JoSSEd
Journal of Science and Science Education
ISSN: 2774-1869 eISSN: 2774-2105

Materials and Osseointegration Processes in Dental Implants: A Systematic Review

Susanna Halim[1*], Niki Yuchinda[1], Jessica Angelie[1], Annisa Rizkia Ginting[1], Vonny Maria[1]

[1] Faculty of Medicine and Dentistry, University of Prima Indonesia, Indonesia

Received: November 13, 2025
Revised: March 21, 2026
Accepted: April 25, 2026
Published: April 30, 2026

Corresponding Author:
Susanna Halim
susannahalim@unprimdn.ac.id

DOI: 10.29303/jossed.v7i1.13455

Abstract: Tooth loss is a common oral health problem that affects chewing ability, appearance, and quality of life. Dental implants have become the most effective solution to restore both function and aesthetics. The success of dental implants depends on biomaterial composition and the osseointegration process between the implant and the alveolar bone. This study analyzed recent advancements in implant materials, surface modifications, and biological factors influencing osseointegration and long-term stability. A randomized clinical trial compared zirconia and titanium implants, evaluating various surface treatments and the use of nano-hydroxyapatite as a bioactive material to enhance osseointegration. Results showed that titanium and zirconia remain dominant implant materials, with clinical success rates above 90%. Surface treatments such as sandblasting, anodization, and nano-hydroxyapatite coating significantly improved osseointegration. Moreover, the application of Platelet-Rich Plasma (PRP) and Platelet-Rich Fibrin (PRF) accelerated tissue healing. Systemic conditions like diabetes, bone quality, and surgical techniques also affected outcomes. Overall, innovations in biomaterials and surface engineering have enhanced implant stability, aesthetics, and durability, showing great promise in improving clinical success and patients' quality of life.

Keywords: Dental Implant; Implant Surface Treatment; Osseointegration

Introduction

Oral health is a fundamental aspect in supporting essential functions such as chewing, speaking, and maintaining aesthetics and self-confidence. Optimal dental and oral conditions enable individuals to engage in social activities without feelings of embarrassment or discomfort (Kurniawati et al., 2023). However, oral diseases are classified as non-communicable diseases with the widest global prevalence. According to data from the World Health Organization (WHO), approximately 3.5 billion people, or nearly 45% of the global population, have experienced oral health problems at some point in their lives, ranging from childhood to old age (WHO, 2022). Based on the 2023 Indonesian Health Survey (SKI), 56.9% of Indonesians aged three years and older were reported to have experienced dental and oral health problems.

The 2023 Indonesian Health Survey (SKI) also reported a decrease in the DMF-T index (Decayed, Missing, and Filled Teeth) compared to the 2018 Basic Health Research (Riskesdas) data, as shown in Figure 1.1. Nevertheless, oral health conditions among Indonesians aged 3–4 years, 5 years, and above 35 years remain categorized as having a high to very high DMF-T index (Ministry of Health, 2023).

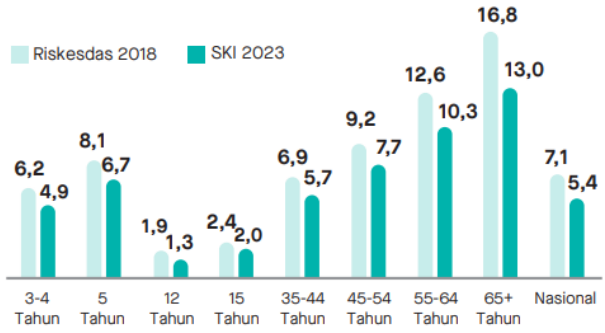

Figure 1. Oral and Dental Health Problems by age Group
Source: Ministry of Health, 2023

If oral and dental health problems are left untreated, they may progress into more severe conditions, potentially leading to tooth loss—particularly among adults and the elderly. Tooth loss, also known as edentulism, refers to the absence of one or more teeth in the dental arch, or even complete loss of all

How to Cite:
Halim, S., Yuchinda, N., Angelie, J., Ginting, A. R., & Maria, V. (2026). Materials and Osseointegration Processes in Dental Implants: A Systematic Review. *Journal of Science and Science Education*, *7*(1), 17–27. https://doi.org/10.29303/jossed.v7i1.13455

teeth. This condition can result in various complications, including alveolar bone resorption, displacement of adjacent teeth, and damage to supporting tissues, all of which may hinder the success of optimal prosthetic restorations (Wahyuni et al., 2021). Several factors contribute to tooth loss, such as dental caries, periodontal disease, trauma or injury, and the need for prosthodontic or orthodontic treatments. In addition, pathological conditions like pulpal and periradicular diseases, as well as certain systemic diseases, can also cause tooth loss. Among young adults, the predominant causes are dental caries and orthodontic considerations for tooth alignment improvement (Puspitasari et al., 2022).

The 2018 Basic Health Research (RISKESDAS) report indicated that the prevalence of tooth loss tends to increase with age, with the highest rate observed among individuals aged over 65 years, reaching 17.05%. Only 8.1% of the population received dental care or treatment from professional healthcare providers such as dentists (Ardinansyah et al., 2025). Furthermore, data from the 2023 Indonesian Health Survey (SKI) showed that the prevalence of tooth loss in Indonesia remains relatively high at 21% (Ramadhan et al., 2023).

