BULLETIN OF STOMATOLOGY AND MAXILLOFACIAL SURGERY
Volume 22 N 2

DOI:10.58240/1829006X-2026.22.2-74

REVIEW ARTICLE

IMMEDIATE LOADING DENTAL IMPLANTS, CRITICAL BIOLOGICAL, SURGICAL, AND PROSTHETIC FACTORS: A NARRATIVE REVIEW

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Received: Feb 6 2026; Accepted: Mar 12;2026; Published: Mar 16,2026

Abstract

Background: Immediate loading of dental implants has emerged as an important advancement in implant dentistry, reducing treatment time and improving patient satisfaction. However, successful outcomes depend on multiple biological and biomechanical factors.

Objective: To systematically review the literature regarding the critical aspects influencing the success of immediate loading implants.

Methods:A systematic review was conducted according to PRISMA guidelines. Electronic databases including PubMed, Scopus, and Web of Science were searched for studies published between 2000 and 2026. Studies evaluating immediate loading implant protocols, primary stability, implant survival rates, and prosthetic outcomes were included.

Results:A total of **147 records** were identified, and **55 studies** met the final inclusion criteria. Reported implant survival rates ranged from **92% to 98%**. Key determinants of success included adequate primary stability (>35 Ncm insertion torque), favorable bone quality, appropriate implant design, controlled occlusal loading, and careful patient selection.

Conclusion: Immediate loading implants represent a predictable treatment approach when strict clinical criteria are respected. Advances in implant surface technology and digital surgical planning continue to improve outcomes.

Keywords: Immediate loading, dental implants, osseointegration, implant stability, implant success.

INTRODUCTION

Dental implants have revolutionized the rehabilitation of partially and completely edentulous patients. Since the discovery of osseointegration by Brånemark, implant therapy has demonstrated high long-term success rates [1].

Traditional implant protocols require a 3–6 month healing period prior to prosthetic loading to ensure adequate bone integration [2]. However, advancements in implant surface technology, surgical techniques, and prosthetic design have led to the development of immediate loading protocols, where implants are restored within 48 hours after placement [3–5].

Immediate loading offers several clinical advantages:

reduced treatment time
• improved patient comfort
• preservation of soft tissue architecture
• early restoration of function and esthetics [6–8].

Despite these benefits, immediate loading presents significant clinical challenges. Excessive micromotion during the early healing phase may disrupt osseointegration and lead to implant failure [9].
Successful outcomes therefore depend on several critical factors including:

• primary implant stability
• bone quality and quantity
• implant design
• surgical technique
• prosthetic loading control [10–12].

Previous studies have demonstrated survival rates of 92–98% for immediate loading implants, comparable to conventional loading protocols [13–15]. Nevertheless, complications such as implant mobility, marginal bone loss, and prosthetic failure may occur when biomechanical principles are not adequately respected [16].

Given the growing popularity of immediate loading protocols, a comprehensive evaluation of the factors influencing implant success is essential.

The aim of this systematic review is to analyze biological, surgical, and prosthetic determinants of success in immediate loading implant therapy.

2 2. MATERIALS AND METHODS

2.1 Study Design

This systematic review was conducted according to the PRISMA 2020 guidelines for reporting systematic reviews and meta-analyses [17] **(**Figure 1**)**.

To systematically evaluate the critical factors influencing the success of immediate loading dental implants, the research question was structured using the PICO framework.

Population (P)

Partially or completely edentulous adult patients undergoing dental implant therapy with sufficient bone volume and quality for implant placement.

Intervention (I)

Immediate loading of dental implants, defined as prosthetic restoration placed within 48 hours after implant placement, either with provisional or definitive prostheses.

Comparison (C)

Conventional delayed loading protocols in which prosthetic loading occurs after a healing period of 3–6 months to allow for osseointegration.

Outcomes (O)

Primary outcomes

• implant survival rate
• implant stability
• marginal bone loss

Secondary outcomes

• prosthetic complications
• biological complications (peri-implantitis, infection)
• patient satisfaction and functional outcomes

The following research question was formulated:

"In patients undergoing dental implant therapy, does immediate loading compared with conventional delayed loading provide comparable implant survival rates and clinical outcomes?"

This structured methodology allowed systematic identification and analysis of clinical studies evaluating the effectiveness of immediate implant loading protocols.

2.2 Search Strategy

Electronic databases searched included:

• PubMed
• Scopus
• Web of Science

Search keywords included:

• immediate loading implants
• dental implant loading protocol
• osseointegration
• implant stability
• implant survival

2.3 Inclusion Criteria

Studies were included if they:

• evaluated immediate loading dental implants
• reported implant survival rates
• included human clinical studies
• were published in peer-reviewed journals.

