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Comparison of Implant Stability in Immediate Versus Delayed Implant Placement Using Resonance Frequency Analysis: A Systematic Review

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Gaurang Mistry [1], Sheetal Parab [1], Mayuri Bachhav [1], Mishal DeSouza [1], Ankita Chitnis [1], Christina Pereira [1]

1. Prosthodontics, DY Patil University School of Dentistry, Nerul, Navi Mumbai, IND

Corresponding author: Christina Pereira, christinatreville@gmail.com

Abstract

This systematic review compared implant stability following immediate and delayed dental implant placement using resonance frequency analysis (RFA), expressed as Implant Stability Quotient (ISQ) values. The review followed PRISMA 2020 guidelines and was registered with the International Prospective Register of Systematic Reviews (PROSPERO; registration number CRD420251071221). PubMed/MEDLINE, Scopus, CENTRAL, and Embase were searched for English-language publications from January 2000 to May 2025, supplemented by Google Scholar and reference screening. Comparative clinical studies involving adults and reporting baseline and follow-up ISQ values were eligible. Risk of bias was assessed using the revised Cochrane risk-of-bias tool for randomized trials (RoB 2) and the Risk Of Bias In Non-randomized Studies of Interventions (ROBINS-I) tool. Six studies involving 404 participants and 608 implants were included: two randomized trials and four non-randomized comparative studies. Delayed placement generally demonstrated higher baseline ISQ values. Immediate-placement groups commonly showed subsequent stability gains, although the magnitude and persistence of between-group differences varied. Survival was not uniformly 100%; Atieh et al. reported survival of 71.4% following immediate placement and 85.7% following delayed placement. Both randomized trials had some concerns regarding risk of bias. Certainty of the randomized evidence was low for baseline ISQ and very low for follow-up ISQ, implant survival, crestal bone-level changes, and peri-implant soft-tissue outcomes. Differences in implant systems, anatomical sites, loading protocols, and assessment intervals limited direct comparisons, and no meta-analysis was undertaken. The available evidence does not establish equivalent stability or survival between placement protocols. Placement and loading decisions should consider site conditions, achievable primary stability, and clinical and radiographic findings alongside RFA measurements.

Categories: Dentistry
Keywords: delayed implant placement, dental implants, immediate implant placement, implant stability quotient, resonance frequency analysis, systematic review

Introduction And Background

Dental implants are an integral component of modern dental practice and provide a biologically compatible option for replacement of missing teeth [1]. Since Brånemark introduced endosseous implants in the 1960s, implant therapy has advanced in materials, surface technology, surgical protocols, and prosthetic integration [2]. These developments are based on osseointegration, defined as a direct structural and functional connection between living bone and the surface of a load-bearing implant [3]. Implant survival rates frequently exceed 95% in controlled clinical settings, supporting implants as a predictable solution for oral rehabilitation [4].

Implants restore function while helping preserve surrounding oral structures [5]. Because they are independent of adjacent teeth, implants avoid the need for tooth preparation and restorative complications [6]. By transmitting functional loads to the underlying bone, they can mitigate ridge resorption and support maintenance of alveolar dimensions over time [7,8]. Implant indications now extend from single-tooth replacement to overdentures and full-arch fixed prostheses, supported by digital workflows (guided surgery and computer-aided design/computer-aided manufacturing (CAD/CAM)) and surface modifications that may accelerate early bone response [9-11].

Despite these advances, success remains closely linked to implant stability [12]. Primary stability is mechanical at placement, whereas secondary stability develops through biologic remodeling and new bone formation at the implant-bone interface [13]. This interaction guides loading decisions because inadequate stability can permit micromotion and compromise osseointegration [14,15]. Stability is influenced by bone quality, implant design, surgical technique, and site anatomy [16,17]. Timing after extraction adds complexity: immediate placement in a fresh socket may provide less initial cortical engagement than delayed placement in a healed ridge [18]. Resonance frequency analysis (RFA) provides a non-invasive way to quantify stability using Implant Stability Quotient (ISQ) values and to track changes during healing [19,20]. RFA measures the resonance response of a transducer attached to the implant and expresses the result as an ISQ value. Higher values generally indicate greater stiffness of the implant-bone complex.

However, measurements depend on the characteristics of the implant and surrounding tissues, and no single ISQ threshold universally establishes implant success or determines loading suitability [19,20]. However, evidence remains inconsistent on whether immediate and delayed placement yield comparable stability over time [18,21]. This systematic review therefore synthesizes clinical evidence comparing ISQ outcomes between immediate (≤48 hours) and delayed (≥8 weeks) implant placement protocols.

Review

Methodology

The present systematic review was planned and conducted in accordance with the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) 2020 statement [22]. The protocol was registered prospectively in the International Prospective Register of Systematic Reviews (PROSPERO) (CRD420251071221). The review methods, eligibility criteria, and outcomes were defined a priori and followed throughout the conduct of the review.

