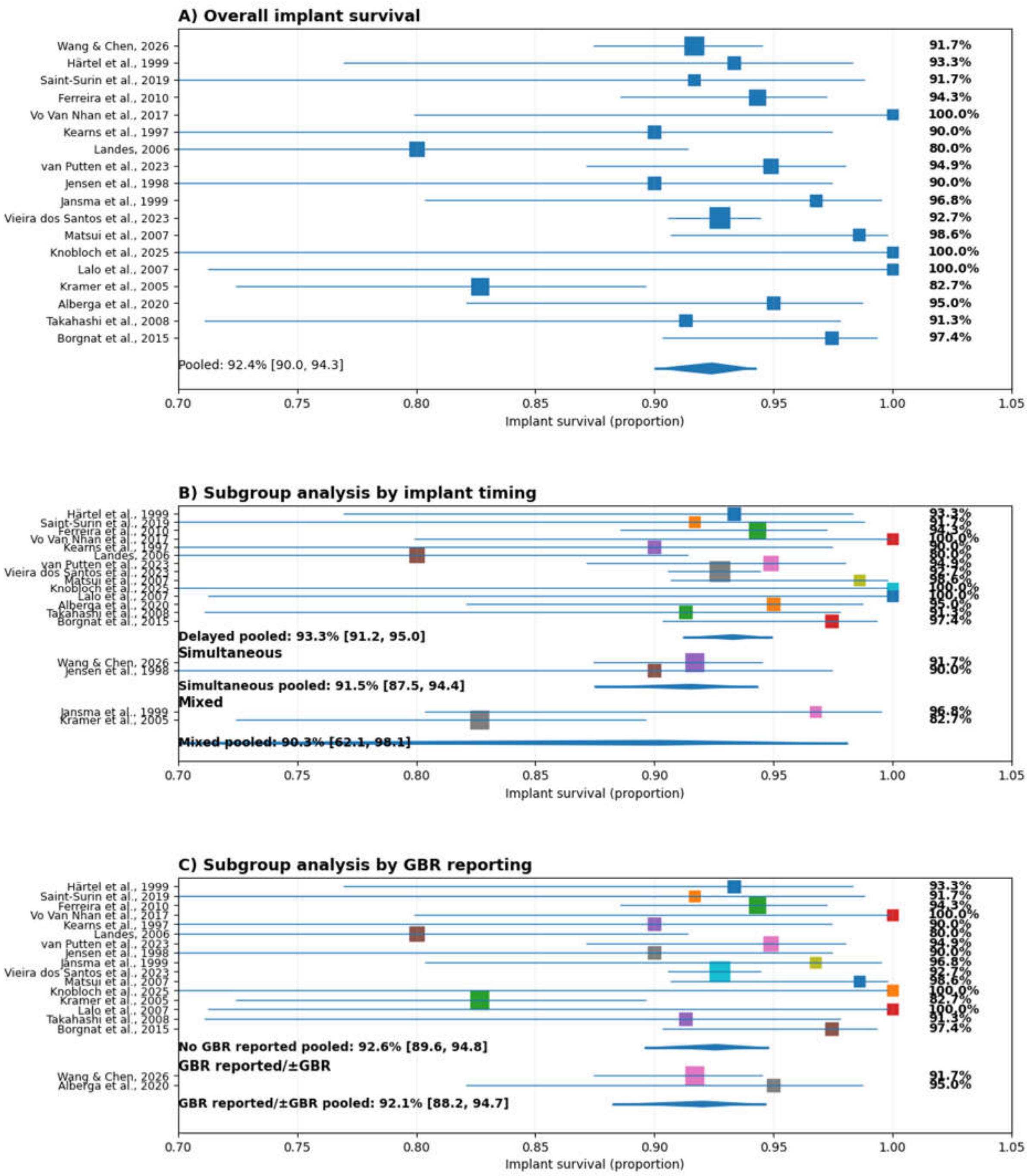

Figure 2. Forest plot of implant survival in grafted alveolar cleft sites: overall and subgroup meta-analysis by implant timing and GBR use.

Early foundational studies from the late 1990s [20–23] demonstrated survival rates of approximately 90% following delayed implant placement in iliac crest–grafted clefts, with failures predominantly occurring during the early osseointegration phase. Subsequent investigations in the 2000s [24–29] reported comparable or improved outcomes, although survival rates as low as 80–82% were observed in cohorts involving short implants, simultaneous placement protocols, or compromised graft volume.

