Understanding the Risk of Peri-Implantitis

Dipanjan Das[1] Nina Shenoy[1] Smitha Shetty[1]

[1] Department of Periodontics, AB Shetty Memorial Institute of Dental Sciences (ABSMIDS), Nitte (Deemed to be University), Mangalore, Karnataka, India

J Health Allied Sci[NU] 2024;14:23–37.

Address for correspondence Dipanjan Das, Postgraduate Student, BDS, Department of Periodontics, AB Shetty Memorial Institute of Dental Sciences (ABSMIDS), Nitte (Deemed to be University), Mangalore 575018, Karnataka, India (e-mail: dipanjanrdas.dd@gmail.com).

Abstract

Although implant therapy has been identified as a successful and predictable treatment for partially and completely edentulous patients, complications and failures can occur. There are two main categories of complications that occur in implant therapy: biological and technical (mechanical). Peri-implantitis is considered as a biological complication that results in bone loss around implants and may lead to implant treatment failure. Peri-implantitis has become a topic of major interest in contemporary dentistry due to its higher prevalence. Even though the main etiologic agent is bacterial biofilm, a myriad of factors influences the initiation and progression of peri-implant disease. The knowledge of the impact of peri-implantitis on the outcome of treatment with oral implants as well as the identification of risk factors associated with this inflammatory condition is essential for the development of supportive maintenance programs and the establishment of prevention protocols. Thus, this article reviews the recent evidence on the factors that may predispose implants to peri-implantitis.

Keywords
- dental implants
- peri-implantitis
- risk factors

Introduction

The use of osseointegrated dental implants as a replacement for missing teeth has ushered in a new era in dentistry.[1] In spite of their enormous success, the number of complications (most common technical and biological) has been steadily increasing.[2] Among the biological complications, peri-implantitis (PI) is most commonly documented.[3]

The American Academy of Periodontology/European Federation of Periodontology (AAP/EFP) World Workshop, 2017 in the recent classification, defined PI as a plaque-associated pathological condition affecting tissues around dental implants, characterized by inflammation in the peri-implant mucosa and subsequent progressive loss of supporting bone.[4] Because of its increased prevalence, PI has become a topic of importance in modern dentistry.[5] The following criteria can be used to make a clinical diagnosis of PI: 1) presence of inflammation-related signs around the implant, 2) radiographic indication of crestal bone loss after initial healing, and 3) greater probing depth compared to initial probing depth after placement of the prosthetic restoration. In the absence of prior radiographs, PI is indicated by a radiographic bone level of more than or equal to 3 mm in combination with a bleeding on probing and pocket depth of more than or equal to 6 mm.[6] With an increased incidence from 0.4 to 43.9% within 3 to 5 years, PI has been reported to affect around 13% of implants and 18.5% of patients.[1,5]

Although bacterial biofilm is the primary etiology of PI, numerous other risk factors may complement its progression.[2] They can be categorized as subject and implant-related risk factors. To develop a perfect strategy for the prevention and treatment of PI, it is imperative to understand the role of all these risk factors in the initiation and progression of the disease. This review attempts to update the current status of the various factors that can potentially influence the development of PI.

Primary Etiological Factor—Oral Biofilm

Oral biofilm is the main etiological factor in the development of PI, according to the 2017 World Workshop consensus report.[4] Dental implants provide a hard, nonshedding

article published online
April 14, 2023

DOI https://doi.org/10.1055/s-0043-1766125.
ISSN 2582-4287.

Thieme Medical and Scientific Publishers Pvt. Ltd., A-12, 2nd Floor, Sector 2, Noida-201301 UP, India

