Impact of Different Dental Implant Alloys and Coating Materials on the Health of Tissues Surrounding Implants: a Systematic Literature Review

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ABSTRACT

Objectives: Recently surface modification techniques have been introduced to dental implants to improve osseointegration, bone formation at the implant surface, and to reduce the occurrence of mucositis and peri-implantitis. The aim of this systematic literature review was to investigate the dependence of the risk of inflammation of the tissues surrounding the implant on different implant alloys and surface coating materials.
Material and Methods: The search for the systematic review of the scientific literature was performed between November 28, 2023, and February 5, 2024. Articles were retrieved using the PRISMA screening system from MEDLINE (PubMed), EMBASE (ScienceDirect), Cochrane Central Register of Controlled Trials (the Cochrane Library), Springer Link, and Google Scholar databases. The literature review included publications in English, randomized controlled clinical trials assessing bleeding on probing, pocket depth, and marginal bone level around the implant.
Results: A total of 41 full-text articles were selected after removing duplicates, of which 5 were included in this systematic literature review. The data from the studies were structured and presented in summary tables. Statistically significant differences in marginal bone level loss were observed using fluoride and sandblasting with large grit and acid-etching methods for implant surface modification. However, the effects of other surface coating materials and different implant alloys on bone loss, bleeding on probing, and pocket depth were not found to be significant.
Conclusions: Despite the limitations of this literature review, it can be concluded that implant alloys and surface coating materials are potential risk factors for the development of inflammation in the tissues surrounding the implant.

Keywords: dental implants; mucositis; peri-implantitis; surface properties; systematic review.

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INTRODUCTION

In modern dentistry, implant placement has become a common method of restoring lost teeth, with a success rate of more than 90% according to scientific studies [1]. The pioneer of dental implantology is Per-Ingvar Brånemark, a physician and research professor who, in 1952, discovered and documented a phenomenon called osseointegration. In 1965, after numerous scientific experiments, Brånemark [2] successfully placed threaded titanium implants.

Despite such promising results in dental implantology, it is important to consider the various factors contributing to clinical success and the oral health of the patient. Although dental implant success is often defined as the "survival" of a functioning implant, various mechanical and biological complications of early and late dental implantation are known in both the scientific literature and clinical practice [3]. Among the most common are diseases of the soft and hard tissues surrounding the implants, such as mucositis and peri-implantitis.

Mucositis is an inflammation of the mucosa surrounding the implant, characterized by bleeding on probing, redness, and swelling of the mucosa. The inflammation is reversible and occurs only in the soft tissues [4]. However, peri-implantitis is an inflammation of the soft and hard tissues surrounding the implant, resulting in bone loss [5]. If the disease is not stopped in time, it can eventually lead to implant loss [6]. The prevalence of diseases affecting the tissues surrounding the implant has been assessed in several clinical studies. Derks et al. [7] reported in a systematic review that the prevalence of mucositis ranges from 19% to 65%. In addition, Diaz et al. [8] reported a prevalence of 19.53% for peri-implantitis in their systematic review and meta-analysis.

The development of mucositis and peri-implantitis can be triggered by a variety of factors, including periodontal disease, inadequate personal oral hygiene, smoking, hyperglycaemia, and various metabolic disorders. Local risk factors include inadequate plaque control, gingival and mucosal inflammation, inappropriate implant positioning, unfavourable prosthodontic design, and unremoved excess cement [9]. Potential risk factors that require additional clinical investigation include genetic and systemic conditions, the use of bisphosphonates, and hormone replacement therapy. Occlusive trauma, lack of keratinized tissues, and the local presence of titanium particles seem to aggravate diseases of the tissues surrounding the implant [10].

However, the properties of the implant and its surface materials, particularly their influence on the surrounding tissues, are equally important [11]. Today, there are three main categories of dental implant materials [12]. The first category is metals. Titanium and titanium alloys are the gold standard for dental implants due to their biocompatibility, corrosion resistance, and mechanical properties. The surface properties of titanium implants are particularly important in the early osseointegration phase [13]. However, commercial pure titanium (CP-Ti) and the Ti_6Al_4V alloy have some disadvantages. For example, the probability of fracture of a small diameter implant (≤ 3.5 mm) may be increased due to the low strength of CP-Ti, which limits its use under high load conditions [14]. The second category of dental implant materials are ceramics, such as zirconia and alumina-based implants. The literature on ceramic dental implants is still scarce, and these implants are usually chosen as an alternative to titanium implants [15]. The third category of dental implant materials is polymers, such as polyether ether ketone (PEEK). The advantages of this category include a lower modulus of elasticity compared to metals, easier processing, and easily adjustable physical properties [16].