More recent studies (2015–2026) [30–37] consistently demonstrated survival rates between 91% and 100%, reflecting advances in surgical technique, grafting protocols, implant design, and prosthetic planning. Late implant loss was uncommon; most failures occurred within the first year after placement and were attributed to insufficient graft volume, inadequate primary stability, or

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early osseointegration failure. Peri-implantitis was reported as a cause of late failure in only a limited number of cases (Table 2 and Table 3).

Table 2. Implant Survival Rates in Grafted Alveolar Cleft Sites.

Study (Year)	Study Design	Patients (n)	Implants (n)	Cleft Type	Graft / Augmentation	Implant Timing	Follow-up	Implant Survival Rate
Kearns et al., 1997 [20]	Prospective cohort	14	20	CLP	Iliac crest cancellous bone graft	Delayed	Mean 39.1 mo	90%
Jensen et al., 1998 [21]	Prospective case series	16	20	Residual alveolar cleft	Mandibular symphyseal bone graft	Simultaneous	Mean 48 mo	90%
Jansma et al., 1999 [22]	Prospective case series	15	31	CLP	Iliac crest / mandibular symphysis autograft	Simultaneous / Delayed	47–56 mo	96.8%
Härtel et al., 1999 [23]	Retrospective case series	14	30	CLP	Autogenous bone grafting (cleft reconstruction)	Delayed	≥24 mo	≈93%
Kramer et al., 2005 [24]	Prospective cohort	45	75	CLAP	Iliac crest autograft (tertiary osteoplasty)	Simultaneous / Delayed	Mean 5.5 yrs	82.2%
Landes, 2006 [25]	Retrospective comparative	20	25	CLAP	Secondary/tertiary osteoplasty	Delayed	Mean 44 mo	≈80%
Lalo et al., 2007 [26]	Retrospective case series	12	20	CLP	Autogenous bone	Delayed	Mean 5.5 yrs	100%
Matsui et al., 2007 [27]	Retrospective cohort	47	71	CLP	Iliac crest PCBM	Delayed	Mean 60 mo	98.6%

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Takahashi et al., 2008 [28]	Longitudinal cohort	16	23	CLP	Iliac crest PCBM	Delayed	Mean 8.6 yrs	90.9%
Ferreira et al., 2010 [29]	Retrospective cohort	120	123	Uni/Bilateral CLP	Iliac crest autograft	Delayed	Mean 34 mo	94.3%
Borgnat et al., 2015 [30]	Retrospective cohort	43	78	CLP	Autogenous bone	Delayed	Up to 15 yrs	97.4%
Vo Van Nhan et al., 2017 [31]	Prospective case series	32	32	CLP	Iliac crest autograft	Delayed	18–53 mo	100%
Saint-Surin et al., 2019 [32]	Retrospective cohort	39	12	Alveolar cleft	Complementary alveolar bone grafting	Delayed	Mean ≈27 mo	91.7%
Albergaa et al., 2020 [33]	Retrospective comparative	27	40	CLP	Iliac crest ± GBR	Delayed	Mean 72.4 mo	95.0%
van Putten et al., 2023 [34]	Retrospective cohort	64	78	CLA / CLAP	Secondary/tertiary grafts	Delayed	Median 46 mo	95.0%
Vieira dos Santos et al., 2023 [35]	Retrospective cross-sectional	—	688	CLP	Grafted cleft sites ± regrafting	Delayed	Mean 53.2 mo	92.73 %
Knobloch et al.,	Prospective cohort	14	17	Cleft palate	Surgically corrected cleft site	Delayed	5 yrs	100%

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2025 [36]								
Wang & Chen, 2026 [37]	Retrospective comparative	240	240	Unilateral CLP	Iliac crest + GBR (mesh)	Simultaneous	12 mo	91.7–98.3%

Table 3. Implant Loss, Timing, and Causes of Failure in Grafted Alveolar Cleft Sites.