Focused Question and Outcomes

The review question was framed using the population, intervention, comparator, and outcome (PICO) approach: in adults receiving dental implants, how does implant stability measured using RFA-derived ISQ values differ between immediate placement, within 48 hours of extraction, and delayed placement, at least eight weeks after extraction? The primary outcome was implant stability measured as ISQ at baseline (at placement) and at follow-up time points. Secondary outcomes included implant survival, crestal bone level changes, and biological or prosthetic complications when these were reported alongside the stability data.

Eligibility Criteria

Studies were included if they were clinical human comparative investigations involving adults aged 18 years or older and directly compared immediate versus delayed implant placement. Eligible designs included randomized controlled trials and controlled clinical studies with prospective or retrospective data. To ensure meaningful assessment of stability trends, studies were required to report RFA-derived ISQ values at a minimum of two time points, specifically at placement (baseline) and at least one subsequent follow-up. Only studies published in English from January 2000 onward were considered. Studies were excluded if they were case reports, case series without a comparator group, narrative reviews, systematic reviews, letters, or in vitro/animal studies. Studies that did not report ISQ values, used stability measures other than RFA, or combined different implant placement timings without presenting separable data for immediate and delayed groups were excluded. Studies involving extensive grafting or sinus lift procedures were excluded when outcomes were not stratified by augmentation status, as this could confound stability interpretation.

Information Sources and Search Strategy

A comprehensive electronic literature search was performed in PubMed/MEDLINE, Scopus, the Cochrane Central Register of Controlled Trials (CENTRAL), and Embase (via Ovid), and a supplementary search was performed in Google Scholar (first 300 sources sorted according to relevance). The search covered publications from January 2000 to 25 May 2025 and was restricted to English-language studies. The strategy combined controlled vocabulary terms (where applicable) and free-text keywords related to dental implants, immediate placement, delayed placement, RFA, and ISQ, using Boolean operators to optimize sensitivity and specificity. Reference lists of included studies and relevant review articles were manually screened to identify additional eligible reports through citation tracking (snowballing). Grey literature, conference abstracts, and unpublished theses were not included. The search strategy across each database is summarized in Table *1*.

Database	Search strategy
PubMed/MEDLINE	("Dental Implants"[MeSH] OR "dental implant*") AND ("immediate implant placement" OR "delayed implant placement" OR "post-extraction implant*") AND ("resonance frequency analysis" OR "implant stability quotient" OR ISQ)
Scopus	TITLE-ABS-KEY("dental implant*" AND ("immediate placement" OR "delayed placement" OR "post-extraction") AND ("resonance frequency analysis" OR "implant stability" OR ISQ))
Embase (Ovid)	(dental implant*).mp. AND (immediate placement OR delayed placement OR post-extraction).mp. AND (resonance frequency analysis OR implant stability quotient OR ISQ).mp.
Cochrane CENTRAL	("dental implant*" OR "oral implant*") AND ("immediate placement" OR "delayed placement") AND ("resonance frequency analysis" OR "implant stability" OR ISQ)
Google Scholar	("dental implants" OR "oral implants") AND ("immediate placement" OR "delayed placement") AND ("resonance frequency analysis" OR "implant stability quotient" OR ISQ)

TABLE 1: Database-specific search strategies used for the systematic review

CENTRAL: Cochrane Central Register of Controlled Trials; ISQ: Implant Stability Quotient; MeSH: Medical Subject Headings; TITLE-ABS-KEY: title - abstract - keywords; .mp.: multipurpose field search

Search period: January 2000 to May 2025. Searches were restricted to English-language publications. Reference lists of included articles and relevant reviews were additionally screened to identify potentially eligible studies.

Study Selection

All records retrieved from the databases were compiled and screened for eligibility. After removal of duplicates, two reviewers independently evaluated titles and abstracts against the prespecified criteria. Full texts were obtained for all records considered potentially eligible or where eligibility could not be determined from the abstract alone. The same two reviewers independently assessed full-text articles for final inclusion. Any disagreements were resolved through discussion and consensus, and a third reviewer was involved when required to reach a final decision.

Data Extraction

A standardized data extraction form was developed and pilot-tested before formal extraction. Two reviewers independently extracted data from each included study. Disagreements were resolved through discussion, with a third reviewer consulted when consensus could not be reached. Extracted information included study identifiers (author, year, country), study design and sample size, number of participants and implants in each placement group, participant characteristics (age, sex, smoking status where reported), implant site characteristics (maxilla/mandible, anterior/posterior), and bone-related details (bone quality/type when provided). Implant-related variables such as system/brand, surface characteristics, diameter, and length were recorded, along with surgical protocol details including timing definitions, insertion torque when reported, any use of minor grafting for jumping gaps, and perioperative medications. Prosthetic protocol and loading strategy were extracted, including timing of provisionalization or definitive restoration when described. For stability outcomes, ISQ values at baseline and each follow-up time point were extracted for immediate and delayed groups, along with measurement orientation if reported. Secondary outcomes, including implant survival, crestal bone level changes, and biological or prosthetic complications, were extracted when available. Extracted data were entered into a spreadsheet to facilitate structured comparisons across studies.