On the other hand, modification of the implant surface has been proposed to improve the osseointegration of material and bone tissue. It has been observed that implant surface materials, after treatment, interact better with the surrounding tissues and induce direct bone-to-implant contact [11]. Implant surface conditions such as surface roughness, surface charge, surface energy, and chemical composition likely have a significant influence on the osseointegration process [17]. Modifications of implant surfaces can be performed by additive or subtractive methods. In additive methods, other materials are added to the surface, which can be either superficial or integrated, and are classified into coating and impregnation, respectively. Subtractive methods involve the removal of a layer of the implant core material or plastic deformation of the surface, thereby roughening the surface of the implant core material [18].

The coating process involves the spraying of thermally molten materials to deposit a thick layer on the surface, such as plasma spray coating of hydroxyapatite (HA) or titanium plasma spray (TPS) [19]. Another surface modification technique is sandblasting, where particles are projected onto the implant surface under pressure using ceramic materials. Additionally, etching metal surfaces with acids can modify the surface roughness of the implant. Strong acids such as hydrofluoric acid (HF), nitric acid (HNO_3), sulfuric acid (H_2SO_4), or a combination of these acids are commonly used in this process. Double

acid-etching (DAE) involves treating the surface with chemicals or acids sequentially or in combination [20]. On the other hand, sandblasting with large grit and acid-etching (SLA) implant surfaces are used to induce erosion by applying a strong acid to the abrasive surface. This treatment combines high grit sandblasting and acid-etching in sequence to produce macro-roughness and micro-depressions, thereby increasing surface roughness and improving osseointegration [11].

Although dental implants are nowadays a relatively fast and reliable method of restoring lost teeth, surface treatments have been introduced to modify and maintain the desired material properties and to improve implant outcomes [21]. Given the limited information in the scientific literature on the importance and effects of different implant materials and surface modification techniques on the surrounding tissues and their effectiveness in promoting osseointegration, the aim of this systematic literature review is to investigate the dependence of the risk of inflammation of the tissues surrounding the implant on different implant alloys and surface coating materials.

MATERIAL AND METHODS

Protocol and registration

This systematic review was conducted in accordance with the PRISMA (Preferred Reporting Items for Systematic Reviews and Meta-Analyses) requirements [23].

This study was registered on the international prospective register of systematic reviews PROSPERO. Registration number: CRD42024565721. The protocol can be accessed at: https://www.crd.york.ac.uk/prospero/display_record.php?ID=CRD42024565721

Focus question

The focus question for this systematic literature review (Table 1) was formulated based on the Patient, Intervention, Comparison and Outcom (PICO) model as described in the Cochrane Handbook for Systematic Reviews of Interventions 6.4. [22]: What are the implications for the tissues surrounding the implant of different implant alloys and surface coating materials?

Search

An electronic search was carried out according to the PRISMA guidelines [23]. One independent researcher (K.M.) conducted the article search in the electronic databases MEDLINE (PubMed), EMBASE (ScienceDirect), Cochrane Central Register of Controlled Trials (the Cochrane Library), Springer Link, Google Scholar and additional hand search. The search for the systematic reviews of the scientific literature was performed between November 28, 2023, and February 5, 2024.

Quality assessment

The risk of bias in the selected studies was assessed using the Cochrane risk of bias tool - RoB 2.0 (https://methods.cochrane.org/).

Five areas were evaluated: the randomization process, deviations from the intended interventions, missing outcome data, the measurement of the outcome, and the selection of the reported results. All areas were classified as having a low, unclear, or high risk of bias. The overall risk of bias for each randomized controlled clinical trial was assessed as follows:

- Low risk: all domains had a low risk of bias.
- Some concerns: at least one domain was assessed as having some risk of bias, but no single domain had a high risk of bias.