Study (Year)	Implants Placed (n)	Implants Lost (n)	Timing of Loss	Reported Cause of Implant Loss
Kearns et al., 1997 [20]	20	2	Early	Inadequate graft volume; early osseointegration failure
Jensen et al., 1998 [21]	20	2	Early	Graft sequestration; wound dehiscence
Jansma et al., 1999 [22]	31	1	Early	Failure during healing phase
Härtel et al., 1999 [23]	30	2	Early	Insufficient bone volume; early osseointegration failure
Kramer et al., 2005 [24]	75	10	Early (≤1 yr)	Short implant length (<13 mm); early osseointegration failure
Landes, 2006 [25]	25	5	Early & late	Osseointegration failure; short implants; smoking; poor bone quality
Lalo et al., 2007 [26]	20	0	—	None reported
Matsui et al., 2007 [27]	71	1	Early	Failure of osseointegration
Takahashi et al., 2008 [28]	23	2	Early	Insufficient grafted bone volume
Ferreira et al., 2010 [29]	123	7	Early	Inadequate primary stability; insufficient bone volume
Borgnat et al., 2015 [30]	78	2	Early	Poor bone quality; early osseointegration failure
Vo Van Nhan et al., 2017 [31]	32	0	—	None reported
Saint-Surin et al., 2019 [32]	12	1	Early	Early osseointegration failure
Alberga et al., 2020 [33]	40	2	Early	Lack of primary stability
van Putten et al., 2023 [34]	78	5	Early (2); Late (3)	Early: inadequate osseointegration; Late: peri-implantitis

Vieira dos Santos et al., 2023 [35]	688	50*	Not specified	Not specified
Knobloch et al., 2025 [36]	17	0	—	None reported
Wang & Chen, 2026 [37]	240	5	≤12 mo	Graft instability; early implant failure

The large retrospective cohort by Vieira dos Santos et al. [35] reported a survival rate of 92.73% across 688 implants, reinforcing the reproducibility of favorable outcomes in cleft populations when appropriate surgical staging is employed. Similarly, morphology-guided augmentation strategies demonstrated survival rates of up to 98.3% at 12 months, suggesting that defect configuration may influence short-term implant stability.

When pooled by era, weighted implant survival increased from 91.2% (95% CI: 87.9%–94.5%) in early studies (1997–2008) to 94.2% (95% CI: 92.9%–95.5%) in modern studies (2010–2026), representing an absolute difference of 3.0% that reached statistical significance (two-proportion Z-test, $p = 0.038$).

Random-effects meta-analysis confirmed a pooled implant survival rate of 92.4% (95% CI: 90.0–94.3), with moderate heterogeneity across studies ($I^2 = 33.5\%$) (Figure 2A).

Subgroup Analysis by Implant Timing

Subgroup analysis according to implant placement timing (**Figure 2B**) showed that delayed placement was the most frequently adopted approach (k = 14; n = 1,257) and yielded a pooled survival rate of 93.3% (95% CI: 91.2–95.0). Simultaneous placement was reported in fewer studies (k = 2; n = 260) and demonstrated a pooled survival of 91.5% (95% CI: 87.5–94.4).

Studies categorized as mixed timing showed a pooled survival of 90.3% (95% CI: 62.1–98.1), with wider confidence intervals reflecting the limited number of studies and smaller sample sizes. These studies were not included in direct subgroup comparisons due to methodological heterogeneity.

Overall, the overlapping confidence intervals and similar point estimates indicate that implant survival did not differ significantly between delayed and simultaneous placement strategies. The slightly higher point estimate observed for delayed placement is unlikely to be clinically meaningful.

Subgroup Analysis by GBR Reporting

Subgroup analysis based on the reporting or use of guided bone regeneration (GBR) is presented in Figure 2C. Studies without GBR reporting constituted the majority of the dataset (k = 16) and demonstrated a pooled survival rate of 92.6% (95% CI: 89.6–94.8).

In contrast, studies explicitly reporting GBR use (k = 2) showed a pooled survival of 92.1% (95% CI: 88.2–94.7). The pooled estimates were nearly identical, and the confidence intervals showed substantial overlap, indicating no statistically significant subgroup effect. These findings suggest that the use or reporting of GBR did not materially influence implant survival outcomes in the analyzed studies.

3.4. Risk of Bias Assessment

According to the Newcastle–Ottawa Scale, most included studies were judged to have a moderate risk of bias, primarily due to retrospective designs and limited adjustment for confounding factors. A small number of case series were classified as high risk, while only one study achieved a low-risk rating. Overall, the methodological quality of the evidence was considered acceptable for observational implant research (Figure 3).

