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Original Article

Prompt Loading of Implant-Backed Fixed Prostheses in Back Regions: A Systematic Exploration of Evidence

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ABSTRACT

Contemporary dental practice increasingly focuses on minimally invasive treatments as a primary therapeutic objective. Selecting appropriate cases for immediate implant placement can significantly shorten treatment duration, lower financial expenditure, and enhance overall patient satisfaction. A systematic literature search was performed in March 2025 across Medline, PubMed, and Web of Science databases, with no time limits applied. Additional manual screening was conducted to retrieve supplementary sources. Studies addressing current data on immediately loaded dental implants supporting fixed partial restorations in posterior regions were included. Publications lacking abstracts or not written in English were excluded. Ten articles met the inclusion criteria. The included studies reported survival outcomes ranging between 86% and 100%, with implant failure rates under 21.6% and an average follow-up of 55.6 months. Statistical testing indicated no significant survival differences between implants in the upper and lower jaws ($\chi^2 = 0.42$, $p = 0.81$, df = 2). Follow-up durations ranged from one to ten years, demonstrating variability in design and observation periods. The reviewed evidence reveals marked diversity in immediate loading protocols for implant-supported fixed restorations in posterior areas. Variations in prosthetic components and implant systems were noted, but overall findings suggest that immediate loading remains a dependable, patient-oriented treatment option providing stable long-term success.

Keywords: Immediate loading, Fixed partial restoration, Implants, Prosthetic materials

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Introduction

The pursuit of less invasive dental interventions remains a defining trend in current clinical practice [1]. Such methods primarily aim to shorten treatment courses, lower overall costs, lessen postoperative discomfort and complications, and enhance patient comfort [2].

Within implant dentistry, the concept of immediate loading refers to placing a prosthesis on an implant within approximately 48 hours after surgery—subjecting it to functional load without awaiting the traditional osseointegration period [3]. Conventionally, a three-month healing phase precedes loading to allow bone integration with the implant surface [4, 5].

Successful immediate loading relies heavily on careful case selection to ensure optimal primary stability—mechanical fixation obtained at the time of placement—and adequate bone quality [6]. This approach aligns with the philosophy of minimally invasive techniques by limiting the number of surgical steps and postoperative appointments. Because the prosthetic phase coincides with implant placement, no secondary surgery is required, reducing trauma and patient recovery time [7].

Combining both implant insertion and prosthesis delivery in a single stage minimizes manipulation of surrounding tissues, thereby decreasing inflammation and postoperative complications [8]. Furthermore, immediate loading allows patients to regain function and aesthetics right away, accelerating oral rehabilitation and easing the adaptation period [9].

Extensive research has explored the outcomes of immediate loading across various applications—from full-arch reconstructions using three to four implants to single-unit anterior restorations [10, 11]. Findings indicate that immediate-loading strategies preserve bone volume and gingival form, limiting resorption and maintaining soft-tissue contour, both vital for aesthetic integrity. Integrating this approach within implantology supports the minimally invasive philosophy, improving both patient satisfaction and clinical predictability [12].

This paper aims to evaluate the existing literature concerning immediate loading protocols for fixed partial restorations in posterior sites, with a particular focus on primary stability, potential complications, and long-term success rates.

Materials and Methods

Search strategy

A digital literature exploration was undertaken using a customized search plan formulated around the PICO framework [13]. The guiding PICO inquiry was: *What evidence exists regarding the application of immediate loading implants for fixed partial restorations in the posterior zone?* **(Table 1)**.

Table 1. Search outline structured by the PICO model

Research Focus	Details
(PICO) Core Inquiry	What is the existing evidence on immediate implant loading for fixed partial restorations in posterior dental areas?
Search Approach	Individuals with partial tooth loss in posterior regions of the mandible or maxilla.
Study Cohort	
Procedure or Exposure	Insertion of implants with concurrent placement of temporary restorations.
Control Group	Implant-based restorations in partially edentulous areas without immediate provisional placement.
Results Measured	Success rate, incidence of complications.
Databases Searched	PubMed Medline, Web of Science, supplemented by manual literature review.
Target Journals	Periodontology 2000, Clinical Advances in Periodontics, Dentistry Journal of Oral Pathology and Medicine, Journal of Clinical Periodontology, Frontiers in Oral Health, International Journal of Periodontics and Restorative Dentistry, Lasers in Dental Science, Journal of Periodontal Research.
Inclusion Criteria	Studies of all evidence levels except expert opinions; publications in English; articles from the past 10 years.
Exclusion Criteria	Literature reviews, animal-based studies, laboratory experiments, duplicate publications on the same cohort, editorial letters, inaccessible full-text articles.

The review included men and women aged 18 years and above who underwent immediate implant-supported prosthetic placement. Eligible cases involved both immediate post-extraction insertions and situations with adequate bone volume for direct implantation. The intervention assessed consisted of implant procedures in which the prosthesis was placed and functionally loaded within 0–48 hours, following the immediate loading concept. Comparative analysis involved conventional loading techniques where prostheses were installed after full osseointegration—representing the biological bond between implant and bone—prior to functional activation.