A study by Juliatri and Anindita (2021) reported that 66% of individuals experienced the loss of one or more teeth, with a total of 240 missing teeth. The primary cause of tooth loss was dental caries, accounting for 144 teeth or approximately 60%. Among the missing teeth, 202 had not been replaced with dental prostheses. This finding highlights the high prevalence of tooth loss and the low utilization of dental prosthetics as a rehabilitative measure. Tooth loss can be effectively managed through the placement of dental implants, which function as artificial tooth roots embedded in the jawbone to support crowns or prosthetic teeth. This method provides greater comfort and stability compared to conventional dentures (Prawesthi et al., 2022).

Dental implants serve as replacements for missing teeth by surgically inserting a titanium-based material into the soft tissue and jawbone, allowing it to function like a natural tooth root in supporting a prosthetic crown. For optimal performance, implant materials must exhibit biocompatibility, sufficient mechanical strength, and the ability to support restorative structures. The dental implant system consists of three main components: the fixture, abutment, and superstructure. The fixture is the part embedded within the jawbone, the abutment serves as the connector between the fixture and the superstructure, and the superstructure represents the prosthetic restoration fixed atop the abutment to replace the lost tooth crown (Kusuma & Suwandi, 2023).

One of the main advantages of dental implants is their ability to provide comfort comparable to natural teeth, both in terms of function, aesthetic appearance, and adaptability within the oral cavity. Implants also demonstrate high durability, with a reported success or survival rate of approximately 90% over a period of up to 15 years (Halim & Poedjiastoeti, 2024).

This systematic review was designed to evaluate studies on dental implants that investigate various treatment strategies, clinical protocols, and peri-implant tissue maintenance techniques to assess their effectiveness in preserving the health of surrounding bone and soft tissues, as well as supporting the long-term success of implants.

The focus of this review is to identify the most effective maintenance protocols for preventing complications such as peri-implantitis, marginal bone loss, and implant failure, while also determining best practices that can be consistently implemented in clinical settings. Therefore, in vitro laboratory studies, cell-based research, and other non-clinical procedures were excluded to ensure that the analysis remains focused on clinical evidence related to dental implants.

Method

The twenty articles analyzed in this systematic review demonstrated diverse methodological characteristics, including clinical studies, case reports, experimental research, as well as systematic and narrative reviews. This methodological variation provides a comprehensive overview of the advancements in materials, surface treatments, and biological factors influencing the success of osseointegration in dental implants.

Several studies employed a systematic review and meta-analysis approach, such as that conducted by Morena et al. (2024), which examined randomized clinical trials in humans to compare the performance of zirconia and titanium implants. Statistical analyses were performed on survival rates, prosthetic complications, and marginal bone loss with a minimum follow-up period of one year. A similar approach was adopted by Shrivastava et al. (2024), who reviewed the relationship between implant material type and the incidence of peri-implantitis, as well as by Arefnia et al. (2025), who focused on patient-reported outcomes in the use of zirconia implants. Additionally, Hu et al. (2025) combined a systematic review with a retrospective case series to evaluate implant success in patients with pathological bone conditions such as cemento-osseous dysplasia, while Hao et al. (2021) conducted a meta-analysis of clinical and in vivo studies to compare the

effectiveness of various implant surface treatments on osseointegration levels.

On the other hand, several studies employed a narrative review approach to synthesize relevant literature without conducting formal statistical analyses. Hossain et al. (2023) summarized research findings on the development of metallic and ceramic materials for dental implants and the factors contributing to implant failure, while Muharni (2023) reviewed the potential application of nano-hydroxyapatite (nano-HA) as a bioactive material to accelerate the osseointegration process. Similarly, Arsista and Eriwati (2018) adopted a comparable approach by examining the design and function of various implant systems available on the market. Takefuji (2025) conducted a brief review highlighting factors influencing implant success and failure, including bone quality, surgical technique, and the patient's systemic condition.

Clinical and observational studies were also widely represented in this review. Goker et al. (2025) conducted a multicenter retrospective study analyzing patient data from various clinics to assess implant success rates and complications over a five-year follow-up period. Similarly, AlRowis et al. (2025) reviewed ten years of clinical data to determine the relationship between implant site, bone quality, and systemic diseases with implant failure rates. Rinda and Ariesanti (2023) performed an observational study on patients with dental implants to evaluate factors influencing early marginal bone loss, including implant design, occlusal load, and alveolar bone quality.

Several other studies were presented as clinical case reports, providing direct insights into the application of dental implants in specific situations. Kusuma and Suwandi (2023) reported a case involving the placement of a screw-cement retained prosthesis with an evaluation of its functional outcomes, while Prawesthi and Handayani (2023) described the fabrication process of a multilayered zirconia crown using CAD/CAM technology applied to an endosseous implant. Chandra and Gani (2023) reported the successful placement of an implant in a patient with diabetes mellitus under strict glycemic control, demonstrating that individuals with systemic conditions can still achieve favorable clinical outcomes with proper planning. Halim and Poedjiastoeti (2024) described a single implant placement in the posterior region using a standard surgical technique and recovery follow-up that showed optimal functional results, whereas Susanna Halim et al. (2024) reported the success of a sinus lift procedure using a minimally invasive osteotomy technique to increase bone volume prior to implant placement.

In addition to clinical studies and case reports, this review also included experimental and simulation-based research focusing on the development of implant materials. Sukaryo et al. (2023) conducted a laboratory study to synthesize a Zr-Nb alloy coated with Ti-N using the sputtering technique, followed by testing its mechanical properties and corrosion resistance. Firdhaus and Handoko (2023) employed Finite Element Analysis (FEA) simulations to analyze stress distribution and mechanical durability across various virtual implant designs.