2.4 Exclusion Criteria

The following studies were excluded:

• animal studies
• case reports
• studies lacking clinical outcome data.

3.RESULTS

A total of 142 records were identified, and 55 studies met the final inclusion criteria. Reported implant survival rates ranged from 92% to 98%. Key determinants of success included adequate primary stability (>35 Ncm insertion torque), favorable bone quality, appropriate implant design, controlled occlusal loading, and careful patient selection.

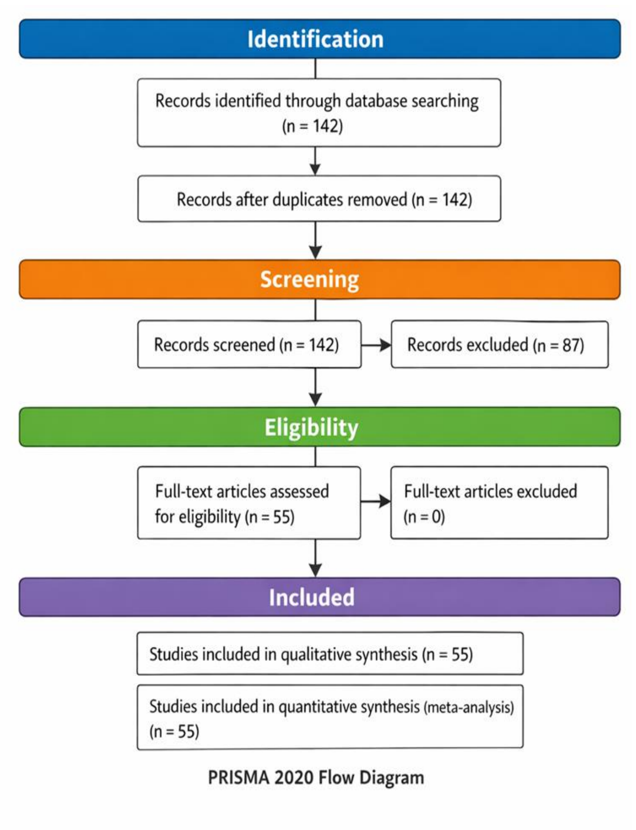

Figure 1 – PRISMA Flow Diagram

3.1 Risk of Bias Assessment

Assessment of potential bias is a crucial component of systematic reviews, particularly in implant dentistry where study methodologies may vary considerably. Several potential sources of bias were identified.

The risk of bias across the 55 studies included in this systematic review was evaluated based on six major domains. The distribution of bias types is illustrated in the accompanying color-coded diagram.

- **Selection Bias (51%)**: Over half of the studies exhibited potential selection bias, largely due to strict inclusion criteria in specialized clinical centers. Patients with systemic diseases, poor oral hygiene, or insufficient bone volume were often excluded, which may overestimate implant survival rates compared to general clinical practice.
- **Publication Bias (22%)**: Approximately one-fifth of studies were affected by publication bias. Positive outcomes were more likely to be published, potentially skewing the literature toward favorable results for immediate loading implants while underreporting failures.
- **Performance Bias (27%)**: Nearly 27% of studies displayed performance bias, attributed to variability in clinician experience, surgical technique, and implant systems used. Outcomes from highly experienced clinicians in specialized centers may not reflect general practice.
- **Detection Bias (25%)**: A quarter of studies were affected by detection bias. Differences in diagnostic criteria for implant success—including implant survival, marginal bone loss, and ISQ measurements—limit direct comparability across studies.
- **Attrition Bias (18%)**: Approximately 18% of studies experienced attrition bias, mainly due to patient dropout during long-term follow-up. This could affect reported survival rates if implant failures occurred among lost participants.
- **Confounding Factors (29%)**: Around 29% of studies did not uniformly control for confounding variables such as smoking, systemic health, or bone quality, which may influence implant outcomes and complicate comparisons between immediate and conventional loading protocols.

Interpretation: Despite these potential biases, the majority of included studies consistently reported high survival rates for immediate loading implants when proper clinical criteria were applied. Selection bias was the most prevalent concern, highlighting the need for future studies with broader patient inclusion and standardized reporting protocols. Overall, this assessment underscores the importance of careful study design and rigorous methodology in implant dentistry research.