The investigation also examined how immediate loading influenced prosthetic outcomes, its associated prognostic factors, and the general clinical success of the treatment.

This systematic review was formally recorded on the International Platform of Systematic Review Protocols under registration number INPLASY2024120112 (DOI: 10.37766/inplasy2024-12-0112; https://inplasy.com/inplasy-2024-12-0112/, accessed 27 January 2025).

The databases PubMed and Web of Science were searched to locate publications discussing immediate loading of dental implants with fixed partial prostheses in posterior areas. The keyword combination applied included both MeSH and free-text terms:

((Immediacy [Mesh] OR “Immediate loading” OR “Immediate prosthesis” OR “Immediate function”) AND (Implant [Mesh] OR “Dental implant” OR “Implant-supported prosthesis”)).

Manual verification of reference lists from the retrieved articles and reviews was also carried out. In addition, journals manually reviewed comprised: The International Journal of Oral & Maxillofacial Implants (JOMI), Forum Implantologicum, Clinical Implant Dentistry and Related Research, Journal of Clinical Periodontology, and Clinical Oral Implants Research.

Studies of any methodological level were accepted, except those based solely on expert opinion. Only papers written in English and issued within the last ten years were eligible.

Exclusion parameters included letters to editors, literature reviews, animal experiments, and laboratory-based studies. Any paper without accessible full text was disregarded. Prior review studies were also excluded to prevent repetitive data reporting and potential bias.

Two independent reviewers (G.D. and A.A.) conducted a two-phase screening, initially reviewing titles and abstracts, followed by comprehensive full-text evaluation. During the second stage, a standardized data extraction sheet was applied to confirm eligibility, evaluate methodological robustness, and collect study attributes and results. Differences in reviewer assessments were addressed through discussion, and if unresolved, referred to a third reviewer (M.F.). When multiple reports originated from the same project, they were consolidated, treating each study—not each report—as the main analytical unit, in alignment with the Cochrane Handbook [14].

Quality assessment

The methodological quality of the selected papers was examined using validated assessment tools. Two authors (G.D. and M.F.) conducted independent evaluations, and inconsistent findings were resolved by consulting a third reviewer (S.C.).

For non-randomized investigations, the ROBINS-I (Risk of Bias in Non-Randomized Studies of Interventions) checklist was applied. For controlled clinical trials (CCTs) and randomized controlled trials (RCTs), the Cochrane Risk of Bias 2 (RoB 2) framework was employed to evaluate potential methodological bias [15, 16].

Data extraction

Two reviewers (G.D. and S.C.) independently performed the data collection process. All primary variables were validated by both reviewers, while half of the secondary variables (50%) underwent cross-verification following several procedural steps. Core information gathered included the study title, author list, publication year, journal or source, and any reported funding.

Additional extracted elements involved participant demographics, performed interventions, and recorded treatment outcomes. When numeric data were not provided in the text, Web Plot Digitizer version 2.0 was utilized to retrieve quantitative values, adhering to the standards described in the Cochrane Handbook. Data extraction was manually recorded, and average values were subsequently calculated for statistical interpretation. Studies were excluded from further analysis when data were unavailable or incomplete, and clarification from original authors could not be obtained.

A linear regression model was applied to determine how follow-up duration related to the two categories of treatment complications. Regression coefficients, including the slope, intercept, and coefficient of determination (R^2), were calculated for both biological and mechanical complications. In addition, a Pearson correlation test was conducted to measure both the direction and strength of the association between complication incidence and follow-up time. Results were visualized through scatter plots with regression lines to illustrate trends.

Relationships among categorical variables were tested using the Chi-square (χ^2) method. All analyses were completed using statistical software to enhance consistency and accuracy. The assumptions of independent sampling and expected counts greater than five were confirmed before performing the χ^2 test.

The review also evaluated primary implant stability in each included study. These assessments incorporated parameters such as insertion torque, resonance frequency analysis (RFA), and Implant Stability Quotient (ISQ). Data on stability measurements, their respective methodologies, and reported outcomes were summarized in a dedicated table to offer a comparative overview of study approaches and results.

Results

Study selection

The final search was completed on 30 December 2024. The findings are reported in accordance with the Systematic Scoping Review Statement. From the initial search, 1,203 distinct records were identified and screened based on their titles and abstracts. Of these, 52 studies were selected for full-text evaluation [17]. After applying inclusion and exclusion criteria, 10 studies remained eligible for analysis—9 retrieved from the electronic search and 1 identified through manual screening [18–27].

Strong inter-reviewer agreement was achieved during both phases of study screening. The included research consisted of three prospective studies, two retrospective investigations, two multicenter randomized controlled clinical trials, two single-center randomized trials, and one split-mouth randomized controlled trial **(Figure 1)**.