Overall, the research methods employed across the twenty articles demonstrated an integration of experimental, clinical, observational, and literature review approaches. This combination provides a comprehensive understanding of the factors.

Scientific reports in both English and Indonesian published since 2020 and available on Google Scholar and ScienceDirect were systematically searched. The main keywords used included "dental implant," "implan gigi," "peri-implant care," "osseointegration," and "implant success." Since this review focuses on clinical outcomes and peri-implant tissue health, in vitro studies, purely laboratory-based research, and studies unrelated to dental implant placement or maintenance were excluded. Only experimental and clinical studies that directly evaluated dental implant outcomes were included in this analysis.

Specific aspects extracted from the included studies comprised the type of implant, the use of adjunctive materials or surface treatments, and peri-implant care regimens at designated follow-up periods. The aim was to enable a comprehensive comparison of various protocols and interventions to determine best practices for implant success and long-term peri-implant tissue health. Overall, the search yielded 20 relevant articles focusing on dental implant materials and treatment. The final selection included 20 studies that specifically evaluated factors influencing the success, survival, and maintenance of dental implants in clinical or experimental settings.

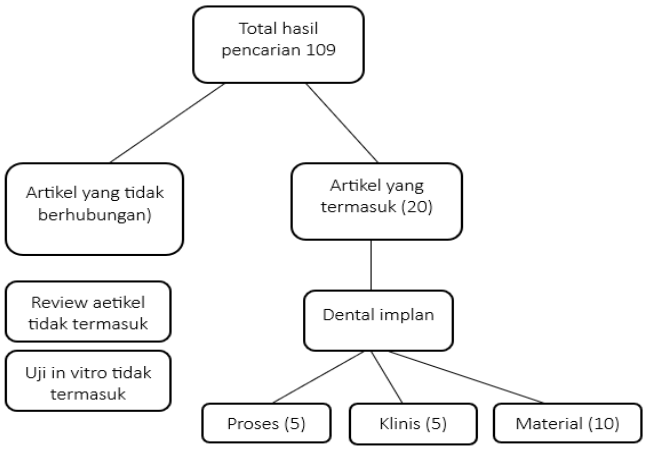

Figure 2. Systematic Review Flowchart

Result and Discussion

The use of zirconia material has clinical performance comparable to titanium in terms of survival rate of prosthetic complications and marginal bone loss (Morena et al., 2024). Research by Aremia et al. (2025) also reported high aesthetic results and satisfaction with zirconia implants. In a study by Hao et al. (2021), chemical modification and surface texture significantly improved osseointegration. The use of PRP and PRF also improved initial osseointegration and implant stability, especially in low-quality bone.

Table 1. Grouping of Included Studies

Grouping	Included Studies
Implant Materials	1. Morena et al. (2024) → Zirconia vs Titanium 2. Shrivastava et al. (2024) → Titanium & Zirconia 3. Arefnia et al. (2025) → Zirconia 4. Sukaryo et al. (2023) → Zr-Nb alloy 5. Muharni (2023) → Nano-hydroxyapatite (Nano-HA) 6. Arsista & Eriwati (2018) → Implant design; others discussed general topics
Surface Treatment / Coating	1. Hao et al. (2021) → Surface treatment in animal models 2. Sukaryo et al. (2023) → Ti-N sputtering 3. Muharni (2023) → Nano-hydroxyapatite coating
Biologics Supporting Osseointegration	Taghizadeh et al. (2024) → PRP & PRF
Clinical Outcomes	1. Goker et al. (2025) → Survival & clinical complications 2. AlRowis et al. (2025) → Failure factors 3. Hu et al. (2025) → Implants in cemento-osseous dysplasia 4. Chandra & Gani (2023) → Implants in diabetic patients 5. Rinda & Ariesanti (2023) → Marginal bone resorption 6. Takefuji (2025) → Prevalence & durability 7. Arefnia et al. (2025) → Patient-reported outcomes
Research Design	Systematic Review / Meta-analysis: Morena et al. (2024), Hao et al. (2021), Shrivastava et al. (2024), Arefnia et al. (2025), Hu et al. (2025) Narrative Review: Hossain et al. (2023), Arsista & Eriwati (2018), Muharni (2023), Takefuji (2025) Retrospective: Goker et al. (2025), AlRowis et al. (2025) Case Report / Clinical Case: Prawesthi & Handayani (2023), Halim & Poedjiastoeti (2024), Chandra & Gani (2023) Material Experiment: Sukaryo et al. (2023) Simulation: Firdhaus & Handoko (2023) Article Review: Halim et al. (2024)
Clinical Application Sites / Special Cases	Halim & Poedjiastoeti (2024) → Single posterior tooth loss Halim et al. (2024) → Post sinus lift / osteotomy Prawesthi & Handayani (2023) → CAD/CAM zirconia crown Chandra & Gani (2023) → Diabetic patients Hu et al. (2025) → Cemento-osseous dysplasia

Table 2. Studies Discussing Dental Implant Materials

Reference	Model / Subject	Tissue / Cell Type	Dose / Material Volume	Route / Technique of Administration	Co-administration Factors	Study Approach / Procedure	Time / Duration	Main Results / Findings
Morena et al. (2024)	Human (RCT)	Alveolar bone (implant site)	N/A	Endosseous implant placement	N/A	Systematic review and meta-analysis	≥1 year follow-up	Zirconia implants demonstrated comparable clinical success to titanium in terms of bone loss and implant stability. Both materials showed >90% survival rate.
Hossain et al. (2023)	Literature review (in vitro & in	Soft tissue	Various (dependin	Various implant materials	N/A	Narrative review	N/A	Summarized synthesis of multiple implant