Criteria for selection and rejection of articles

Inclusion criteria

The following inclusion criteria were assessed for selection of articles:

Table 1. PICO framework

Component	Description
Population (P)	Patients with at least one implant
Intervention/indicator (I)	Implant threading
Comparison (C)	Differences in clinical criteria immediately after implant loading versus 5 years (or more) after implant loading
Outcome of interest (O)	Clinical criteria including bleeding and/or suppuration on probing, pocket depth, and marginal bone level
Focus question	What are the implications for the tissues surrounding the implant of different implant alloys and surface coating materials?

- Type of publication: randomized controlled clinical trials (RCTs).
- Study sample size: at least 10 implants.
- Clinical parameters included in the study:
  1. Bleeding and/or suppuration on probing (BOP/SUP).
  2. Depth of pockets (PD).
  3. Marginal bone level (MBL).
  4. Statistical significance of these parameters.
- Materials used in the study.
- Language: article must be written in English.
- Follow-up period: no shorter than 5 years.

Exclusion criteria

The following exclusion criteria were as follows:
- Type of publication: literature reviews, meta-analyses, single clinical case studies, lectures, and letters.
- Study type: *in vitro* studies.
- Scope of study: articles investigating zygomatic, pterygoid, and orthodontic implants.
- Publication date: publications older than 10 years.
- Language: articles written in a language other than English.

Information sources

For the systematic review of the scientific literature, articles were searched in the electronic databases MEDLINE (PubMed), EMBASE (ScienceDirect), Cochrane Central Register of Controlled Trials (the Cochrane Library), Springer Link, and Google Scholar and involved a comprehensive manual review of relevant journals. These included the "Clinical Oral Implants Research", "Journal of Clinical Periodontology", "Journal of Periodontology", "BMC Oral Health", "Journal of Clinical Medicine", "Clinical Oral Implants Research", "BioMed Research International", "BMJ", "Implant Dentistry", "Journal of Oral and Maxillofacial Research", "BMC Microbiology", "Clinical Oral Implants Research", "Journal of Clinical Periodontology", "Implant Dentistry", "Journal of Oral and Maxillofacial Research", and "Journal of Oral and Maxillofacial Surgery".

Additionally, the manual search encompassed reviewing the bibliographies of all selected articles for full-text screening and examining previously published reviews pertinent to this systematic review.

A structured search of these databases was conducted without time and other constraints to answer the following question: What are the effects of different alloys and surface coating materials on the tissues surrounding the implant?

Electronic data retrieval strategy

The selection of articles started on 28 November 2023, and the last search was performed on 5 February 2024. Scientific publications were extracted from the databases using MeSH and free-text search terms in various combinations, including: "dental implant," "mucositis, oral," "peri-implantitis," "prevalence," "materials, surface coated." The detailed search strategy was as follows: dental implant [MeSH Terms] AND periimplantitis [MeSH Terms] OR mucositis, oral [MeSH Terms] AND materials, surface coated [MeSH Terms] AND bleeding on probing, gingival [MeSH Terms] OR pocket [MeSH Terms] OR pocket depth AND margin bone level OR turned implant OR implant surface roughness.

Selection of studies

The selection of articles was conducted in several steps to minimize errors, such as omitting eligible articles or excluding them incorrectly from the systematic literature review. The process was as follows:
1. Initial screening by title. Publications were initially screened based on their titles. To be considered, articles had to be written in English and published within the last 10 years.
2. Abstract examination. Abstracts of the selected publications were then reviewed according to the predefined criteria. Abstracts that did not meet the selection criteria were rejected.
3. Full-text review. In the final stage, the full-text articles were read. An assessment of their eligibility for the systematic review was performed, and articles meeting all the inclusion criteria were selected for inclusion in this systematic literature review.

The titles were independently screened by two reviewers (K.M. and R.B.) based on the inclusion criteria. A third reviewer (A.P.) checked for possible errors. To avoid possible errors, the reviewers were calibrated. After selecting 10% of the publications for this purpose, inter-rater reliability was calculated using Cohen's kappa coefficient (κ).