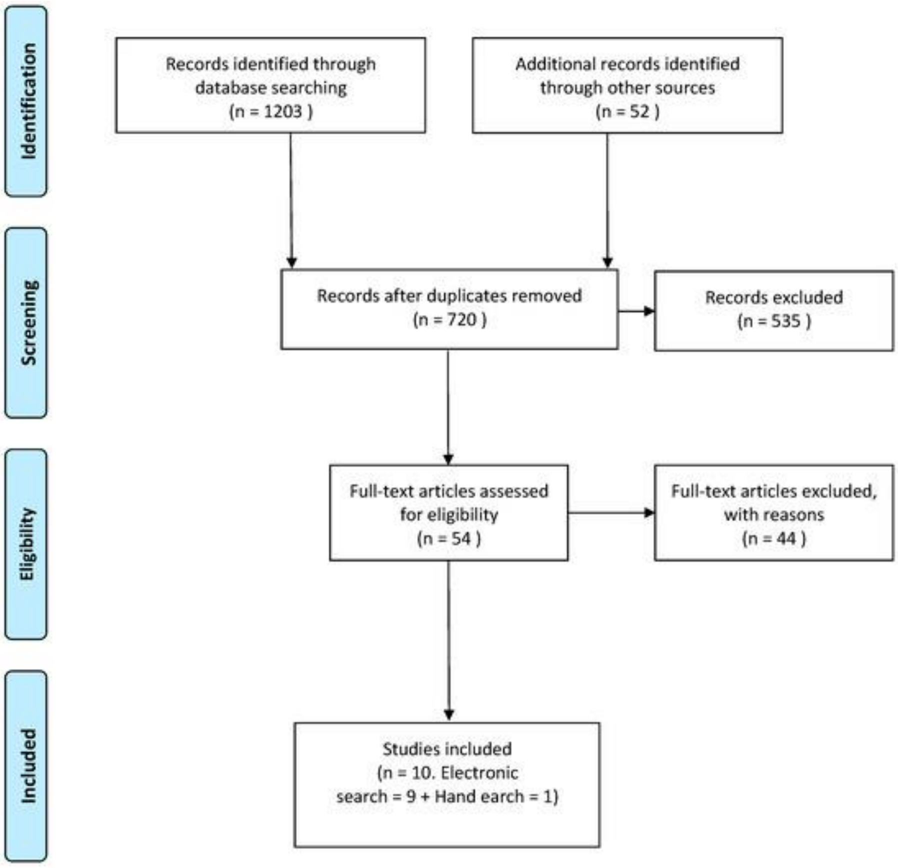

Figure 1. Flowchart of study selection according to **PRISMA 2020** guidelines

Risk of bias

Application of the Cochrane RoB 2 tool **(Table 2)** indicated that five of the analyzed studies presented concerns related to randomization—either due to incomplete methodological descriptions or retrospective design, both of which could introduce selection bias.

Furthermore, three studies exhibited issues linked to missing data, primarily from inadequate reporting practices, as observed in Weerapong *et al.* [22] and Kim *et al.* [27]. In two investigations (Perelli *et al.* [18] and Maló *et al.* [20]), the lack of assessor blinding increased the probability of measurement bias.

Overall, four studies were determined to have a low risk of bias across all evaluated domains. The remaining studies demonstrated varying levels of methodological concern, particularly those with longer observation periods and higher attrition rates.

Table 2. Summary of bias assessment according to RoB 2 for CCTs and RCTs included in this review

	D1	D2	D3	D4	D5	Overall
Cesaretti [21]	+	+	+	+	+	+
Weerapong *et al.* [22]	+	+	-	+	+	-
Daher *et al.* [25]	+	+	+	+	+	+
Esposito *et al.* [26]	+	+	+	+	+	+
Kim YY *et al.* [27]	+	+	-	+	+	-

D1: Randomization bias; D2: Deviation from intervention; D3: Incomplete data; D4: Measurement bias; D5: Selective reporting bias.
Judgment: - Some concerns; + Low.

Risk of bias evaluation

The reviewed retrospective and prospective investigations exhibited differing levels of bias across evaluated domains. Bias associated with confounding (D1) and participant selection (D2) was generally minimal, suggesting sound methodological control during recruitment and adequate handling of potential confounders. Conversely, challenges were identified in intervention classification (D3) and deviations from planned procedures (D4) in a few studies, which might reflect either procedural inconsistencies or insufficient methodological detail.

Bias linked to incomplete datasets (D5) appeared as one of the more prominent issues, as several reports lacked appropriate handling of missing data, thereby potentially diminishing the dependability of their conclusions. Problems related to outcome measurement (D6) were also observed, particularly in studies where outcome assessors were not blinded, raising concerns about measurement-related bias. Meanwhile, reporting bias (D7) was relatively minor since most investigations presented comprehensive data sets without major omissions.