Risk of Bias Assessment

Methodological quality was assessed at the study level using design-appropriate tools. Randomized controlled trials were evaluated using the Cochrane Risk of Bias 2 (RoB-2) tool [23], which assesses bias arising from the randomization process, deviations from intended interventions, missing outcome data, outcome measurement, and selective reporting. Non-randomized comparative studies were assessed using the Risk Of Bias In Non-randomized Studies of Interventions (ROBINS-I) tool [24], evaluating bias due to confounding, participant selection, intervention classification, deviations from intended interventions, missing data, outcome measurement, and selection of the reported result. Two reviewers independently assessed risk of bias. Disagreements were resolved through discussion, with a third reviewer consulted when consensus could not be reached. Each domain was rated according to the guidance of the respective tool, and an overall judgment was assigned for each study.

Certainty of Evidence

The certainty of evidence for key outcomes was assessed using the Grading of Recommendations Assessment, Development, and Evaluation (GRADE) approach [25]. The evidence for each outcome was evaluated across the domains of risk of bias, inconsistency, indirectness, imprecision, and publication bias, and then rated as high, moderate, low, or very low certainty. Judgments were based on the collective body of evidence contributing to each outcome and were aligned with the risk of bias findings and the consistency of reported effects across studies.

Data Synthesis and Analysis

Study characteristics and outcomes were summarized in structured tables and synthesized narratively. ISQ findings were examined separately at placement and during follow-up, retaining the assessment intervals and measurement orientations reported by each study. Between-group differences and within-group changes were described without treating measurements obtained at different intervals or orientations as directly interchangeable. A meta-analysis was not undertaken because differences in assessment schedules, loading protocols, implant systems, and anatomical sites limited the comparability of the available data. Randomized and non-randomized findings were identified by study design, and interpretation considered their respective risk-of-bias assessments.

Results

Study Selection

The literature search identified a total of 443 records from PubMed (n = 18), Scopus (n = 38), Embase (n = 87), and Google Scholar (n = 300). After removing 141 duplicate records, 302 records were screened based on their titles and abstracts. Of these, 265 were excluded for not meeting the predefined eligibility criteria. Full texts were sought for the remaining 37 reports, of which four could not be retrieved. Consequently, 33 reports underwent full-text eligibility assessment. Twenty-seven reports were excluded due to irrelevant outcomes (n = 12), inadequate or ambiguous data (n = 8), inappropriate study groups (n = 6), or non-English full texts (n = 1). Finally, six studies fulfilled the eligibility criteria and were included in the systematic review. The study selection process is presented in Figure *1*.