Data extraction

The research data selected for the systematic literature review were collected and tabulated according to the Cochrane Training, methodological guidelines [22]. The following data were extracted from the studies:
- General information - main author of the study,

year of publication.
- Study type - randomized controlled clinical trials.
- Study sample - number of implants.
- Subject population - age, sex, health status.
- Study methodology - study blinding, randomization, and allocation concealment.
- Study results and conclusions.

Study variables

To assess the clinical outcome, at least some of the following variables were analyzed:
- Bleeding and/or suppuration on probing (mm/%). The presence of bleeding or suppuration during probing.
- Depth of the pockets (mm). Measurement of the depth of the periodontal pockets. During the follow-up examinations, variables were evaluated at six sites per implant (mesiobuccal, buccal, distobuccal, distolingual, lingual, and mesiolingual) and then averaged using a manual periodontal probe (PCP UNC 15 - Hu Friedy Manufacturing Co.; Chicago, IL, USA).
- Marginal bone level (mm). Measurement of bone loss level. Periapical radiographs were taken immediately after implant insertion and at baseline after loading. The marginal bone level was examined on both the mesial and distal aspects of each implant by measuring the distance between the flat top of the implant shoulder and the bone crest using a scale with 0.1 mm increments. The mean marginal bone level was then calculated from these measurements.
- Statistical significance. The statistical significance of the clinical parameters.

Data synthesis

For the studies included in this systematic literature review that described clinical indicators of inflammation in the soft and hard tissues surrounding the implants, data were organized using a data synthesis approach. From the full-text articles included in the literature analysis, only relevant and significant data were selected and tabulated.

Statistical analysis

Mendeley® Reference Manager v2.110.2 software (Elsevier; London, UK) was used to manage articles. The level of agreement between two raters was measured using Cohen's kappa coefficient (κ). Meta-analysis was not performed due to the heterogeneity of the articles. The data results included in the analysis of this study were considered significant when the difference in data results between the study groups was statistically significant (with a statistical confidence level of $P < 0.05$).

RESULTS

Study selection

The initial search identified 158 articles. The selection strategy is illustrated in the PRISMA flow diagram (Figure 1). After removing duplicates, 108 articles were screened. Following the screening of titles and abstracts, 41 articles were selected for full-text reading. Ultimately, five articles were deemed eligible for inclusion in this systematic review [24-28].
Inter-rater reliability (K.M. and R.B.) for 10% of the publication sample was $\kappa = 0.91$.

Quality assessment

The risk of bias was assessed as low in two studies [25,28] and somewhat questionable in one study [27]. The detailed results of the included studies in terms of risk of bias are shown in Figure 2.

Study characteristics

The main characteristics of the articles are summarized in Table 2. The detailed results of the articles included in this review are presented in Table 3. All included articles were randomized controlled clinical trials (two of them prospective) published between 2018 and 2023 [24-28]. This review examined four dental implant systems: Astra Tech Implant System™ EV (Dentsply Sirona; Mölndal, Sweden), Straumann ITI® (Straumann AG; Basal, Switzerland), Ziterion® Vario T (Ziterion GmbH; Uffenheim, Germany), and Brånemark MK III® (Nobel Biocare AB; Gothenburg, Sweden). Surface treatments such as SLA, anodic oxidation, TiO_2 blasting, sandblasting, and implant surface milling were evaluated.

Bleeding on probing

In the studies by Gadzo et al. [24] and Ioannadis et al. [25], the occurrence/increase of bleeding on probing was assessed immediately after implant loading and at least 5 years after loading using TiO_2 blasting and SLA techniques. The estimated rates were statistically insignificant ($P > 0.05$).
In the studies by Koller et al. [26] and Raes et al. [27], the results of bleeding on probing were only reported at least 5 years after implant loading.