In summary, the included research demonstrated an overall low-to-moderate risk of bias; however, greater consistency in reporting missing data and clearer classification of interventions would strengthen methodological robustness. These observations underline the value of rigorous procedural standards for both retrospective and prospective clinical designs. Moreover, while no study explicitly identified a funding source, six studies acknowledged industrial involvement (such as implant or biomaterial manufacturers) as collaborative partners.

Table 3. Assessment of bias risk using the ROBINS-I tool for observational studies included in the review

	D1	D2	D3	D4	D5	D6	D7	Overall
Perelli *et al.* [18]	-	+	+	-	+	+	+	-
Anitua *et al.* [19]	-	+	+	+	+	-	-	-
Maló *et al.* [20]	-	+	+	-	+	+	+	-
Agliardi *et al.* [23]	-	+	+	+	+	-	-	-
Amato *et al.* [24]	+	+	+	+	+	+	+	+

D1: Bias due to confounding. D2: Bias due to selection of participants. D3: Bias due to classification of interventions. D4: Bias due to deviations from intended interventions. D5: Bias due to missing data. D6: Bias in measurement of outcomes. D7: Bias in selection of the reported result. Judgment: - Some concerns; + Low.

Data synthesis

All included studies indicated that participants were in good general health, although definitions within inclusion and exclusion criteria differed. Some trials used broad descriptors of systemic wellness, while others listed specific medical conditions as exclusion parameters or included only individuals with well-managed chronic disorders.

None of the studies provided a consistent definition for periodontal status, yet all confirmed that participants either received periodontal treatment before enrollment or exhibited no active periodontitis upon inclusion. Few reports detailed the supportive periodontal care measures or their frequency.

The types of implant systems and surface characteristics varied notably between investigations. Implant distribution also differed: while some studies focused exclusively on molars, others encompassed both premolars and molars. Antibiotic and postoperative protocols were likewise inconsistent. Most reports stated that antibiotic therapy began on the day of surgery and continued for 4–10 days, with analgesics prescribed as needed.

The extracted data included: study reference, publication year, number and type of implants, country, study design, type of prosthesis, number of failed implants, and overall survival rate. These variables were compiled into a summary table to enable straightforward cross-study comparison and interpretation of outcome trends.

Table 4. Overview of the principal features and findings of the included studies

Citation, Year, Location	Research Method	Implant Count	Implant Specifications	Restoration Features	Failed Implants
Perelli *et al.* (2020) [18], Italy	Forward-looking investigation	Upper: 46 Lower: 23	Brief, round, screwed fixtures, 7.0 mm or 8.5 mm long	Temporary: Acrylic resin, screw-secured. Permanent: Metal-ceramic fixtures, screw-secured and cement-secured	6 failures in upper area
Anitua *et al.* (2019) [19], Spain	Historical patient analysis	48	Ultra-brief fixtures (6.5 mm) from BTI Biotechnology Institute, Vitoria, Spain	Temporary: Acrylic resin, screw-secured. Permanent: Metal-	None

				ceramic fixtures, screw-secured	
Maló *et al.* (2015) [20], Portugal	Historical patient analysis	Upper: 215 Lower: 266	Round fixtures, 7–15 mm long, TiUnite coating, instant function method	Temporary: Acrylic resin screw-secured Permanent: Metal-ceramic fixtures, screw-secured	Upper: 6 failures Lower: 2 failures
Cesaretti (2015) [21], Cuba	Multi-center randomized trial	Upper: 71	Straumann SLA, 4.1 mm wide, 8–12 mm long	Temporary: Acrylic resin, screw-secured. Permanent: Metal-ceramic fixtures, screw-secured	None
Weerapong *et al.* (2019) [22], Thailand	Randomized patient trial	Lower: 46	PW+ Implant, 6–10 mm long	Temporary: Hybrid ceramic, CAD/CAM produced, screw-secured. Permanent: Not detailed	2 brief, 1 regular failure
Agliardi *et al.* (2014) [23], Italy	Forward-looking patient investigation	Upper: 20	NobelSpeedy Groovy (Nobel Biocare), upright and inclined, 11.5–25 mm long, TiUnite coating	Temporary: Acrylic resin, screw-secured. Permanent: CAD/CAM titanium framework with acrylic teeth, screw-secured	None
Amato *et al.* (2024) [24], Italy	Forward-looking investigation	Upper: 128 Lower: 50	Not detailed	Temporary: Acrylic resin, screw-secured. Permanent: Not detailed	One failure
Daher *et al.* (2020) [25], Lebanon	Split-mouth randomized trial	Upper:120	NobelActive (Nobel Biocare), variable-thread tapered, 10–15 mm long, dual acid-etched	Temporary: Acrylic resin, screw-secured. Permanent: Metal-ceramic fixtures, screw-secured	None
Esposito *et al.* (2024) [26], Italy	Multi-center randomized trial	72 fixtures: 34 biting, 38 non-biting	T3 Certain Tapered Prevail (ZimVie Dental), dual acid-etched, 8.5–13 mm long	Temporary: Acrylic resin, screw-secured. Permanent: Metal-ceramic fixtures, screw-secured	2 failures (biting group), 0 (non-biting group)
Kim *et al.* (2021) [27], South Korea	Randomized patient trial	Upper: 46 Lower: 56	Tapered (TI) Luna Shinhung and Straight (SI) Straumann Bone Level, SLA coating, 8–10 mm long	Temporary: PMMA, screw-secured. Permanent: Metal-ceramic or zirconia-based, likely screw-secured or cement-secured	2 TI, 7 SI failures