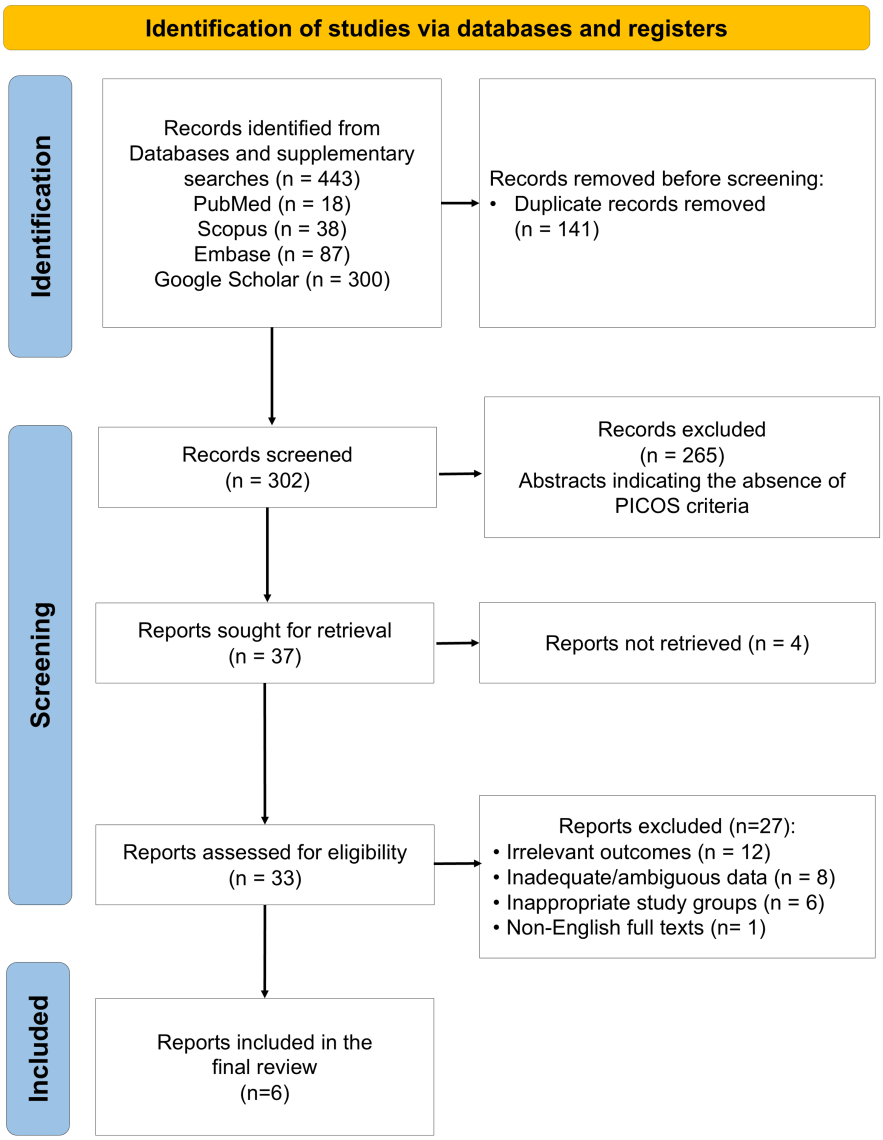

FIGURE 1: PRISMA flow diagram indicating the selection process of the articles in the present systematic review

PICOS: Population, Intervention, Comparison, Outcomes, and Study design

Study Characteristics

The six included studies were published between 2014 and 2025 and involved 404 participants and 608 implants [26-31]. They were conducted in New Zealand [26], Croatia [27], the United States [28], China [29], Italy [30], and India [31]. Two were randomized controlled trials [30,31], one was a prospective non-randomized comparative study [26], and three were retrospective comparative studies [27-29]. Study characteristics and participant and implant counts are presented in Table *2*.

Author (year)	Country	Study design	Participants (n)	Implants (total/Imm/Del)	Age range (mean)	Gender	Edentulous status	Implant sites	Bone quality	Implant brand/system	Diameter (mm)	Length (mm)
Atieh et al. (2014) [26]	New Zealand	Prospective controlled clinical trial	28	28/14/14	NR (50.3 ± 13.5)	10 M, 18 F	Partially	Posterior mandibular molars: 15 R1M, 11 L1M, 1 R2M, 1 L2M	Type II: 21; III: 7	MAX (Southern Implants)	8 (n = 17); 9 (n = 11)	7 (n = 1); 9 (n = 9); 11 (n = 18)
Granić et al. (2015) [27]	Croatia	Retrospective clinical study	60	60/30/30	22-65 (44.25)	NR	Partially	Maxillary premolar region (n=60)	NR	Nobel Replace Tapered Groovy	NR	NR
Rowan et al. (2015) [28]	USA	Retrospective clinical study	85	137/41/96	19-93	NR	NR	Maxilla: 80; mandible: 57	NR	Nobel Replace Tapered Groovy	3.5-5.0	10-16
Huang et al. (2016) [29]	China	Retrospective clinical study	177	329/103/226	19 to >80	103 M, 74 F	Mixed	Maxilla: 112; mandible: 217	I: 95; II: 51; III: 62; IV: 83	SICace	3.5, 4, 4.5, 5	7.5, 9.5, 11.5, 13, 14.5
Malchiodi et al. (2016) [30]	Italy	Randomized controlled trial	40	40/20/20	35-75	24 M, 16 F	Partially	Imm: 8 Mo, 12 PM; Del: 15 Mo, 5 PM	II-IV	SybronPRO XRT, RBM surface	3.3, 4.1	9-13
Muthaiyan et al. (2025) [31]	India	Prospective randomized clinical study	14	14/ 7/7	18-60	NR	Partially, single-tooth	NR	NR	NR	NR	NR

TABLE 2: Study characteristics, participant demographics, and implant specifications

Del: delayed placement; F: female; Imm: immediate placement; L1M: left first molar; L2M: left second molar; M: male; Mo: molar; NR: not reported; PM: premolar; R1M: right first molar; R2M: right second molar; RBM: resorbable blast media; USA: United States of America

Participant and Site Profile

The included populations covered a broad adult age range, with the highest reported age being 93 years [28]. Both sexes were represented where demographic information was available. Reporting of smoking status, edentulous status, and bone quality varied across studies. Implants were placed in both jaws and in different anatomical regions, while reported bone-quality categories extended from Type I to Type IV [26-31].

Implant Systems and Surgical Protocols

Implant systems and surgical protocols varied across studies. Reported systems included MAX implants from Southern Implants [26], NobelReplace Tapered Groovy implants [27,28], SICace implants [29], and SybronPRO XRT implants [30]. Insertion torque was reported using different formats, limiting direct comparison. Immediate placement involved fresh extraction sockets, whereas delayed placement involved healed sites, with variation in the specified healing interval. Grafting practices also differed, particularly for management of residual gaps around immediately placed implants. Surgical and perioperative details are summarized in Table *3*.