Reference	Model / Subject	Tissue / Cell Type	Dose / Material Volume	Route / Technique of Administration	Co-administration Factors	Study Approach / Procedure	Time / Duration	Main Results / Findings
	vivo studies)	and bone	g on study)					materials (titanium, zirconia, ceramics, polymers), focusing on biocompatibility, cost, and strength factors.
Kusuma & Suwandi (2023)	Human (clinical study)	Implant–prosthesis interface	N/A	Screw cement retention system	Screw vs cement retention	Clinical procedural study	N/A	Screw-retained crowns showed easier retrievability and lower biological complications compared to cement-retained restorations.
Prawesthi & Handayani (2023)	Human (case study)	Anterior maxillary bone	N/A	CAD/CAM zirconia crown	N/A	Case report on prosthetic rehabilitation	≥1 year	Successful esthetic restoration with zirconia crowns; excellent soft tissue adaptation and gingival contour.
Arefnia et al. (2025)	Human (systematic review)	Peri-implant tissue	N/A	Placement of zirconia implants	N/A	Systematic review on patient-reported outcomes	≥1 year	Patients reported high satisfaction levels with zirconia implants; no significant difference in implant survival compared to titanium.
Sukaryo et al. (2023)	In vitro (material science)	Alloy surface	N/A	Ti–Nb sputtering	Sputtering pressure, material ratio	Material experiment	N/A	Ti–Nb alloy showed increased hardness, improved corrosion resistance, and better biocompatibility than pure titanium.
Muharni (2023)	Literature review (biomaterial)	Alveolar bone	N/A	Application of nano-hydroxyapatite	Various (nano-HA ratio)	Narrative review	N/A	Nano-hydroxyapatite enhances osseointegration, bone healing, and implant stability.
Firdhaus & Handoko (2023)	Simulation (Finite Element Analysis)	Virtual bone structure	N/A	Finite element simulation	N/A	Mechanical stress analysis on implant design	N/A	Design simulation revealed that implant shape significantly affects stress distribution and overall mechanical strength.

Table 3. Studies Discussing Osseointegration and Healing Process in Dental

Reference	Model / Subject	Tissue / Cell Focus	Approach / Intervention	Additional Factors	Observation Period	Main Findings
Hao et al. (2021) (Meta-analysis)	Clinical & in vivo studies	Peri-implant alveolar bone	Surface treatment of implants (SLA, anodization, plasma-sprayed)	Surface roughness, wettability, surface chemistry	6–24 months	Modified surface topography significantly enhances osseointegration and bone–implant contact compared to untreated surfaces.
Taghizadeh et al. (2024) (Systematic review)	Clinical & animal studies	Peri-implant tissue	Platelet-Rich Plasma (PRP) & Platelet-Rich Fibrin (PRF) as adjuvants	Growth factor concentration, application method	1–12 months	PRP & PRF improve osseointegration quality and accelerate implant stability, particularly in low bone density regions.
Chandra & Gani (2023)	Human (patients with type 2 diabetes mellitus)	Alveolar / mandibular bone	Conventional implant placement under controlled glycemic levels	Blood glucose control, aseptic procedure	Several months (until osseointegration achieved)	Implants achieved successful osseointegration in diabetic patients with good glycemic control, though healing was slower than normal patients.
Rinda & Ariesanti (2023)	Human (implant patients)	Peri-implant alveolar bone	Analysis of marginal bone loss	Implant design, bone quality, oral hygiene	3–12 months	Reduced marginal bone loss observed in patients with optimal bone quality and consistent oral hygiene maintenance.
Susanna Halim et al. (2024)	Human (sinus lift cases)	Posterior maxillary alveolar bone	Sinus lift with osteotomy and large bone graft	Minimally invasive surgical technique	2020–2024 (literature & case reports)	Osteotome technique effectively increases bone height and implant stability, with minimal trauma and improved esthetic outcomes.

Table 4. Studies Discussing Clinical Outcomes: Success, Failure Factors, and Complications of Dental Implants

Reference	Model / Subject	Focus / Variables	Approach / Method	Observation Period	Key Results / Findings
Goker et al. (2025)	Human (retrospective clinical study)	Implant survival rate and postoperative complications	Data collection from patient records; evaluation of clinical parameters	5-year follow-up	The overall implant survival rate exceeded 95%. Most complications were mild (peri-implant mucositis). Titanium implants showed higher long-term stability.
AlRowis et al. (2025)	Human (retrospective cohort)	Implant failure factors (systemic & procedural)	Retrospective analysis of failed implant cases	3–5 years	Major causes of failure included poor bone quality, uncontrolled diabetes, and smoking. Early detection and maintenance reduced failure rates significantly.
Hu et al. (2025)	Human (clinical study)	Dental implants in cemento-osseous dysplasia (COD) patients	Literature review and clinical case analysis	Variable (case-dependent)	Implant placement in COD areas is feasible with careful case selection and atraumatic technique, though bone remodeling

					response differs from normal bone.
Takefuji (2025)	Literature review (multi-country analysis)	Global prevalence, durability, and longevity of implants	Narrative review based on epidemiological data	2019–2024 data	The average survival rate of dental implants remains above 90% worldwide, with zirconia gaining attention for esthetic regions.
Prawesthi & Handayani (2023)	Human (case report)	Aesthetic and functional outcomes of zirconia crowns	Clinical rehabilitation of single anterior tooth	1-year post-placement	Excellent gingival response, color stability, and patient satisfaction achieved using zirconia prosthesis.
Halim & Poedjiastoeti (2024)	Human (case report)	Single posterior tooth loss rehabilitation	CAD/CAM fabricated zirconia crown placement	1-year follow-up	Restored masticatory function and improved aesthetics; stable soft tissue integration with no complications.
Arsista & Eriwati (2018)	Literature review	Implant design and biomechanical principles	Narrative synthesis of prior studies	N/A	Implant design strongly influences load distribution and marginal bone preservation. Cone-shaped and threaded implants improve long-term performance.