Table 5 presents additional detail regarding the number of implants, follow-up duration, and nature of reported complications (biological and mechanical). It also outlines each study's overall complication percentage and the corresponding implant survival rate.

Table 5. Detailed summary of complication types, follow-up periods, and implant survival outcomes

Source, Year, Region	Implant Quantity	Observation Period	Tissue-Related Issues	Structural Issues	Success Rate (%)	Issue Incidence (%)
Perelli *et al.* (2020) [18], Italy	69	8 years	6 upper jaw fixtures failed in first year	No restoration failures over 8 years	95.6%	4.34%
Anitua *et al.* (2019) [19], Spain	48	14 months	Increased bone resorption in short-long combined group	No restoration failures; higher distal bone resorption	100%	6.25%
Maló *et al.* (2015) [20], Portugal	481	10 years	12 tissue-related issues; inflammation around implants	43 structural issues	96.7%	21.6%
Cesaretti (2015) [21], Cuba	71	3 years	No tissue-related issues	No structural issues	100%	0%

Weerapong *et al.* (2019) [22], Thailand	46	1 year	2 compact fixtures failed early	Crown breakages: 3 compact, 2 standard	Compact: 91.3%, Standard: 95.7%	10.87%
Agliardi *et al.* (2014) [23], Italy	20	50 months	No tissue-related issues	None observed	100%	0%
Amato *et al.* (2024) [24], Italy	178	6 to 10 years (average 7 years)	1 fixture failure in cohort 1	None observed	99.5%	0.56%
Daher *et al.* (2020) [25], Lebanon	120	12 months	Elevated bone resorption in second molars; implant inflammation	Structural failures in restoration connections	100%	15%
Esposito *et al.* (2024) [26], Italy	72	10 years	5 implant inflammation cases in load-bearing group	Restoration breakages and detachments	Non-load-bearing: 100%, Load-bearing: 94.12%	12.5%
Kim *et al.* (2021) [27], South Korea	102	12 months	2 infections at bone regeneration sites; implant inflammation (1 case)	Restoration breakages (4 in TI, 6 in SI groups)	TI: 96.2%, SI: 86.0%	11%

Incidence of complications

The reviewed publications displayed wide discrepancies in follow-up duration, extending from 1 to 10 years, which was accompanied by substantial variation in both biological and mechanical complication frequencies. Research with shorter monitoring periods—around one year—tended to show more early implant losses and mechanical issues, such as fractures of crowns. In contrast, investigations conducted over longer intervals (up to ten years) identified a greater prevalence of biological conditions like peri-implantitis, together with prosthetic fractures and other mechanical failures.

Reported implant survival rates were inconsistent: while some studies documented no failures even after several years, others noted early or progressive complications. Overall, these findings highlight considerable diversity in performance outcomes, which appear to depend on design type, implant characteristics, and observation period. The summarized relationship between follow-up length and overall complication rate is illustrated in **Figure 2**.

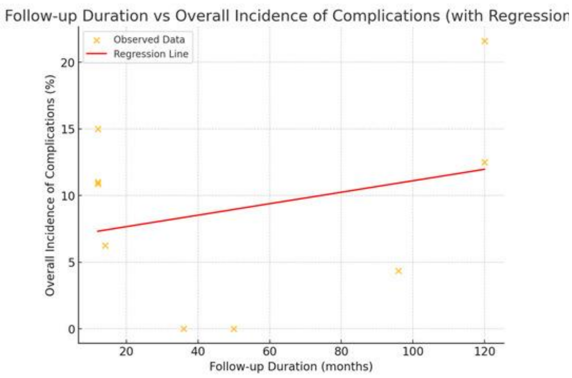

Figure 2. Relationship between duration of follow-up and total complication occurrence

Results from the linear regression analysis revealed that the connection between follow-up duration and complication rate was weak. The slope value (0.043) suggested that for every month added, complications increased by approximately 0.043%. The intercept, measured at 6.81, represents the projected complication level at time zero. The determination coefficient ($R^2 = 0.081$) indicated that only 8.1% of the variance in complication frequency could be explained by the linear relationship, reflecting very limited model fit. A 95% confidence interval was used to evaluate precision.