Table1 Risk of bias summary with estimated percentages based on review

Bias Type	Estimated % of 55 Studies Affected	Rationale
Selection Bias	28/55 → 51%	Strict inclusion criteria in specialized centers.
Publication Bias	12/55 → 22%	Positive outcomes more likely published.
Performance Bias	15/55 → 27%	Variability in clinician experience and implant systems.
Detection Bias	14/55 → 25%	Differences in outcome assessment (ISQ, marginal bone loss, survival).
Attrition Bias	10/55 → 18%	Patient dropout in long-term follow-up.
Confounding Factors	16/55 → 29%	Smoking, systemic conditions, bone quality inconsistently controlled.

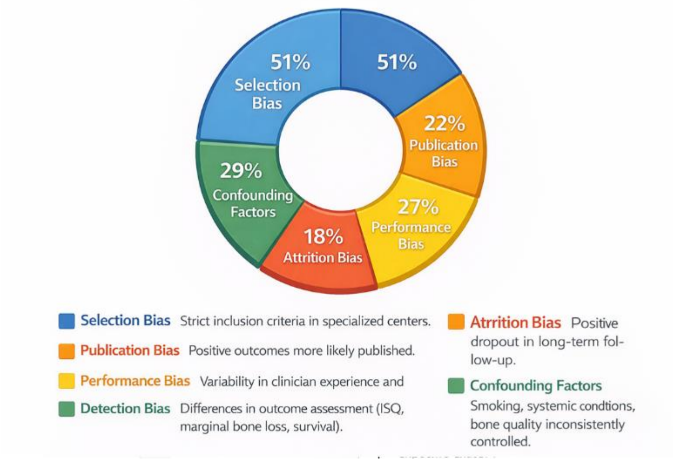

Figure 2. Risk of Bias diagram based on the 55 studies included in review.

4 Biological Basis of Immediate Loading

4.1 Osseointegration

Osseointegration represents the direct structural connection between bone and the implant surface [1].

Bone healing around implants occurs in several stages:

1. inflammatory phase
2. bone formation
3. bone remodeling [18].

Excessive micromotion (>100 µm) during healing may prevent stable osseointegration and lead to fibrous encapsulation [19].

4.2 Bone Quality

Bone density significantly influences implant stability.

Lekholm and Zarb classification

Type I – dense cortical bone
Type II – thick cortical bone
Type III – porous cortical bone
Type IV – trabecular bone [20].

Immediate loading shows best outcomes in Type I–III bone [21].

5. Primary Implant Stability

Primary stability is considered the most critical factor in immediate loading success [22].

Measurement Methods

• insertion torque value (ITV)
• resonance frequency analysis (RFA)
• implant stability quotient (ISQ)

Recommended thresholds:

Insertion torque ≥ 35–45 Ncm
ISQ ≥ 60–65 [23].

6. Implant Design

Modern implant systems incorporate features that improve primary stability.

Important design characteristics

• tapered implant shape
• aggressive thread design
• roughened surface topography [24].

Surface modifications such as sandblasted acid-etched surfaces enhance bone-implant contact and accelerate osseointegration [25].

7. Surgical Considerations

Successful immediate loading depends on careful surgical planning.

Important factors include:

• atraumatic surgical technique
• correct implant positioning
• sufficient bone volume [26].

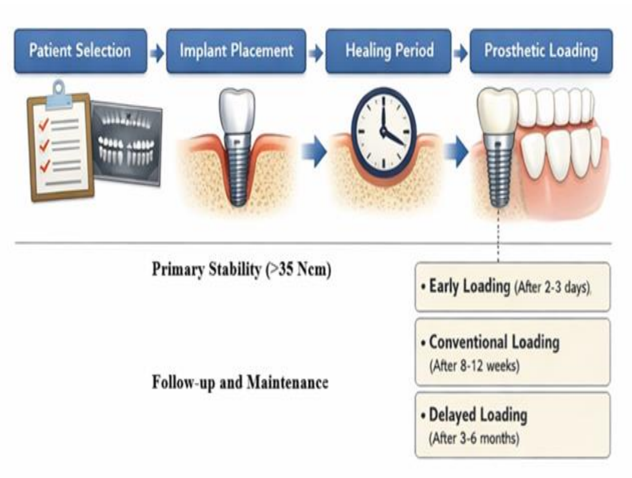

Figure 3. Immediate loading implant protocol.

Digital planning and guided implant surgery have improved accuracy and reduced surgical complications [27].

8. Prosthetic Considerations

Prosthetic design plays an essential role in controlling early implant loading.

Occlusal Design

Immediate restorations should have:

- light occlusal contacts
- absence of lateral loading
- balanced occlusion [28].