Dental Implant Materials

Based on the findings from several studies summarized in Table 2, it can be concluded that the selection of implant materials and surface treatments plays a fundamental role in the clinical success and osseointegration process of dental implants. Morena et al. (2024) reported that both titanium and zirconia implants demonstrated comparable clinical success rates, particularly in terms of survival rate and marginal bone stability. These findings indicate that zirconia represents a promising alternative to titanium, especially in fulfilling aesthetic demands in the anterior region. Similarly, Arefnia et al. (2025) emphasized that patients receiving zirconia implants reported high levels of aesthetic satisfaction and comfort, reinforcing the relevance of this material in meeting the needs of modern dental patients.

Furthermore, studies by Shrivastava et al. (2024) and Sukaryo et al. (2023) expanded the understanding of metallic material variations and novel alloys, such as the Zr-Nb alloy coated with Ti-N via sputtering. This surface treatment was shown to enhance mechanical strength and corrosion resistance—key challenges in the moist, electrolyte-rich oral environment. Meanwhile, Muharni (2023) examined the role of nano-hydroxyapatite (nano-HA) as a bioactive material capable of accelerating new bone formation and strengthening the bond between the implant and bone tissue. This nanoscale approach demonstrates significant potential in improving biological compatibility and the overall effectiveness of osseointegration.

Another study by Prawesthi and Handayani (2023) demonstrated the application of multilayered zirconia fabricated using CAD/CAM technology, which provides optimal aesthetic and functional outcomes for posterior teeth. The use of computer-aided design systems ensures high precision in crown fabrication, thereby reducing the risk of restoration failure. On the other hand, Hossain et al. (2023), through their narrative review, highlighted the development of various implant materials ranging from titanium alloys and zirconia to bioceramics, emphasizing that the success of these materials is highly influenced by their design, manufacturing process, and placement techniques.

In general, the findings from these studies indicate a shifting trend toward implant materials that combine high mechanical strength, corrosion resistance, and superior bioactivity. Innovations in surface engineering and the development of nanotechnology-based materials and novel metal alloys have further expanded the clinical options available to dental practitioners and patients. Consequently, future research in the field of dental implants is likely to focus on optimizing the combination of material composition and surface technology to achieve an ideal balance between function, aesthetics, and long-term biocompatibility.

Osseointegration Process

The dental implant placement process begins with a comprehensive preoperative evaluation. The dentist conducts a thorough medical and oral examination to ensure that the patient is a suitable candidate for the procedure (Rivero et al., 2025). Patients with systemic conditions, such as diabetes mellitus, require special

consideration due to their influence on bone and soft tissue healing. For diabetic patients, maintaining good glycemic control is essential to minimize the risk of complications. Chandra and Gani (2023) emphasized that well-controlled diabetic patients demonstrate implant success rates comparable to those of non-diabetic individuals. In addition, radiographic planning and an assessment of alveolar bone quality and quantity are performed to determine the optimal site for implant placement.

After the evaluation, the next step is the selection of an implant type suitable for the patient's condition and the restorative plan. Factors to consider include the implant's diameter, length, and surface design. Hao et al. (2021) demonstrated that implants with specific surface treatments, such as SLActive or TiUnite, can enhance the osseointegration process. These surface modifications influence both the speed and quality of bone integration with the implant. Selecting the appropriate surface is particularly crucial for patients with compromised bone conditions. Therefore, the choice of implant type and surface should be tailored to the patient's clinical situation.

The surgical phase begins with local anesthesia and an incision in the gingival mucosa to expose the alveolar bone. Osteotomy is then performed to prepare the implant site (Cho et al., 2021). In cases of vertical bone deficiency or low maxillary sinus position, augmentation procedures such as a sinus lift may be necessary. Susanna Halim et al. (2024) emphasized that the osteotomy technique for sinus lift is effective in enhancing initial implant stability and vertical bone volume. This procedure must be performed carefully to avoid complications such as sinus membrane perforation. Furthermore, precise planning of implant placement and angulation is critical to ensure long-term success.

After the implant site is prepared, the implant is placed with precision to ensure optimal orientation and primary stability. In patients with delayed healing potential, the use of PRP (Platelet-Rich Plasma) or PRF (Platelet-Rich Fibrin) may be considered. Taghizadeh et al. (2024) demonstrated that PRP and PRF can enhance primary stability and accelerate bone integration. This effect occurs because PRP/PRF stimulates cell proliferation and angiogenesis around the implant site (Acerra et al., 2025). Achieving good primary stability is crucial to reduce the risk of implant mobility and integration failure. Intraoperative monitoring is required to ensure that placement aligns precisely with the surgical plan.

During the healing period, it is crucial to regularly monitor the condition of the implant and surrounding tissues. Rinda and Ariesanti (2023) identified that mucosal thickness, implant vertical position, and surgical technique influence early marginal bone loss. Marginal bone loss can affect both the aesthetic outcome and the long-term stability of the implant. Radiographic and clinical examinations are performed to ensure proper bone integration. Good oral hygiene care and patient instruction regarding oral cleanliness are key to achieving success. Additionally, systemic factors such as blood glucose levels must be carefully controlled in diabetic patients.