Author (year)	Placement torque (N cm)	Primary-stability threshold	Grafting performed	Antibiotic/antiseptic protocol	Placement-timing definition	Loading protocol	Healing abutment	Prosthetic phase
Atieh et al. (2014) [26]	>45 (n = 19); ≤45 (n = 9)	NR; threshold sought: 60.5 ISQ at eight weeks	None	Amoxicillin 2 g or clindamycin 600 mg, 1 h preoperatively; 0.2% CHX rinse	Imm: fresh molar socket; Del: healed molar ridge ≥8 weeks	Provisional crown ≤48 hours, out of occlusion; definitive crown at 8 weeks	Yes	Provisional acrylic followed by screw-retained zirconia-ceramic restoration
Granić et al. (2015) [27]	NR	None	None	Amoxicillin 500 mg every eight hours for seven days; clindamycin if allergic; 0.12% CHX	Imm: extraction socket; Del: healed ridge ≥4 months	Two-stage; nonfunctional for 20 weeks; loaded thereafter	Yes	Single metal-ceramic crown
Rowan et al. (2015) [28]	NR	ISQ 65 benchmark	MasterGraft in all immediate sites; none in delayed sites	NR	Imm: fresh socket; Del: healed ridge ≥2 months	Two-stage; restoration after 2-6 months	Yes	NR
Huang et al. (2016) [29]	10-60 (categorized)	NR	Yes, 27 implants	NR	Imm: fresh socket; Del: healed ridge ≥8 weeks	Two-stage; restoration at 6-52 weeks	Yes	NR
Malchiodi et al. (2016) [30]	49 ± 9.9	NR	Gap grafting in immediate group	Amoxicillin/clavulanate 2 g preoperatively + 1 g at six hours; CHX	Imm: extraction socket; Del: after 12 weeks	Two-stage; crown at approximately three months	Yes	Single cement-retained crown
Muthaiyan et al. (2025) [31]	NR	NR	Jump-gap grafting in immediate group when present	Amoxicillin 500 mg three times daily from one day before surgery; ibuprofen	Imm: extraction socket; Del: healed ridge	Immediate loading within 48 hours in both groups	No	Temporary crown within 48 hours; final restoration at six months

TABLE 3: Surgical procedures, placement protocols, and prosthetic rehabilitation

CHX: chlorhexidine; Del: delayed placement; h: hour(s); Imm: immediate placement; ISQ: Implant Stability Quotient; N cm: Newton-centimeter; NR: not reported

Prosthetic and Loading Protocols

Prosthetic and loading protocols differed across studies. Atieh et al. provided provisional restorations within 48 hours, positioned out of occlusion [26], whereas Muthaiyan et al. described immediate loading within 48 hours in both placement groups [31]. Other studies used staged restoration protocols with varying healing intervals [27-30]. Restoration retention was not uniform: Atieh et al. reported screw-retained definitive restorations [26], while Malchiodi et al. reported cement-retained crowns [30]. These differences were considered when interpreting stability and survival findings. Protocol details are presented in Table *3*.

Risk of Bias Within Studies

Both randomized trials were judged to have some concerns overall, mainly related to limitations in reporting clarity for randomization processes and prespecified analysis strategies, while other domains were generally rated as low risk (Figure *2*) [30,31].

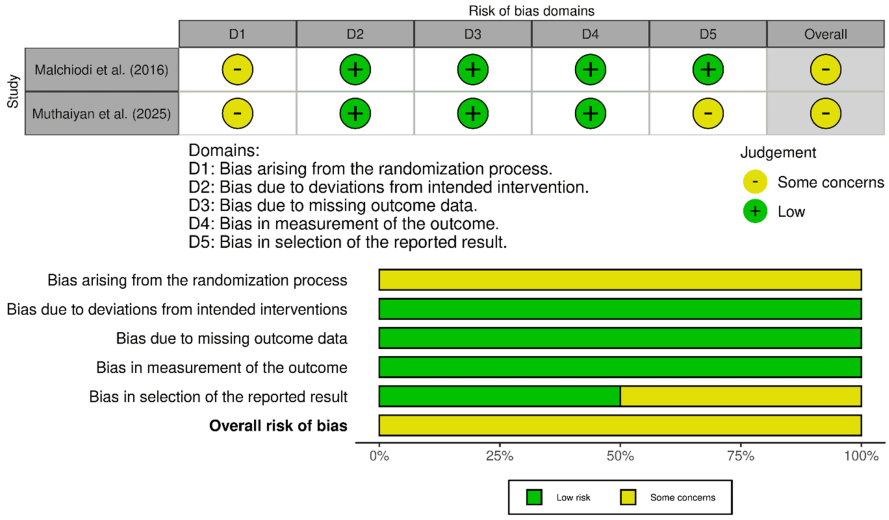

FIGURE 2: Risk of bias across the included randomized controlled trials

Studies included [30,31].

Among the non-randomized studies, two were assessed as low overall risk of bias [26,28], and two were assessed as moderate overall risk of bias primarily due to potential confounding and limitations in intervention classification [27,29]. Across non-randomized studies, risk related to missing outcome data and deviations from intended interventions was generally low, and there were no serious concerns regarding selective outcome reporting [26-29]. Overall judgments were some concerns for the randomized trials and low or moderate risk for the non-randomized studies. These assessments were considered when interpreting the findings but did not independently establish the certainty of evidence for each outcome (Figure 3).