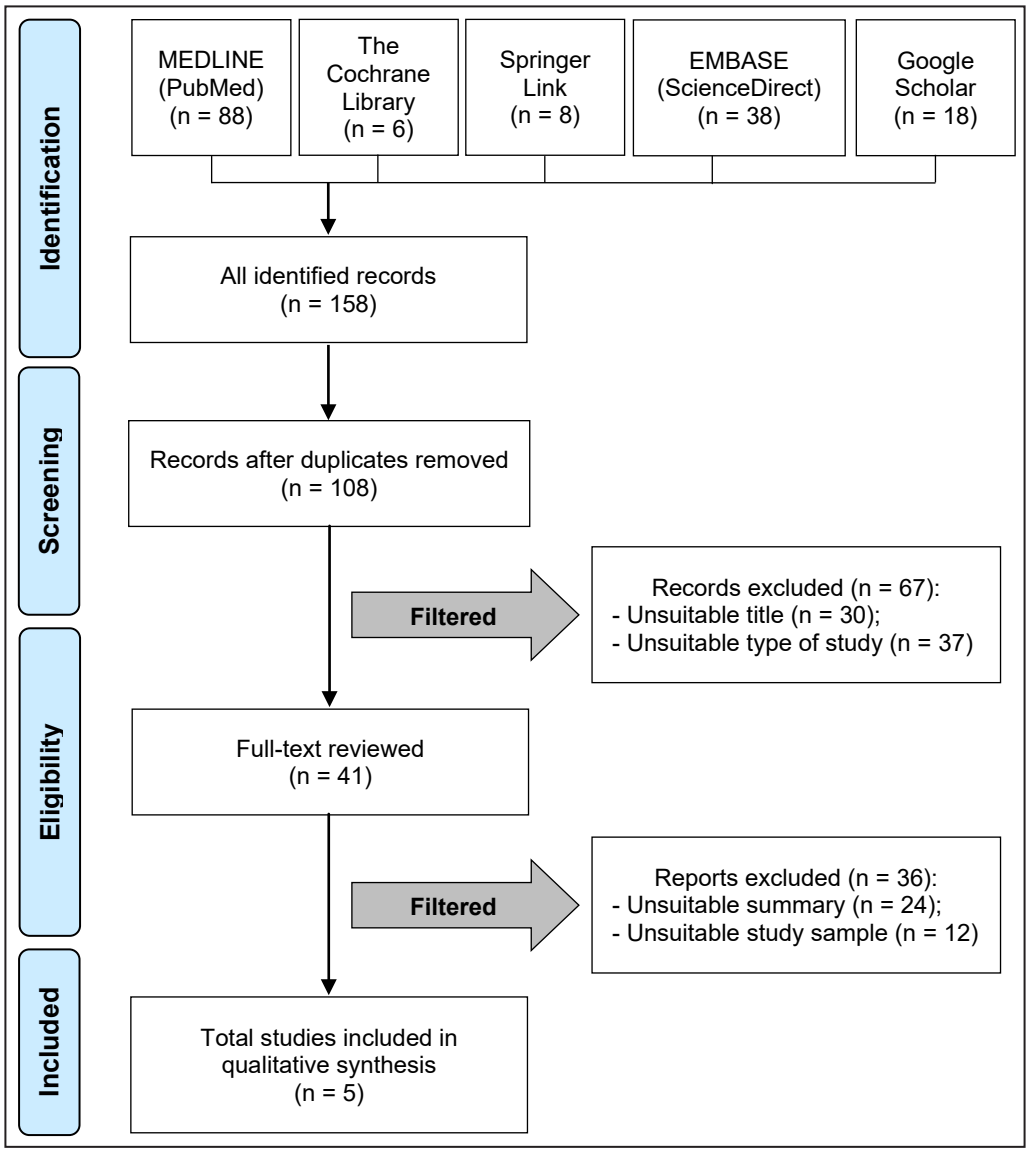

Figure 1. PRISMA flow diagram of the study search and selection.

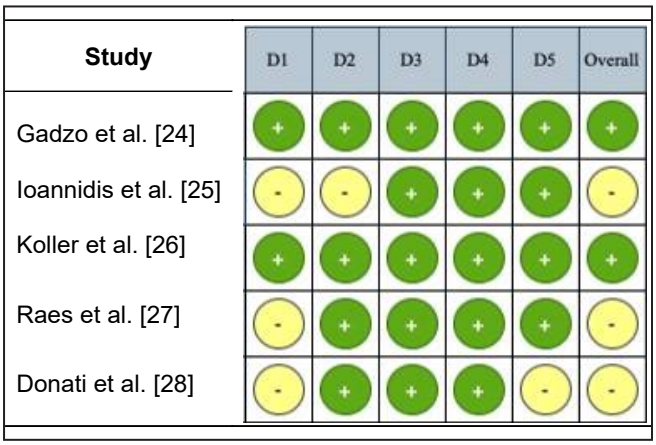

Figure 2. Risk of bias assessment using the modified the Cochrane risk of bias tool (RoB 2.0).
+ = low; - = some concerns; D1 = bias arising from randomizing process; D2 = bias due to deviation from intended intervention; D3 = bias due to missing outcome data; D4 = bias of measurement of the outcome; D5 = bias in selection of the reported result.