After an adequate healing period, clinical and radiographic evaluations are performed to assess osseointegration and the readiness for restoration. If the results are satisfactory, the restorative phase proceeds with the placement of a crown or fixed prosthesis (Rostamzadeh et al., 2025). Collaboration between the surgeon and the prosthodontist is essential to ensure optimal functional and aesthetic outcomes. Long-term success depends on the quality of osseointegration and the patient's adherence to proper oral hygiene maintenance. Chandra and Gani (2023) emphasized that regular follow-up is crucial to detect early complications, particularly in patients with specific medical conditions. With meticulous procedures and attention to detail, dental implants can provide effective and long-lasting oral rehabilitation.

Clinical Discussion

Several studies have examined the factors influencing the success and failure of dental implant placement in human patients. In his narrative review, Takefuji (2025) noted that the prevalence of dental implant placement continues to increase; however, the success of the procedure is highly dependent on the patient's bone condition, the quality of the surgical technique, and the presence of systemic diseases. Other factors, such as excessive occlusal loading on the implant, can also increase the risk of failure.

Excessive load on dental implants is one of the key factors contributing to implant failure. Such failure occurs when the functional load applied to the implant exceeds the bone's capacity to withstand the stress. Sailer et al. (2022) explained that overload-induced implant failure arises when the occlusal or masticatory forces surpass the biomechanical tolerance of the surrounding bone tissue. This condition can lead to microfractures, progressive bone resorption, and eventual loss of osseointegration.

In addition, Sadowsky S. J. (2019) reported that bruxism — an unconscious habit of grinding or clenching the teeth — can generate excessive occlusal load on dental implants. This condition poses a significant risk for implant failure and other technical complications, such as screw loosening, prosthetic fracture, and marginal bone loss around the implant site.

A multicenter retrospective study by Goker et al. (2025) demonstrated that dental implants placed in routine clinical practice achieved a high survival rate exceeding 95%. Reported complications, such as peri-implantitis and prosthetic issues, were relatively low, with minimal variation in outcomes across clinics. These findings emphasize that thorough clinical planning and consistent adherence to standardized procedures are key to achieving optimal implant success.

Meanwhile, a retrospective analysis conducted by AlRowis et al. (2025) highlighted several specific factors that increase the risk of implant failure, including poor bone quality, patients' systemic conditions, implant placement location (with posterior sites being more vulnerable), and patient-related habits. This study underscores the importance of individualized patient evaluation prior to the procedure to minimize the risk of implant failure.

In specific pathological conditions, Hu et al. (2025) conducted a systematic review and retrospective study on patients with cemento-osseous dysplasia. The results indicated that implants can achieve successful outcomes with careful planning, although complications may arise if the dysplasia is not well-controlled. The authors emphasized the importance of routine radiographic monitoring to ensure bone integrity and proper implant positioning.

Additionally, a case report by Halim and Poedjiastoeti (2024) demonstrated the successful placement of a single posterior tooth implant. The surgical procedure was performed following standard techniques, and the patient exhibited favorable bone healing and optimal tooth function. These results highlight the importance of individualized case planning, particularly regarding patient anatomy and prosthetic design, to ensure implant success.

Conclusion

Based on the reviewed studies, advancements in dental implant materials and technology have shown significant progress in terms of material composition, manufacturing processes, and osseointegration capabilities. Titanium and its alloys remain the primary choice due to their biocompatibility, strength, and corrosion resistance. Recent studies indicate a growing trend toward the use of zirconia as a metal alternative because of its superior aesthetics and lower risk of allergic reactions, although its long-term durability continues to be evaluated (Morena et al., 2024; Arefnia et al., 2025).

Innovations in implant surface treatment have also been a key focus, with techniques such as sandblasting, acid etching, and nano-hydroxyapatite coating shown to enhance osseointegration and primary implant stability (Hao et al., 2021; Muharni, 2023; Sukaryo et al., 2023). Additionally, biological approaches using Platelet-Rich Plasma (PRP) and Platelet-Rich Fibrin (PRF) have been demonstrated to accelerate tissue healing and strengthen the bone-implant interface (Taghizadeh et al., 2024; Acerra et al., 2025).

From a clinical perspective, implant success is highly influenced by patient physiological factors, surgical technique, and occlusal load, which can lead to implant failure if not properly managed (Sadowsky, 2019; AlRowis et al., 2025; Takefuji, 2025). Several studies also highlight the challenges in patients with systemic conditions, such as diabetes mellitus, which require more careful surgical planning (Chandra & Gani, 2023; Rivero et al., 2025).

Research indicates that the success of dental implants is determined by a synergy between appropriate material selection, precise manufacturing processes, suitable surface treatments, and standardized clinical management. Current research trends focus on the development of metal- and ceramic-based composite materials using nanotechnology to enhance biological integration, aesthetics, and the long-term durability of dental implants.

Based on the findings of this systematic review on dental implant materials and osseointegration processes, it is recommended that future studies conduct experimental and clinical research with larger sample sizes and longer observation periods to comprehensively assess osseointegration success. The development of innovative materials, such as zirconia-titanium alloys or nano-hydroxyapatite, as well as the application of advanced surface modification technologies like plasma or laser treatments, should be further enhanced to improve biocompatibility and implant stability. For dental practitioners, these findings can serve as a reference for selecting implant materials that best suit individual patient conditions to minimize the risk of failure. Furthermore, collaboration among academics, clinicians, and the dental industry is essential to develop high-quality, efficient, and sustainable local implant materials, ultimately improving long-term osseointegration success and patients' quality of life.