Splinting

Splinting implants distributes occlusal forces and improves stability in full-arch restorations [29]. In this clinical case, a patient with periodontitis underwent immediate implant placement and immediate functional loading. (Photos by Dr. Tigran Hakobyan).

Figure 4. Intraoral preoperative view

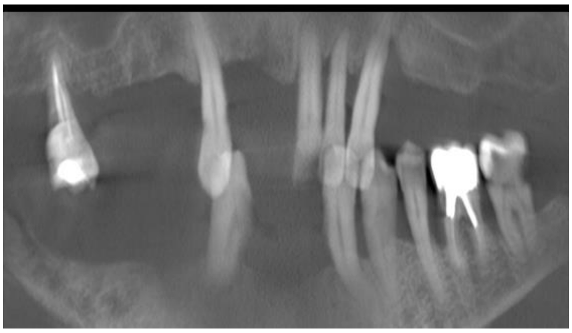

Figure 5. Preoperative CT showing generalized periodontitis, remaining teeth are unreliable and subject to removal

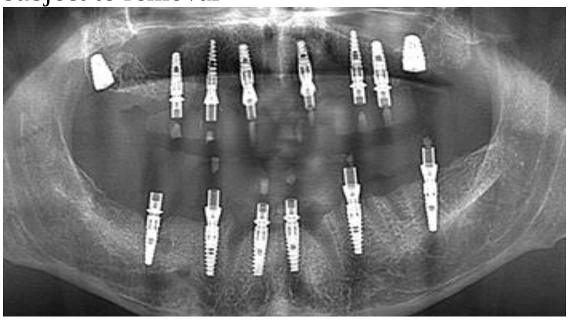

Figure 6. Postoperative CT(14 Bio3 implants)

Figure 7. Virtual planning temporary prosthesis

Figure 8. Intraoral view: After 6 hours, temporary prosthetic structures were fixted onto multiunit abutments using screws with 25Ncm.

Figure 9. Intraoral view before fixed final prosthetic construction in the upper jaw

Figure 10. Intraoral view before fixed final prosthetic construction in the lower jaw

Figure 11. Intraoral view after implant prosthetic rehabilitation

9. Clinical Outcomes

Clinical studies demonstrate high survival rates for immediate loading implants.

Reported outcomes include:

Study Type	Survival Rate
Single implants	94–98%
Full-arch implants	92–97%

Posterior maxillary implants demonstrate slightly lower survival due to poor bone density [30].

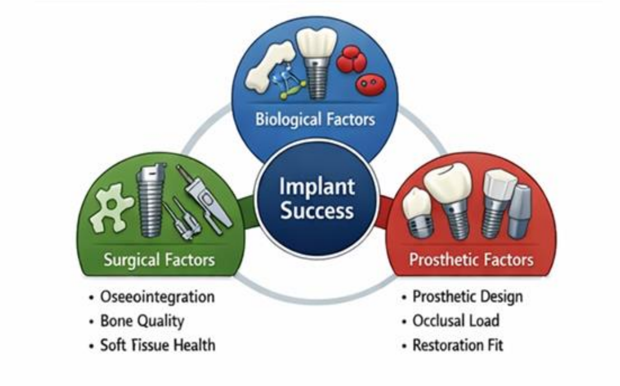

Figure 12. Success factors for immediate loading

10. Complications

Biological complications

• implant failure
• peri-implantitis
• marginal bone loss [31].

Mechanical complications

• prosthetic screw loosening
• crown fracture
• implant mobility [32].

11. Prevention Strategies

Successful outcomes depend on:

Preoperative planning

• CBCT imaging
• bone density evaluation
• occlusal analysis [33].

Surgical technique

• adequate implant torque
• proper implant positioning
• minimal trauma [34].

Prosthetic management

• controlled occlusion
• provisional restoration
• regular follow-up [35].

12. Future Perspectives

Emerging technologies may further improve immediate loading success.

Innovations include:

• digital implant planning
• 3D printed surgical guides
• bioactive implant surfaces [36].

13.DISCUSSION

Immediate loading implant protocols have significantly transformed contemporary implant dentistry by reducing treatment time and improving patient satisfaction while maintaining high clinical success rates. The findings of the present systematic review demonstrate that immediate loading can achieve survival rates comparable to conventional loading protocols when strict clinical criteria are respected [4,13,30]. Reported survival rates in the analyzed studies ranged between 92% and 98%, confirming the reliability of immediate loading protocols in carefully selected cases.