A Spearman correlation test further confirmed this observation, yielding a coefficient of 0.043 and a p-value of 0.913, signifying no statistically relevant correlation between the duration of observation and complication rate.

Collectively, the statistical data demonstrate no meaningful linear relationship between time of follow-up and the occurrence of complications. This absence of association might result from uncontrolled confounders, variations in sample design, or inherent random variation across studies.

Complication trends in relation to follow-up duration

Biological complications

• Slope (0.0595): Each additional month of follow-up corresponded to an approximate increase of 0.0595 units in biological complication rate, suggesting a gradual escalation over time.

• Intercept (−0.309): The theoretical baseline at 0 months was close to zero (−0.309), implying minimal initial biological issues.

• R^2 (0.522): About 52.2% of the variation in biological complications was explained by follow-up duration, indicating a moderate positive association.

Mechanical complications

• Slope (0.1299): Mechanical complications rose more sharply, with a slope of 0.1299, showing a faster accumulation rate compared to biological factors.

• Intercept (−0.624): The starting point, at 0 months, was −0.624, suggesting almost no early mechanical complications.

• R^2 (0.199): The 19.9% explanatory power indicates that factors other than follow-up duration largely influenced mechanical outcomes.

In summary, biological complications displayed a moderate correlation with extended follow-up periods, reflecting their progressive development over time. Mechanical complications, however, were less dependent on time, implying a greater contribution from external, procedural, or material-related influences rather than duration itself.

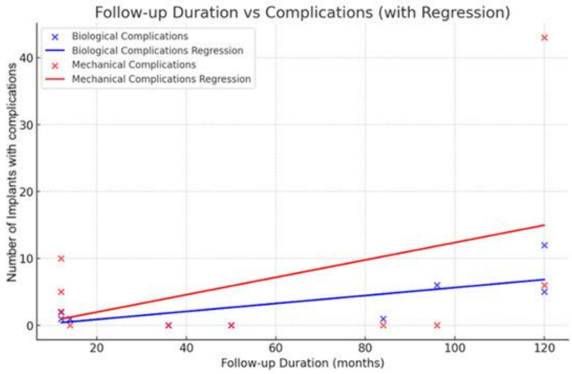

Figure 3. Scatter plots with linear regression lines showing the relationship between follow-up duration and the incidence of biological and mechanical complications.

Primary stability

A consistent topic throughout the reviewed literature was the evaluation of primary implant stability, as detailed in **Table 6**.

Table 6. Overview of assessment techniques and findings related to primary stability.

Citation, Year, Location	Anchor Strength Assessment
Perelli *et al.* (2020) [18], Italy	Twist Resistance: 47.12 ± 6.37 Ncm (Tapered); 41.60 ± 9.77 Ncm (Straight)
Anitua *et al.* (2019) [19], Spain	ISQ metrics evaluated (Osstell Mentor)
Maló *et al.* (2015) [20], Portugal	Twist Resistance > 30 Ncm mandated for instant application
Cesaretti (2015) [21], Cuba	Oscillation Analysis (RFA), ISQ metrics > 70
Weerapong *et al.* (2019) [22], Thailand	Manual Twist Devices, no specific benchmarks reported
Agliardi *et al.* (2014) [23], Italy	Twist Resistance ≥ 35 Ncm (Anchor reliability threshold)
Amato *et al.* (2024) [24], Italy	Twist Resistance captured, exact figures not shared
Daher *et al.* (2020) [25], Lebanon	ISQ values recorded at 3, 6, and 12 months
Esposito *et al.* (2024) [26], Italy	Twist Resistance: spanning 30–50 Ncm
Kim *et al.* (2021) [27], Republic of Korea	No specific mention of anchor strength evaluation

Across all included studies, insertion torque was repeatedly emphasized as a key determinant of initial implant stability. The optimal torque range identified was 30–50 Ncm, which is regarded as essential for ensuring success in immediate loading protocols. Several authors proposed that a minimum torque of 35 Ncm should be achieved before functional loading begins.

Two main approaches were used to assess implant stability.

The first method, Resonance Frequency Analysis (RFA), was adopted in six investigations and expressed as Implant Stability Quotient (ISQ) values. RFA serves as an indirect indicator of the rigidity between the bone and implant interface and remains one of the most reliable methods for evaluating both initial fixation and long-term stability [23–27].

The second commonly used approach involved manual torque measurements, implemented in four studies, where the insertion torque was recorded during placement using torque wrenches to confirm that sufficient mechanical fixation was achieved [18–22].

These findings collectively demonstrate the methodological variation across studies and underline how crucial stability measurement is to the overall clinical predictability of immediately loaded implants.

Discussion

The immediate loading approach has gained growing clinical acceptance because it reduces treatment duration and enhances patient comfort by placing temporary restorations soon after implant surgery. Evidence shows that marginal bone preservation and implant survival rates under immediate protocols are comparable to those achieved with delayed loading techniques [28].