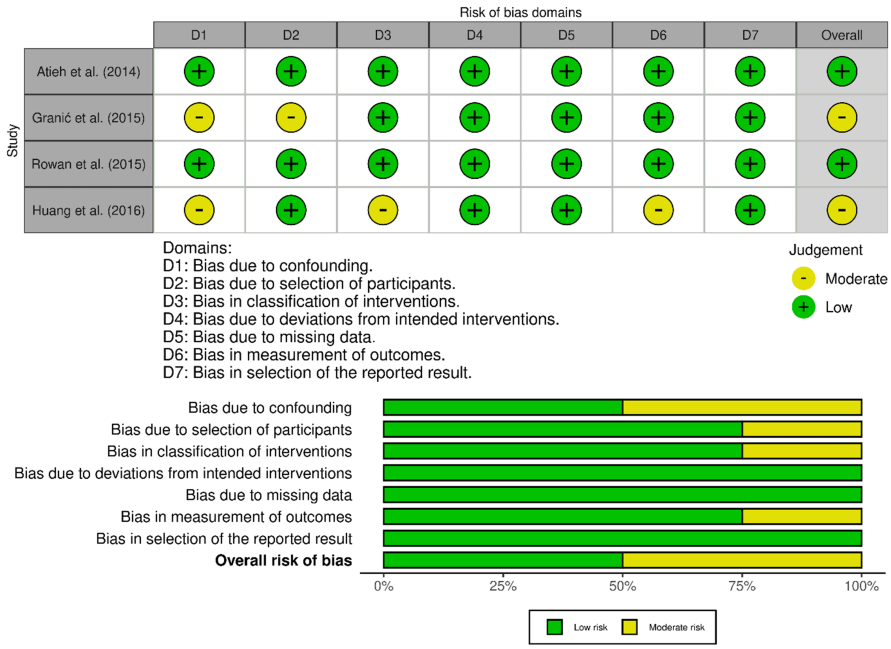

FIGURE 3: Risk of bias across included non-randomized clinical trials

Studies included [26-29].

Primary Outcome: ISQ at Baseline and Follow-Up

ISQ measurements are summarized in Table 4. Among studies with numerical group means tabulated, baseline ISQ values ranged from 60.14 to 73.68 for immediate placement and from 64.17 to 76.73 for delayed placement [27-31]. These ranges include separately reported measurement orientations and should not be

interpreted as pooled estimates. Delayed-placement groups generally had higher baseline means. Follow-up schedules varied, with assessments extending to 52 weeks [26,29]. Immediate-placement groups commonly showed increases from baseline, but the trajectories were not uniformly progressive and between-group differences did not consistently disappear. For example, Rowan et al. reported an immediate-placement group mean of 73.88 at 12 weeks and 70.14 at 22 weeks, compared with 65.60 at baseline [28].

Author (year)	Baseline ISQ - Immediate (mean ± SD)	Baseline ISQ - Delayed (mean ± SD)	TP1 (weeks)	ISQ TP1 - Immediate (mean ± SD)	ISQ TP1 - Delayed (mean ± SD)	TP2 (weeks)	ISQ TP2 - Immediate (mean ± SD)	ISQ TP2 - Delayed (mean ± SD)	Additional time points reported	Implant survival - Immediate, n/N (%)	Implant survival - Delayed, n/N (%)	Follow-up for survival assessment	Mean follow-up (months)	Crestal bone loss - Immediate (mm ± SD)	Crestal bone loss - Delayed (mm ± SD)	Other reported outcomes	Study limitations	Author conclusio
Atieh et al. (2014) [26]	NR	NR	8	NR	NR	52	NR	NR	Baseline, 8 and 52 weeks	10/14 (71.4%)	12/14 (85.7%)	12 months	12	NR	NR	ROC AUC 0.93 at eight weeks	Small sample; short follow-up; single implant system/site	Eight-week ISQ was th best predictor
Granić et al. (2015) [27]	61.43 ± 1.65	64.17 ± 1.74	20	66.23 ± 1.81	68.83 ± 1.89	NR	NR	NR	Baseline and 20 weeks	30/30 (100%)	30/30 (100%)	6 months after implant placement	6	NR	NR	ISQ gain in immediate vs delayed groups	Short follow-up; larger studies needed	Supports immediate placement with delaye loading
Rowan et al. (2015) [28]	65.60 ± 9.33	76.73 ± 6.50	12	73.88 ± 10.92	79.58 ± 5.70	22	70.14 ± 7.15	77.31 ± 5.30	Baseline and two follow-ups	41/41 (100%)	96/96 (100%)	Variable; mean 768 days (range 110-1,615 days) after placement	5.2	NR	NR	ISQ gain in immediate vs delayed groups	Short follow-up; larger studies needed	Immediate implants exhibited lower mea ISQ values full conclusion not provide
Huang et al. (2016) [29]	73.68 ± 6.50	75.82 ± 5.49	≈6-52	77.00 ± 4.30	77.63 ± 4.07	NR	NR	NR	NR	103/103 (100%)	226/226 (100%)	NR	NR	NR	NR	Regression model predicting ISQ	Larger studies needed; clinic/system-specific findings	Model estimates ISQ accurately
Malchiodi et al. (2016) [30]	61.90 ± 9.99	66.00 ± 8.25	12	68.15 ± 5.97	66.80 ± 6.01	NR	NR	NR	No	20/20 (100%)	20/20 (100%)	12 months after implant placement	12	0.68 ± 0.43	0.40 ± 0.26	Torque-ISQ correlation; crestal bone loss differences	Small sample; short follow-up	Greater bone remodeling with immediate placement
Muthaiyan et al. (2025) [31]	60.14 ± 8.97 (MD); 62.14 ± 9.26 (BL)	75.57 ± 3.26 (MD); 72.00 ± 6.30 (BL)	NR	NR	NR	24	65.71 ± 7.06 (MD); 68.57 ± 5.47 (BL)	76.43 ± 3.55 (MD); 77.43 ± 2.37 (BL)	No	7/7 (100%)	7/7 (100%)	NR	6	NR	NR	Plaque, BOP, and PD: no intergroup differences	Short follow-up	Higher stability wit delayed placement