Koller et al. [26] compared sandblasted zirconium and sandblasted titanium, and Raes et al. [27] investigated anodic oxidation and milling techniques. The results of these studies showed significantly higher bleeding on probing. Nevertheless, these results were not statistically significant ($P > 0.05$).
The values of changes ranged from -0.2 (SD 0.3) mm to 0.1 (SD 0.3) mm.

Pocket depth

Changes in pocket depth were evaluated in two studies using TiO_2 blasting and SLA techniques. Gadzo et al. [24] reported that no statistically significant difference ($P > 0.05$) was observed in the criteria, between the immediate implant placement and 10 years after. However, according to Ioannadis et al. [25], the difference between the clinical criteria was significant ($P < 0.05$).

Table 2. Studies characteristics

Study	Year of publication	Study type	Patient number	Patient age (years)	Gender	Implant sample	Dental implant systems	Implant alloy or coating material	Follow-up period (years)
Gadzo et al. [24]	2023	RCT	43	67.3 (SD 11)	21 females, 22 males	69	Astra Tech Implant System™ EV (Dentsply Sirona); Straumann ITI® (Straumann AG)	TiO-blasting; SLA	10
Ioannidis et al. [25]	2019	Prospective RCT	64	> 18	38 females, 26 males	57	Astra Tech Implant System™ EV (Dentsply Sirona); Straumann® (Straumann AG)	TiO-blasting; SLA	5
Koller et al. [26]	2020	Prospective RCT	22	> 18	9 females, 13 males	31	Ziterion® Vario T (Ziterion GmbH)	Sandblasted titanium; sandblasted zirconia	5
Raes et al. [27]	2018	RCT	15	46 to 72	4 females, 11 males	83	Brånemark MK III® (Nobel Biocare AB)	Anodic oxidation; turned implant	5
Donati et al. [28]	2018	RCT	25	57.6 (SD 10)	25 females	64	Astra Tech Implant System™ EV (Dentsply Sirona)	Turned implant; TiO-blasting	20

RCT = randomized controlled trials.

Table 3. Studies results

Study	Dental implant systems	Implant alloy or coating material	Clinical parameters immediately after implant loading (mm)			Clinical parameters after 5 years or more after implant loading (mm)			The difference between clinical criteria (mm)		
			BOP	PD	MBL	BOP	PD	MBL	BOP	PD	MBL
			Mean (SD)	Mean (SD)	Mean (SD)	Mean (SD)	Mean (SD)	Mean (SD)	Mean (SD)	Mean (SD)	Mean (SD)
Gadzo et al. [24]	Astra Tech Implant System™ EV (Dentsply Sirona); Straumann ITI® (Straumann AG)	TiO-blasting; SLA	0.2 (0.2); 0.2 (0.2)	3.1 (0.5); 2.7 (1)	-0.1 (0.4); 0.04 (0.54)	0.1 (0.1); 0.1 (0.1)	2.8 (0.5); 2.9 (0.7)	-0.1 (0.47)*; -0.78 (0.96)*	-0.2 (0.3); -0.1 (0.2)	-0.3 (0.6); 0.2 (1.1)	0.01 (0.41)*; -0.82 (1.26)*
Ioannidis et al. [25]	Astra Tech Implant System™ EV (Dentsply Sirona); Straumann® (Straumann AG)	TiO-blasting; SLA	0.24 (0.22); 0.21 (0.18)	3.13 (0.51); 2.83 (0.88)	0.29 (0.44)*; 0.22 (0.44)*	0.26 (0.2); 0.3 (0.26)	3.19 (0.39); 3.33 (0.57)	0.13 (0.54); 0.34 (0.45)	0.03 (0.33); 0.1 (0.3)	0.06 (0.65)*; 0.48 (0.92)*	-0.18 (0.47)*; 0.1 (0.35)*
Koller et al. [26]	Ziterion® Vario T (Ziterion GmbH)	Sandblasted titanium; sandblasted zirconia	-	-	0.92 (0.72); 1.51 (0.68)	16.43 (6.16)%*; 12.6 (7.66)%*	-	1.38 (0.81); 1.17 (0.73)	-	-	-
Raes et al. [27]	Brånemark MK III® (Nobel Biocare AB)	Anodic oxidation; turned implant	-	-	-1.85 (0.8); -1.82 (0.62)	3.78 (2.28)*; 2.76 (2.52)*	4.19 (2.61); 3.09 (1.01)	-	-	-	-1.65 (1.65); -1.00 (0.9)
Donati et al. [28]	Astra Tech Implant System™ EV (Dentsply Sirona)	Turned implant; TiO-blasting	-	-	-	-	3.7 (1.03); 4. (1.3)	-0.41 (1.25); -0.83 (1.59)	-	-	-0.41 (1.25); -0.83 (1.59)