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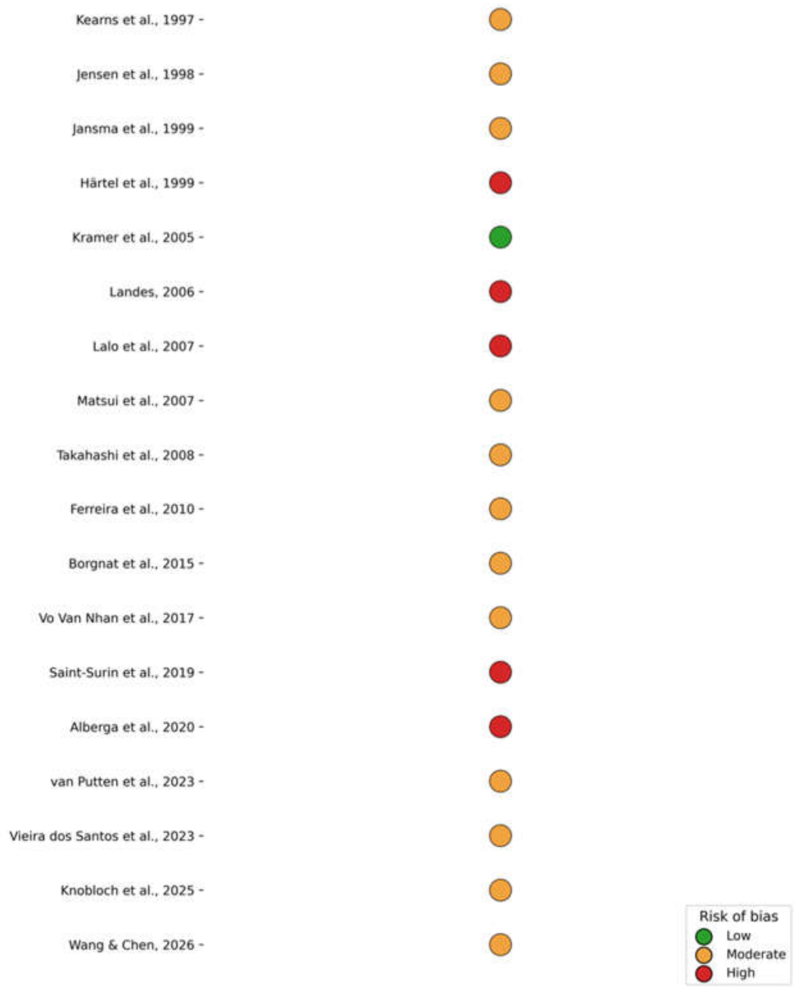

Figure 3. Risk of bias assessment.

4. Discussion

The present systematic review demonstrates a pooled weighted implant survival of 94.2% in the modern era (2010–2026) compared to 91.2% in early-era studies (1997–2008), representing a statistically significant temporal improvement ($p = 0.038$). These findings confirm that implant-supported rehabilitation in grafted alveolar cleft sites has become increasingly predictable over time and likely reflect cumulative advances in surgical techniques, grafting protocols, implant design, and multidisciplinary treatment planning. The overall pooled survival of 92.4% further supports the reliability of implant therapy in this anatomically complex population, despite the biological challenges associated with grafted bone and scarred soft tissues.

These results align broadly with previously published systematic reviews while providing additional resolution through chronological stratification and explicit analysis of implant failure patterns. Pathak et al. [9] reported a pooled survival rate of 93.5% irrespective of graft type, closely approximating the pooled value identified in the present review and reinforcing the predictability of implant therapy in grafted cleft sites. However, their meta-analysis did not stratify outcomes temporally or distinguish early from late implant loss, and the inclusion of esthetic and patient-reported outcomes broadened the scope but limited survival-specific interpretation. Similarly, Sales et al. [5] identified a survival rate of approximately 93% across 483 implants with a mean follow-up of around 60 months, though their review highlighted significant heterogeneity and the limited availability of prospective studies—limitations that remain evident in the current evidence base.

Wang et al. [3] reported a mean survival of 91.5% ± 4.77% with a mean follow-up of 54 months, a figure that closely mirrors the early-era pooled survival identified in this analysis. This parallel suggests that improvements observed in contemporary studies likely reflect technological and protocol advancements rather than differences in patient populations. Importantly, Wang et al. also emphasized the high rate of secondary or tertiary grafting, reported in up to 43.1% of cases, reinforcing the role of graft stability, maturation, and surgical staging as key determinants of implant prognosis. In contrast, Wermker et al. [4] reported 5-year survival rates ranging from 80% to 96% (mean 88.6%), lower than more recent pooled estimates, likely due to the inclusion of earlier implant systems, machined surfaces, and less standardized grafting and timing protocols. Their review also highlighted the generally low methodological quality of the available literature, a concern that persists across cleft implant research.