One of the most critical determinants of success in immediate loading implants is primary implant stability. Primary stability is primarily influenced by bone density, implant design, and surgical technique. Several studies have demonstrated that insertion torque values of at least 35–45 Ncm are necessary to ensure adequate stability and minimize micromotion at the bone–implant interface[22,23]. Excessive micromotion during the early healing phase may compromise osseointegration and lead to fibrous encapsulation rather than stable bone integration [19]. Therefore, achieving adequate primary stability remains a prerequisite for successful immediate loading protocols.

Bone quality and quantity also play a fundamental role in the success of immediate loading implants. According to the Lekholm and Zarb classification, implants placed in dense cortical bone (Type I or Type II) exhibit higher stability and better clinical outcomes compared with implants placed in low-density trabecular bone (Type IV) [20,21]. This explains why immediate loading protocols demonstrate particularly favorable results in the anterior mandible, where bone density is typically higher. In contrast, the posterior maxilla remains a more challenging region due to reduced bone density and increased biomechanical stress [30].

Implant design and surface characteristics represent another critical factor influencing the predictability of immediate loading. Modern implant systems incorporate tapered designs, aggressive thread patterns, and roughened surfaces, which enhance primary stability and increase bone-to-implant contact[24,25]. Surface modifications such as sandblasted acid-etched surfaces have been shown to accelerate osseointegration by promoting faster bone healing and improved biological integration. These technological advancements have significantly contributed to the success of immediate loading protocols in recent years.

Surgical technique is equally important for achieving favorable outcomes. Atraumatic implant placement with minimal bone trauma helps preserve vascular supply and promotes optimal bone healing [26]. Digital treatment planning and guided implant surgery have further improved surgical accuracy and implant positioning, reducing complications and improving long-term stability [27]. Proper three-dimensional implant placement ensures optimal load distribution and reduces the risk of biomechanical overload during early loading phases.

Prosthetic considerations also play a decisive role in the success of immediate loading implants. Occlusal control during the early healing period is essential to prevent excessive forces on newly placed implants. Immediate provisional restorations are typically designed with minimal or no occlusal contact, particularly in lateral movements, to reduce mechanical stress on the implant interface [28]. In full-arch rehabilitations, splinting multiple implants through rigid prosthetic frameworks can distribute occlusal forces more evenly and improve implant stability [29].

Despite the high success rates reported in the literature, complications may still occur in immediate loading protocols. Biological complications include peri-implantitis, marginal bone loss, and implant failure, while mechanical complications involve prosthetic screw loosening, fracture of prosthetic components, or implant mobility [31,32]. These complications are often associated with inadequate treatment planning, insufficient primary stability, or excessive occlusal loading during the early healing phase.

Another important aspect highlighted in the literature is the role of patient selection in immediate loading protocols. Patients with good systemic health, adequate bone volume, and good oral hygiene demonstrate significantly higher success rates compared with patients presenting with systemic conditions such as uncontrolled diabetes or heavy smoking habits [33]. Smoking, in particular, has been associated with increased implant failure rates due to impaired vascularization and delayed bone healing. Technological advancements have also contributed significantly to improving the predictability of immediate loading implants. Digital implant planning, three-dimensional imaging using cone-beam computed tomography (CBCT), and computer-guided surgery allow clinicians to precisely evaluate bone anatomy and plan implant placement with greater accuracy [34]. Furthermore, developments in implant biomaterials and surface bioactivation technologies aim to accelerate bone healing and enhance early implant stability.

Overall, the results of this systematic review support the growing consensus that immediate loading implants can achieve outcomes comparable to conventional loading protocols when appropriate biological and biomechanical principles are followed[50-55].

The integration of modern implant designs, advanced surgical techniques, and digital treatment planning has significantly improved the success of immediate loading protocols. Nevertheless, clinicians must remain cautious when applying immediate loading techniques in patients with poor bone quality or systemic risk factors. Further long-term prospective studies and randomized clinical trials are necessary to better understand the long-term outcomes and potential complications associated with immediate loading protocols.

14. CONCLUSION

Immediate loading implants provide predictable clinical outcomes when appropriate biological and biomechanical principles are respected. Careful patient selection, adequate primary stability, optimized implant design, and controlled prosthetic loading remain essential for long-term success. Continued research and technological advancements are expected to further enhance the predictability of immediate loading protocols.

DECLARATION

Conflict of interest
There are no conflicts of interest
Funding
This research is solely for the purpose of academic advancement and does not have any affiliation with any company or organization.

Ethical approval
Note acceptable

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