TABLE 4: Implant stability measurements, clinical outcomes, and study conclusions

AUC: area under the curve; BL: buccolingual; BOP: bleeding on probing; ISQ: Implant Stability Quotient; MD: mesiodistal; NR: not reported; PD: probing depth; ROC: receiver operating characteristic; SD: standard deviation; TP: time point

Secondary Outcomes

Atieh et al. reported survival of 10/14 implants (71.4%) following immediate placement and 12/14 implants (85.7%) following delayed placement [26]. In contrast, Granić et al. reported 100% survival in both groups (30/30 each) [27], as did Rowan et al. (41/41 immediate and 96/96 delayed) [28], Malchiodi et al. (20/20 in each group) [30], and Muthaiyan et al. (7/7 in each group) [31]. The duration of survival assessment differed among studies, limiting direct comparisons. Peri-implant soft-tissue indices and biological or prosthetic

complications were inconsistently reported, limiting comparisons between placement protocols.

Certainty of Evidence

The GRADE assessment of randomized evidence is presented in Table 5. Certainty was low for baseline ISQ because of risk-of-bias concerns and imprecision. Certainty for follow-up ISQ was very low owing to additional inconsistency in comparative findings. Implant survival evidence was rated very low because the small randomized samples and absence of failures did not permit reliable exclusion of clinically important differences. Certainty for crestal bone-level changes was very low because of methodological concerns, imprecision, and differences in measurement methods and assessment intervals. Soft-tissue outcomes were supported by one small randomized trial and were also rated very low. Publication bias was not formally assessed. Non-randomized findings were considered separately within the narrative synthesis.

Outcome	Randomized evidence	Risk of bias	Inconsistency	Indirectness	Imprecision	Proposed certainty
Primary stability at placement, measured using ISQ	Two trials; 54 participants and implants [30,31]	Serious[a]	Not serious	Not serious	Serious[c]	Low
Follow-up stability, measured using ISQ at study-specific intervals	Two trials; 54 participants and implants [30,31]	Serious[a]	Serious[b]	Not serious	Serious[c]	Very low
Implant survival during reported follow-up	Two trials; 54 participants and implants [30,31]	Serious[a]	Not reliably assessable because failures were absent	Not serious for short-term survival	Very serious[d]	Very low
Crestal bone-level changes	Two trials; 54 participants and implants [30,31]	Serious[a]	Serious[e]	Not serious	Serious[c]	Very low
Peri-implant soft-tissue indices: plaque index, bleeding on probing, and probing depth	One trial; 14 participants and implants [31]	Serious[a]	Not assessable from one trial	Not serious	Very serious[f]	Very low

TABLE 5: GRADE Certainty of Evidence across the included studies

Grading footnotes:

[a] Risk of bias: Downgraded one level for the reported concerns regarding randomization and prespecified analysis reporting.

[b] Follow-up ISQ: Downgraded for differences in the direction and magnitude of between-group findings at different assessment intervals.

[c] Imprecision: Downgraded because the small randomized evidence base limits confidence in the magnitude of comparative effects.

[d] Survival: Downgraded two levels because small samples without failures cannot exclude clinically important survival differences.

[e] Bone-level changes: Downgraded for differences in measurement methods, reference points, follow-up intervals, and reported effect magnitudes.

[f] Soft-tissue outcomes: Downgraded two levels because evidence comes from a single trial with seven participants per group.

Publication bias was not formally assessed; its absence should not be inferred. No upgrading was applied.

GRADE: Grading of Recommendations Assessment, Development and Evaluation; ISQ: Implant Stability Quotient

Discussion

The present systematic review synthesized evidence from six clinical studies comparing implant stability outcomes between immediate and delayed implant placement using RFA reported as ISQ values [26-31]. A consistent pattern across these studies was that delayed implants tended to show slightly higher baseline ISQ values than immediate implants [26-31]. This is biologically plausible because implants placed in healed ridges generally engage more mature and mineralized bone with better cortical support at the time of insertion [32]. In contrast, immediate implants are placed into fresh extraction sockets, where cortical contact may be reduced, especially when the buccal plate is thin or compromised, which can lower initial mechanical stability and ISQ readings [33]. However, differences in baseline ISQ alone do not establish differences in subsequent clinical outcomes, and the available studies do not demonstrate equivalent

survival between placement protocols [26-31].