Acknowledgments

We express our praise and gratitude to Almighty God for His blessings and grace, which have enabled us to successfully complete this literature review entitled "*Materials and Osseointegration Process in Dental Implant: A Systematic Review*". We would like to express our deepest gratitude to Dr. drg. Susanna Halim, Sert.KGI, FISID, FICD, FWSI, FISQua, AIFO(K), AIFMO(P), AIFMO(U), M. Biomed (AAAM), MKM (MARS), ABM, MBA, CH, CMC, CHHE.IA, C. HATEDIP, our supervising lecturer, for her guidance, direction, and motivation throughout the preparation of this literature review.

We also extend our gratitude to our team members for their cooperation, enthusiasm, and dedication in completing this project.
We acknowledge that this literature review is far from perfect. Therefore, we welcome constructive criticism and suggestions for the improvement of this scientific work. We hope that this writing can provide valuable insights and benefits to readers, particularly in the field of dental implantology.
(Vonny Maria, Niki Yuchinda, Jessica Angelie, Annisa Ginting) Faculty of Dentistry, Universitas Prima Indonesia, 2025.

Author Contributions
All authors have read and approved the published version of the manuscript

Funding
This article was funded by the author's personal funds.

Conflicts of Interest
In this study there is no conflict of interest.

References

Acerra, A., Caggiano, M., Chiacchio, A., Scognamiglio, B., & D'Ambrosio, F. (2025). PRF and PRP in Dentistry: An Umbrella Review. *Journal of Clinical Medicine,* 14(9), 3224. https://doi.org/10.3390/jcm14093224

AlRowis, R., Albelaihi, F., Alquraini, H., Almojel, S., Alsudais, A., & Alaqeely, R. (2025). Factors Affecting Dental Implant Failure: A Retrospective Analysis. *Healthcare*, 13(12), 1356. https://doi.org/10.3390/healthcare13121356

Arefnia, B., Fakheran, O., Jakse, N., & Payer, M. (2025). Patient-reported outcomes of zirconia dental implants: a systematic review and future directions. *Journal of Patient-Reported Outcomes*, 9(1), 7.

Arsista, D., & Eriwati, Y. K. (2018). Desain dan fungsi implan kedokteran gigi yang beredar di pasaran (Design and Function of Dental Implants Widely Circulated on the Market). *Jurnal Kedokteran Gigi Universitas Padjadjaran,* 30(3), 168–174.

Chandra, A., & Gani, A. (2023). Successful dental implant placement in patients with diabetes mellitus. *Makassar Dental Journal*, 12(1), 129–132.

Cho, Y.-D., Kim, S., & Ku, Y. (2021). Effectiveness of dental implantation with the partial split-flap technique on vertical guided bone regeneration: A retrospective study. *Journal of Periodontal & Implant Science,* 51(6), 433–443. https://doi.org/10.5051/jpis.2103780189

Firdhaus, F., & Handoko, H. (2023). Desain dan Simulasi Dental Implant Resistens Menggunakan Finite Elemen Analysis. *Quantum Teknika: Jurnal Teknik Mesin Terapan,* 5(1), 21–25. https://doi.org/10.18196/jqt.v5i1.18831

Goker, F., Mali Rai, P., De Santis, D., Colombo, M., Gornati, L., Savoini, E., Panda, S., & Del Fabbro, M. (2025). Outcomes of Dental Implants in Routine Clinical Practice: A Retrospective Multicenter Study. *International Journal of Dentistry*, 2025, 9930477. https://doi.org/10.1155/ijod/9930477

Halim, A. K., & Poedjiastoeti, W. (2024). Penatalaksanaan Pemasangan Dental Implant pada Kasus Kehilangan Gigi Posterior Tunggal. *Jurnal Kedokteran Gigi Terpadu*, 6(1), 39–41.

Hao, C. P., Cao, N. J., Zhu, Y. H., *et al.* (2021). The osseointegration and stability of dental implants with different surface treatments in animal models: a network meta-analysis. *Scientific Reports*, 11, 13849. https://doi.org/10.1038/s41598-021-93307-4

Hossain, N., Mobarak, M. H., Al Mahmud, M. Z., Islam, M. A., Rayhan, M. T., Hossain, A., & Chowdhury, M. A. (2023). Recent development of dental implant materials, synthesis process, and failure – A review. *Results in Chemistry*, 5, 100999. https://doi.org/10.1016/j.rechem.2023.100999

Hu, H., Liu, L., Man, Y., Ye, Z., & You, M. (2025). Clinical and radiologic outcomes of dental implants in cemento-osseous dysplasia: a systematic review and retrospective case series. *BMC Oral Health*, 25, 1117. https://doi.org/10.1186/s12903-025-06509-x

Juliatri, J., & Anindita, P. S. (2021). Gambaran Kehilangan Gigi pada Mahasiswa Tahap Profesi Dokter Gigi. *E-GiGi*, 9(2), 362–367.

Karyadi, E., & Roza, M. A. (2021). Pengaruh mengunyah buah apel manalagi terhadap penurunan indeks plak usia 9–12 tahun. *JIKG (Jurnal Ilmu Kedokteran Gigi),* 3(2).