*Statistically significant values ($P < 0.05$).
BOP - bleeding on probing; PD - pocket depth; MBL - marginal bone loss level.

Raes et al. [27] and Donati et al. [28] report the results of pocket depth only at least 5 years after implant loading. The results using TiO_2 blasting, milling, and anodic oxidation were statistically insignificant ($P > 0.05$).

The difference between clinical criteria ranged from -0.3 (SD 0.6) mm to 0.48 (SD 0.92) mm.

Level of bone loss

Bone loss rates were assessed in all five studies. Bone loss was significantly higher and statistically significant ($P < 0.05$) in the studies by Gadzo et al. [24] and Ioannadis et al. [25] using TiO_2 blasting and SLA techniques. The changes of values ranged from -0.82 (SD 1.26) mm to 0.1 (SD 0.35) mm.

In the studies by Koller et al. [26], Raes et al. [27] and Donati et al. [28], anodic oxidation, sandblasting, milling, and TiO_2 blasting methods resulted in a non-significant increase in bone loss changes ($P < 0.05$). The differences ranged from -1.65 (SD 1.65) mm to -0.41 (SD 1.25) mm.

DISCUSSION

This review assessed the difference in clinical parameters of the tissues surrounding implants immediately after loading and 5 years (or more) after loading. The focus was on the assessment of bleeding on probing, pocket depth, and bone loss rate, but only two studies reported all three clinical criteria.

Minimal differences were observed between the groups for all outcome measures, including SLA, anodic oxidation, TiO_2 blasting, sandblasting and milling of implant surfaces. The largest differences in clinical parameters were observed with SLA surface. The lowest values of changes in clinical parameters were observed with TiO_2 blasting of the implant surface (in terms of bleeding and of pocket depth) and anodic oxidation of the implant surface (regarding bone loss level).

Several authors have reported the exact incidence of mucositis and peri-implantitis 5 years or more after implant loading. According to Gadzo et al. [24], the prevalence of implant mucositis was 29.7% with TiO_2 blasting and 50.1% with SLA method. The prevalence of peri-implantitis was 0% with TiO_2 blasting method and 6.3% with SLA technique. Raes et al. [27] reported in their study that peri-implantitis was diagnosed after 5 years in 3 turned implants and 12 TiO_2 blasted implants.

However, one study mentioned a higher risk of peri-implantitis associated with implant surface etching compared to implant surface milling [27]. Two other studies report that implant modification techniques have similar risks [25,28]. Nevertheless, Jordana et al. [29] in their systematic review of the literature stated that peri-implantitis is clearly associated with surface roughness. The higher the surface roughness, the higher the average incidence of peri-implantitis. Rough surfaces have been reported to be associated with higher bone-to-implant contact, but they are more conducive to biofilm accumulation and more difficult to disinfect [30]. Yoda et al. [31], in their study, suggest that the minimum level of roughness that affects the initial bacterial adhesion activity varies depending on the type of biomaterial used, and that even surface roughness below 30 nm Ra can promote bacterial adhesion.