Changes in stability during healing were another relevant finding. Immediate-placement groups commonly showed increases in ISQ from baseline, although the trajectories differed across studies and did not consistently converge with delayed-placement values [27-31]. These changes may reflect the development of biological stability during healing, but interpretation also depends on assessment timing, anatomical site, implant characteristics, and loading conditions [34]. Consequently, serial ISQ measurements should be interpreted alongside clinical and radiographic findings rather than used alone to infer successful osseointegration or equivalent prognosis [19,20].

Survival findings require particular caution. Atieh et al. reported survival of 71.4% following immediate placement and 85.7% following delayed placement [26]. These findings contradict a uniform pattern of complete survival and should be considered within the study's immediate restoration protocol. The numerical difference does not, by itself, establish a statistically significant effect of placement timing. Site conditions, restoration and loading protocols, and patient-related factors also require consideration when interpreting survival outcomes [18,21]. Immediate placement may offer practical advantages in selected cases, while delayed placement remains an option when local conditions do not permit adequate primary stability [18].

Crestal bone level changes were reported in four studies and were generally small, with a tendency toward slightly greater early remodelling in immediate placement groups [27,28,30,31]. This may be related to physiological socket healing and bundle bone resorption after extraction, which can be more evident radiographically in immediate placement cases [33,34]. Although these differences appeared limited in magnitude, they reinforce the importance of atraumatic extraction, proper three-dimensional implant positioning, and selective gap management to support early hard-tissue stability [34].

Interpretation of stability outcomes was complicated by heterogeneity in loading protocols [26-31]. Some studies used immediate or early loading guided by insertion torque and ISQ thresholds, whereas others followed conventional loading schedules [26-31]. This is clinically relevant because early mechanical conditions influence osseointegration, and loading decisions should be individualized rather than determined by timing alone [20,21]. The use of ISQ thresholds as a clinical guide is practical, but small numeric differences should still be interpreted along with clinical and radiographic findings rather than as stand-alone predictors of prognosis [20,26,28,31,35,36].

Site anatomy and surgical technique likely contributed to variation in baseline stability. Posterior maxillary sites with lower bone density may remain challenging even in delayed placement, while technique modifications can improve primary stability [37]. In addition, implant macrogeometry and surface characteristics may support early stability gains, especially in immediate placement cases [11,38]. The evidence base remains limited by small sample sizes, retrospective designs, short follow-up, and inconsistent soft-tissue reporting.

Several limitations affect interpretation. The evidence base combines randomized and non-randomized studies, with variation in anatomical sites, implant systems, grafting practices, loading protocols, and follow-up schedules. Participant and implant counts were not interchangeable, particularly in studies involving multiple implants per participant. Stability measurements among retained implants may also be influenced by the loss of failed implants during follow-up. The English-language restriction, exclusion of grey literature, and search cutoff of May 2025 may have resulted in recent relevant evidence being missed. These limitations restrict conclusions about comparative effectiveness and long-term survival.

The limited certainty of the randomized evidence restricts conclusions about the comparative effectiveness of the two placement protocols. In particular, the absence of implant failures in small trials does not establish equivalent survival. Observational findings provide additional clinical context, but potential confounding limits their ability to resolve uncertainty. Differences in ISQ should therefore be interpreted cautiously alongside clinical outcomes, rather than used alone to infer superiority or equivalence. Future multicentre trials with standardised RFA protocols, consistent loading strategies, and longer follow-up are needed to clarify long-term comparative outcomes.

Conclusions

Delayed placement generally showed higher baseline ISQ values, whereas immediate placement commonly demonstrated stability gains during healing. However, heterogeneous protocols, variable survival findings, and limitations of the available evidence prevent firm conclusions about clinical equivalence. Placement and loading decisions should consider site conditions, achievable primary stability, and clinical and radiographic findings alongside RFA measurements.

Additional Information

Author Contributions

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

Concept and design: Christina Pereira, Gaurang Mistry, Sheetal Parab, Mayuri Bachhav, Mishal DeSouza, Ankita Chitnis

Acquisition, analysis, or interpretation of data: Christina Pereira, Gaurang Mistry, Sheetal Parab, Mayuri Bachhav, Mishal DeSouza, Ankita Chitnis

Drafting of the manuscript: Christina Pereira, Gaurang Mistry, Sheetal Parab, Mayuri Bachhav, Mishal DeSouza, Ankita Chitnis

Critical review of the manuscript for important intellectual content: Christina Pereira, Gaurang Mistry, Sheetal Parab, Mayuri Bachhav, Mishal DeSouza, Ankita Chitnis

Supervision: Christina Pereira, Gaurang Mistry, Sheetal Parab, Mayuri Bachhav, Mishal DeSouza, Ankita Chitnis

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