For example, Cesaretti *et al.* observed that over a three-year period, both immediate and delayed loading yielded similar survival rates and marginal bone levels, demonstrating the reliability of either approach. Likewise, Amato *et al.* documented a 99.5% cumulative success rate for immediate loading, confirming its predictability. Perilli *et al.* further verified that short implants show no significant difference in survival whether placed under immediate or delayed conditions, which is especially relevant when bone augmentation can be avoided. Similarly, Daher *et al.*, through a split-mouth study, found no difference in implant or prosthesis failure rates over three years, reinforcing the effectiveness of both strategies.

Nevertheless, delayed loading continues to be a reliable and conservative option, particularly when longer healing times are required for full osseointegration [29]. Conversely, immediate loading presents certain risks, including early implant failure, which makes strict control of primary stability imperative [30].

Another factor crucial to the long-term outcome of immediate rehabilitation is the selection of prosthetic materials. Studies by Maló and Agliardi demonstrated that while acrylic resin can be used for temporary restorations, stronger and more durable solutions—such as metal-ceramic or titanium CAD/CAM frameworks—offer superior longevity and esthetics. These advanced materials support predictable function and higher patient satisfaction.

Advancements in digital CAD/CAM technology have also significantly enhanced precision in fabricating crowns and bridges, improving both accuracy and efficiency [31]. Amato *et al.* employed hybrid ceramic crowns produced via CAD/CAM for immediate restorations, achieving greater treatment precision. Maló and Agliardi utilized a two-phase protocol, beginning with acrylic bridges during initial healing, which were later replaced (after six months) with titanium CAD/CAM frameworks.

Among the reviewed studies, Heinemann *et al.* uniquely examined occlusal loading management. Their trial compared non-occluding temporary prostheses to definitive occluding partial prostheses, emphasizing that occlusal adjustments strongly affect functional outcomes, patient satisfaction, and overall treatment dynamics. Their work underscores the importance of occlusal load control as a decisive factor in achieving optimal success in implant-supported rehabilitation.

Graft-free techniques have gained significant attention in contemporary fixed implant rehabilitation due to their ability to simplify treatment and eliminate the need for complex bone augmentation methods [32]. As an effective alternative, short dental implants have been increasingly used for patients presenting with restricted bone height [33, 34], reducing reliance on surgical interventions like sinus elevation or ridge grafting [35, 36]. Investigations by Anitua *et al.* and Perilli *et al.* confirmed that these short implants demonstrate high long-term survival rates, independent of whether immediate or delayed loading strategies were implemented. These outcomes emphasize the predictability of short implants while also decreasing invasiveness, cost, and treatment duration. Nevertheless, ensuring adequate primary stability remains essential, particularly in immediate loading protocols [37-39].

The mode of prosthetic retention—whether screw-retained or cement-retained—plays a major role in the clinical success of the restoration. While screw-retained prostheses facilitate retrievability and maintenance, cement-retained designs may yield superior aesthetic outcomes. Findings from Heinemann *et al.* and Amato *et al.* reflect the adaptability of these retention systems, allowing customization to suit different clinical conditions.

Across all included studies, implant survival rates and marginal bone stability were consistently high under both loading methods and with various restorative materials [40-42]. According to Cesaretti *et al.* and Agliardi *et al.*, no statistically significant differences were noted in marginal bone alterations between test and control groups, reaffirming the reliability of both strategies in achieving stable long-term performance. Collectively, these findings highlight the versatility and dependability of current implant loading protocols across a range of treatment scenarios [43]. However, challenges such as the elevated early failure risk linked to immediate loading and technical complications observed in some methods underscore the necessity for precise planning and meticulous execution to further refine success outcomes [44-46].

Over the past decade, increased attention has been devoted to evaluating full-arch immediate loading outcomes, revealing distinct differences between the maxilla and mandible [47, 48]. For example, long-term investigations of all-on-four protocols in a Japanese population reported favorable cumulative survival rates, though the maxilla exhibited a slightly higher incidence of late failures compared to the mandible [49].

Data from the present systematic review indicate that in posterior jaw regions, the failure frequencies between maxillary and mandibular implants under immediate loading were generally comparable. Complication rates reported across studies varied from 0% to 21%, with follow-up durations ranging between 12 months and 10 years. Although statistical analysis showed only a weak correlation between follow-up length and complication incidence, a subtle trend suggested that longer observation periods might correspond to increased biological complications. This pattern, however, remains statistically inconclusive and should be interpreted with caution. The trend is consistent with data from traditional fixed prosthesis research, where extended loading durations have similarly been associated with biological and mechanical complications [50].

Interestingly, Maló *et al.* [20] noted a greater occurrence of mechanical failures, which they attributed to support design and cantilever use. This suggests that reducing or optimizing cantilever extensions may decrease the likelihood of mechanical complications in implant-supported frameworks [51]. Overall, both arches demonstrate high survival outcomes under immediate loading, though the maxilla appears more susceptible to early failures [52]. Moreover, the frequency of biological issues seems to rise with long-term monitoring, reinforcing the importance of consistent post-treatment follow-up and strategic prosthetic design to minimize adverse effects [53].