In contrast, according to Inchingolo et al. [17], a combination of sandblasting and etching has been the most widely used surface modification method in the last ten years. Sandblasting is theorized to achieve an ideal roughness for mechanical fixation, while additional etching, by increasing the level of roughness, is thought to enhance the protein adhesion mechanism, which is crucial in the early stages of bone healing.

Koller et al. [26] in their randomized controlled clinical trial reported only the bone loss rate with different implant alloys (sandblasted titanium implant and sandblasted zirconium implant). An insignificant difference was observed between the groups. However, according to Osman et al. [32], due to the higher marginal bone loss and higher fracture rate observed in zirconia implants, modifications to the zirconia implant surface are required to improve the biomechanical integrity of zirconia implants. Zirconia implants are only recommended for use in cases of proven titanium allergy or when metal-free prosthetic rehabilitation is requested [32].

The last systematic literature review of a similar type was performed in 2021. Preclinical *in vivo* studies by Stavropoulos et al. [33] showed that the surface properties of modified implants can have a significant adverse effect on the progression of peri-implantitis, and clinical studies do not confirm that the prevalence of peri-implantitis differs between different implant surfaces. However, the limited information available does not allow any assumptions to be made about the possible effect of implant material on the occurrence and/or progression of peri-implantitis [33].

While the results of this review are informative, there are limiting factors that may contribute to inaccuracies. In particular, the lack of homogeneity in the methodology and data of the studies conducted, and the risk of bias (Figure 2), have limited this

systematic review and the possibility of statistical analysis.

On the other hand, differences in patient age, gender, oral hygiene habits, and periodontal pathologies may have an impact on the occurrence of bias. The patients included in the study were healthy adults with no local oral or systemic pathologies, good oral hygiene (all-oral plaque index < 25%), and adequate control of inflammation (all-oral bleeding index < 25%). However, in two studies, all patients had moderate to severe chronic periodontitis and had lost teeth due to periodontal disease. In one of these studies, 28% were smokers.

Other potential limitations include overloading and iatrogenic risk factors, which are closely linked to prosthetic decisions. In the studies, restorations were fixed with screws or cemented, depending on the clinical situation and the clinician's preference. It has been observed that the occurrence of peri-implantitis can be influenced by non-axial loading, cantilevered prosthetic elements, the crown-to-implant ratio, the type of implant-retainer bond, maladjustment, the properties of the restorative materials and the antagonistic tooth. During functional loading, about 1 to 1.5 mm of physiological bone loss can be expected in the first year and less than 0.2 mm in the second year [34]. All studies that have compared conventional (non-platform bonded) and platform bonded abutments have shown that the use of platform bonded abutments reduces stress concentrations in the bone surrounding the implant [35]. Their beneficial effect was greater for cortical than for trabecular bone. On the other hand, it has been observed that excess cement on the implant or on the abutment can act as a foreign body, provoking an inflammatory reaction that may lead to bone resorption or even implant loss. It is likely that the deeper the implant abutment arm is inserted, the more cement residue may remain after cleaning [36].

Finally, different surgical protocols, scoring systems, samples, and implant systems are limitations of this work. Implant placement was not limited to the maxillary/mandibular or anterior/lateral dental regions, nor were patients requiring bone regeneration excluded.

In summary, this literature review showed that implant surface modifications and roughness have an impact on the level of bone loss around the implants and on the occurrence of bleeding and periodontal pockets. These features are among the most important in characterizing the health of the tissues surrounding the implant. However, there is a lack of information in the scientific literature on the structure of the implant surface, structural modifications, and their influence on the surrounding tissues. Therefore, further clinical studies are needed to investigate the long-term effects of specific alloys and surface coatings, taking into account different patient groups and including standardized assessment criteria.

CONCLUSIONS

Statistically significant differences in bone loss were found between TiO_2 blasting and SLA implant surface modification methods, while other surface coatings and different implant alloys had a negligible effect on bone loss, bleeding on probing, and pocket depth increase.

TiO_2 blasting of the implant surface was found to have the greatest effect on the increase in bleeding on probing and in the depth of the pocket, while anodic oxidation of the implant surface had the greatest effect on the amount of bone loss.

SLA method was found to have the greatest effect on the level of bone loss around the implant, bleeding on probing, and the increase in pocket depth.

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The authors report no conflicts of interest related to this study.

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