Kementerian Kesehatan Republik Indonesia. (2023). *Kesehatan Gigi dan Mulut di Indonesia*. Jakarta: Kementerian Kesehatan Republik Indonesia.

Kurniawati, H., Puri, K. E., & Aziz, A. (2023). Aksi Nyata Sehatkan Gigi Dan Mulut Masyarakat Guna Mewujudkan Indonesia Bebas Karies 2030 di SDN 1 Sandik Lombok Barat. *Jurnal Pengabdian Magister Pendidikan IPA*, 7(1), 355–357.

Kusuma, B., & Suwandi, T. (2023). Penatalaksanaan implan dengan screw cement retained prosthesis. *Jurnal Kedokteran Gigi Terapan (KGT*), 5(2), 5–8. https://doi.org/10.25105/jkgt.v5i2.18801

Morena, D., Leitão-Almeida, B., Pereira, M., Resende, R., Fernandes, J. C. H., Fernandes, G. V. O., & Borges, T. (2024). Comparative clinical behavior of zirconia versus titanium dental implants: a systematic review and meta-analysis of randomized controlled trials. *Journal of Clinical Medicine*, 13(15), 4488.

Muharni, R. (2023). Potential of Nano Hydroxyapatite in Dental Implants: Potensi Hidroksiapatit Nano pada

Dental Implan. *REM (Rekayasa Energi Manufaktur) Jurnal*, 8(2), 87–92.

Prawesthi, E., & Handayani, S. (2023). Pembuatan Mahkota Tiruan All Zirconia Multilayered CAD/CAM Pada Pasien Dengan Dukungan Gigi Implan Tipe Endosseus (Laporan Kasus). *Jurnal Ilmiah dan Teknologi Kedokteran Gigi,* 19(2), 86–92.

Prawesthi, E., Tarsilah, & Marpaung, L. (2022). Penyebab Kehilangan Gigi Pada Remaja Dan Cara Mengatasinya. Poltekkes Kemenkes Jakarta II.

Puspitasari, G. A., Damayanti, L., & Kusumadewi, A. N. (2022). Pola kehilangan gigi berdasarkan klasifikasi Kennedy serta penyebab utama kehilangan gigi pada rahang atas atau rahang bawah usia dewasa muda. *Jurnal Kedokteran Gigi Universitas Padjadjaran*, 34(3), 216–225.

Ramadhan, A. A., Arifin, R., Hatta, I., Hamdani, R., & Dewi, N. (2023). Hubungan Pengetahuan Kesehatan Gigi dan Mulut Dengan Kehilangan Gigi di Wilayah Kerja Puskesmas Semangat Dalam. *Dentin*, 7(3).

Rinda, & Ariesanti, Y. (2023). Faktor-faktor yang mempengaruhi penurunan tulang marginal pada awal pemasangan implan dental. *Jurnal Kedokteran Gigi Terapan (JKGT),* 5(2), 23–25. https://doi.org/10.25105/jkgt.v5i2.18603

Rivero, R. R., da Silva, C. L., Cabral, D. de C., & Maruf, E. M. A. (2025). Preoperative evaluation and surgical planning for dental implant in a patient with systemic comorbidities: A case report. *MedNEXT Journal of Medical and Health Sciences*, 6(3). https://doi.org/10.54448/mdnt25303

Rostamzadeh, S., Ghasemirad, M., Gerayeli, M., Abasi, M., Pouresmaeliyan Roumani, M., Ganjehzadeh, S., & Moharrami, A. (2025). Radiographic Evaluation of Implant Stability and Osseointegration in Adult Orthodontic Patients. *Galen Medical Journal*, 14, e3799. https://doi.org/10.31661/gmj.v14i.3799

Sukaryo, S. G., Nugroho, W. S., Prabowo, Y., Nugraha, A., & Suroto, D. (2023). Synthesis and Ti-N sputtering of Zr-Nb alloys for dental implant material. *Journal of Physics: Conference Series*, 2556(1), 012024. https://doi.org/10.1088/1742-6596/2556/1/012024

Susanna Halim, F., Muharraran, D., Aulia, D. R., Kartika, D. C., & Selvina, W. (2024). *Tinjauan Artikel: Pemasangan Dental Implant Setelah Elevasi Lantai Sinus dengan Teknik Osteotomi*. Universitas Prima Indonesia.

Taghizadeh, E., Negargar, S., Noorizadeh, S., Mirmohammadi, S. M. M., & Salmani, Z. (2024). Efficacy of Platelet-Rich Plasma and Platelet-Rich Fibrin in Enhancing Dental Implant Osseointegration. *Galen Medical Journal*, 13(SP1), e3679.

Takefuji, Y. (2025). Dental implant prevalence and durability: A concise review of factors influencing success and failure. *Biomaterials and Biosystems*, 100109.

Shrivastava, D., Quadri, S. A., Alshadidi, A. A. F., Saini, R., Dewan, M., Oliveira Fernandes, G. V., & Srivastava, K. C. (2024). Clinical Assessment of the Relationship of Dental Implant Materials (Titanium and Zirconia) and Peri-Implantitis: A Systematic Review. *Journal of Maxillofacial and Oral Surgery*, 24(4), 1010–1028. https://doi.org/10.1007/s12663-024-02409-9

Wahyuni, L. A., Nurilawaty, V., Widiyastuti, R., & Purnama, T. (2021). Pengetahuan tentang penyebab dan dampak kehilangan gigi terhadap kejadian kehilangan gigi pada lansia. *JDHT Journal of Dental Hygiene and Therapy*, 2(2), 52–57.