The influence of graft maturation and timing is further supported by Mallick et al. [6], who reported success rates between 95% and 100% when tertiary graft healing intervals of 3–6 months were respected. These findings support the hypothesis that optimized timing and controlled healing significantly contribute to improved outcomes observed in modern cohorts. Conversely, Vuletić et al. [2] provided a narrative overview of grafting protocols and implant rehabilitation without pooled survival synthesis, and Guo et al. [1] focused on secondary bone grafting techniques in children without evaluating implant survival, although both works underscore the foundational importance of graft quality prior to implant placement.

Across all reviews, including the present analysis, implant survival in grafted alveolar cleft sites consistently approaches outcomes observed in non-cleft implant populations. Modern survival rates, frequently exceeding 94%, now approximate general implant benchmarks reported in broader implant literature [29–37]. Nevertheless, survival alone does not fully reflect treatment complexity. High rates of tertiary grafting and staged interventions indicate that favorable outcomes are often dependent on additional augmentation procedures and multidisciplinary coordination. Implant prognosis in cleft patients must therefore be interpreted within the context of surgical burden, orthodontic preparation, and prosthetic planning rather than survival metrics alone [29–39].

The pattern of implant failure identified across studies provides additional clinical insight. Failures occurred predominantly during the early osseointegration phase and were most frequently associated with insufficient graft volume, inadequate primary stability, or early biological failure, whereas late complications such as peri-implantitis were comparatively uncommon. This suggests that implant success in cleft patients is primarily determined by surgical and graft-related factors rather than long-term peri-implant tissue breakdown. Once osseointegration is achieved, implant behavior in grafted cleft bone appears similar to that observed in native maxillary bone.

Despite encouraging survival rates, the current evidence base remains methodologically limited. Consistent with prior reviews, the majority of included studies are retrospective case series with moderate-to-high risk of bias and heterogeneous reporting standards. Variability in follow-up duration, implant systems, grafting techniques, and definitions of survival versus success complicates direct comparison across studies. Earlier systematic reviews similarly reported pooled survival estimates between approximately 88% and 93% without stratification by treatment era or detailed analysis of failure timing [3–5]. By incorporating chronological stratification, weighted pooled survival estimates, and statistical comparison between early and modern cohorts, the present study provides a more granular interpretation of temporal trends. Furthermore, the differentiation between early osseointegration failure and late biological complications offers clinically relevant insight not consistently addressed in previous analyses.

This review has several strengths. It integrates recent literature up to 2026, applies a structured methodological framework, and combines quantitative pooling with subgroup and temporal analyses, allowing a more comprehensive interpretation of implant outcomes in grafted cleft sites. The inclusion of failure timing and causes further enhances clinical relevance by identifying the early healing phase as the most critical period for implant prognosis.

However, several limitations must be acknowledged. The dominance of observational study designs, limited number of prospective investigations, and variability in outcome reporting restrict the strength of causal inference. Subgroup analyses were constrained by imbalances in study

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numbers, particularly for simultaneous implant placement and GBR reporting, and long-term data beyond 10 years remain scarce. In addition, patient-reported outcomes, esthetic assessments, and functional measures were inconsistently reported, limiting evaluation of treatment success beyond survival.

Future research should prioritize prospective multicenter studies with standardized definitions of implant survival and success, longer follow-up durations, and stratified analysis according to grafting protocols, implant timing, and defect morphology. Such studies are essential to refine clinical guidelines and further optimize implant-supported rehabilitation strategies in cleft populations.

5. Conclusions

Implant-supported rehabilitation in grafted alveolar cleft sites demonstrates high and predictable survival, particularly in contemporary clinical practice. Failures occur mainly during the early osseointegration phase and are most commonly related to insufficient graft volume or inadequate primary stability, highlighting the importance of careful surgical planning and graft assessment.

When appropriate bone reconstruction, healing, and multidisciplinary coordination are achieved, implant therapy represents a reliable component of comprehensive cleft care. Further prospective studies with standardized protocols and long-term follow-up are needed to strengthen evidence-based recommendations.

Supplementary Materials: The following supporting information is available through email from the corresponding author if asked.

Author Contributions: "Conceptualization, A.T and O.F..; methodology, A.M and A.G..; software, D.S..; validation, O.F and S.B.; formal analysis, A.T. and A.M .; investigation, A.T. and O.F..; resources, A.M. and A.T.; data curation, O.F..; writing—original draft preparation, . A.T and A.M.; writing—review and editing, O.F and S.B visualization, A.G and D.S.; supervision O.F. and B.S.; project administration O.F and A.G... All authors have read and agreed to the published version of the manuscript.".

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