The reviewed studies described diverse applications of immediate loading and prosthetic fabrication protocols, primarily aimed at enhancing patient satisfaction and shortening treatment timelines. For example, Cesaretti *et al.* implemented a functional immediate loading approach within one hour post-placement, utilizing octa-abutments and temporary abutments before delivering final metal-ceramic reconstructions. Similarly, Amato *et al.* investigated two- to four-unit restorations in both the maxilla and mandible, where provisional prostheses—either screw-retained or cemented—were installed and later replaced with final abutments and definitive impressions after six months. Perilli *et al.* performed immediate screw-retained provisionalization within 24 hours after surgery, while Anitua *et al.* successfully used short implants under immediate load, regardless of whether they were splinted to other short or long implants, achieving high predictability in all configurations.

These results highlight the variability in immediate loading and prosthetic strategies, while also stressing the importance of structured occlusal load management, as emphasized in the study by Heinemann *et al.* This factor remains a key determinant for achieving predictable implant outcomes [54, 55].

It is worth noting that most of the reviewed works did not specify drilling protocols [56]. Among the selected studies, only Anitua *et al.* provided detailed information regarding their drilling procedure. They utilized a low-speed drilling technique (125 rpm) without irrigation, aimed at minimizing thermal injury to the bone while allowing bone collection for grafting purposes. Additionally, the protocol incorporated Plasma Rich in Growth Factors (PRGF) before implant placement. Other studies, such as those by Cesaretti *et al.* and Amato *et al.*, offered some procedural guidance but lacked detailed specifications, leaving uncertainty about variations that might influence outcomes. Given the absence of comprehensive descriptions in most studies, comparisons primarily focused on implant survival, osseointegration, and complication rates. This variability underscores the need for future research to precisely document surgical techniques, particularly drilling methods, as they directly affect clinical success. Establishing standardized procedural guidelines, informed by outcome metrics, could enhance consistency and support evidence-based practice.

Across the reviewed literature, multiple methods were applied to assess primary stability, including insertion torque, resonance frequency analysis (RFA), and Implant Stability Quotient (ISQ) measurements [57, 58]. Most studies relied on insertion torque to evaluate mechanical engagement during placement. For example, Perelli *et al.* [18] reported that tapered implants achieved a torque of 47.12 ± 6.37 Ncm, higher than straight implants (41.60 ± 9.77 Ncm), illustrating the influence of implant geometry on stability. According to Maló *et al.* [20], a minimum torque of >30 Ncm is necessary for immediate loading, while Agliardi *et al.* [23] recommended a threshold of ≥35 Ncm.

RFA was widely employed using devices such as Osstell Mentor, providing ISQ values to monitor stability over time. Anitua *et al.* [19] reported that an ISQ >70 predicted favorable outcomes. Manual torque wrenches were also used in studies like Weerapong *et al.* [22], allowing measurement of insertion torque without specifying a threshold. Some studies additionally performed periodic stability checks at 3, 6, and 12 months, providing insight into dynamic implant behavior over time.

Several limitations must be acknowledged in this review. Methodologies differed greatly, reflecting the diversity of clinical settings and research designs, which highlights the need for standardized reporting to enable valid comparisons. Heterogeneity in data, particularly for radiographic evaluations, was a major challenge [59]. Furthermore, publication bias may have arisen from excluding non-English studies and restricting the search to the past ten years. Differences in radiographic assessment methods prevented robust meta-analysis, while probing data were reported in only three studies, limiting conclusions on peri-implant soft tissue health. Variations in implant types and prosthetic designs across studies can obscure clinically significant differences, despite offering a broader perspective on overall performance. Future research should consider stratified analyses based on these variables to enable more tailored clinical guidance. Additionally, long-term studies are scarce; more research is required with extended follow-up to assess durability and stability of outcomes. Standardized reporting frameworks in longitudinal trials could address these gaps and enhance understanding of factors influencing long-term implant success.

Conclusions

This review highlights the heterogeneity of current studies on immediate loading for implant-supported fixed partial prostheses in posterior regions, including variability in prosthetic materials, implant types, and implant lengths. A common element across all studies was the emphasis on primary stability. Although all authors acknowledged the necessity of controlling occlusal forces to prevent overloading and compromising osseointegration, no standardized protocols for occlusal adjustment were reported.

The average success rate for immediate loading in posterior regions was 96.5%, with complication rates of 8.2%, calculated from the included studies. These findings suggest that immediate loading is a valid and patient-centered therapeutic approach, providing efficient treatment without compromising long-term outcomes. Further studies employing comparable protocols are needed to strengthen the evidence base and refine clinical recommendations.

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