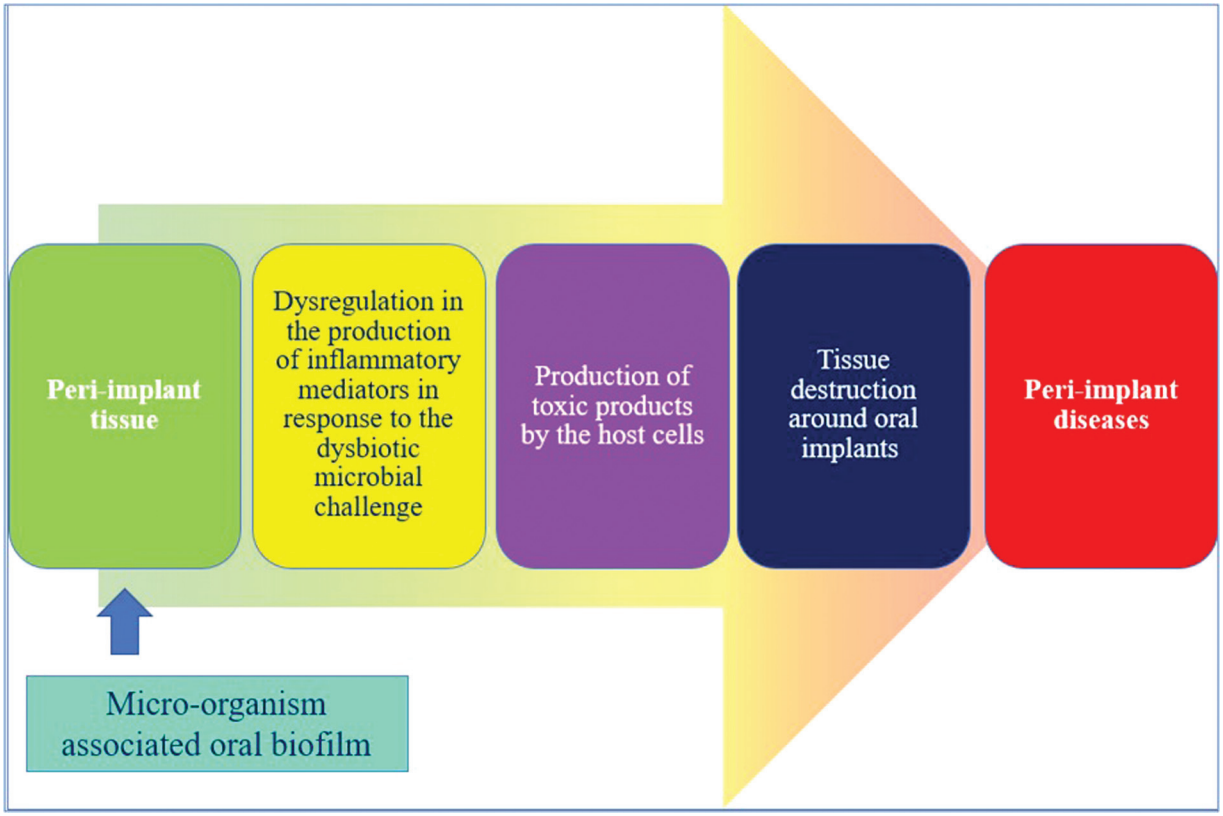

Fig. 1 Role of oral biofilm in the pathogenesis of peri-implantitis.

surface in a fluid environment for biofilm formation, in a similar manner as natural teeth. Excessive biofilm formation can occur because of poor oral hygiene conditions. It can lead to inflammation of peri-implant tissues as peri-implant mucositis and ultimately can progress to PI[7] (►**Fig. 1**).

Periodontopathic microorganisms have been demonstrated in the biofilm associated with PI, but in a heterogeneous nature and with more complexity than periodontitis.[8] A higher incidence of *Porphyromonas gingivalis* and mainly *Prevotella intermedius/nigrescens* are reported in PI. Compared to healthy implant sites, PI is associated with non-culturable anaerobic gram-negative rods and asaccharolytic anaerobic gram-positive rods.[8]

Risk Factors

Factors having a direct causative association with a disease, as demonstrated by longitudinal studies are termed "risk factors," in contrast, factors determined through retrospective, cross-sectional, or observational investigations are termed "risk indicators."[9]

In this review, all the factors that can play a predisposing role in the development of PI will be regarded as "risk factors" (►**Table 1**).

Subject-Level Risk Factors

History of Periodontitis

Evidence-based studies demonstrate that patients with a history of periodontitis (HOP) are more likely to develop PI, which results in decreased survival and success rates of the dental implant.[1,10,11] This is partly because the subgingival microbiota of diseased teeth and implants are identical.[10]

It is also reported that subjects with HOP had a higher rate of implant loss. Active periodontitis on neighboring teeth is also thought to be a determinant of PI in the future.[12] Several cross-sectional studies reported that patients with HOP were 2.2 to 2.5 times more prone to develop a PI.[13,14] However, reduced risk of PI was seen when the periodontal disease was successfully treated ahead of implant insertion and is thus recognized as a crucial primary measure of the entire treatment plan.[15] As per a current systematic review by Ferreira et al, there was a strong association between HOP

Table 1 Risk factors for peri-implantitis[2,10,13]

Subject-level risk factors	Implant-level risk factors
1. History of periodontitis 2. Smoking 3. Poor oral hygiene and lack of maintenance therapy 4. Diabetes mellitus 5. Other systemic conditions 6. Autoimmune diseases 7. Patient's medications 8. Stress 9. Patient related habits 10. Genetic factors	1. Surface characteristics 2. Titanium dissolution products 3. Prosthetic design 4. Implant-abutment connection 5. Tissue phenotype 6. Excess cement 7. Occlusal overload 8. Implant materials 9. Dimension of implants 10. Jaw location of implants 11. Implant position 12. Sinus lift techniques

and the occurrence of PI, and patients with periodontal disease had a 2.3-fold higher chance of developing PI than those with healthy periodontal disease.[10] The available evidence strongly suggests HOP as a potential risk factor for PI development.

Oral Hygiene and Maintenance Therapy

Poor oral hygiene and lack of regular follow-up maintenance are proven risk factors in the development of PI. Serino and Ström demonstrated a 3.8-fold more risk of PI development in patients with improper oral hygiene compared to subjects with proper oral hygiene.[16] A clinical trial also reported the role of poor plaque management in developing PI.[9] These study results have highlighted the significance of plaque control measures (both patient-administered and professionally administered) in reducing peri-implant inflammation.

Inadequate supportive maintenance care was a risk predictor for PI in a retrospective study comprising 200 patients with implant-supported restorations.[17] Costa et al, in a 5-year follow-up study, reported an increased microbial load and higher occurrence of PI due to a lack of routine maintenance.[18] Therefore, patients with implant-supported prostheses need to have regular maintenance therapy for the prevention of PI. According to Monje et al, peri-implant maintenance therapy must be performed during implant along with implant placement and restorations to prevent biologic problems and favor long-term success.[19] There is sufficient evidence that suggests a lack of proper oral hygiene and maintenance therapy is a risk factor for the pathogenesis of PI.

Smoking

Cigarette smoking is a key factor to consider in periodontitis, which has also been associated with bone loss around implants and loss of implants. Smoking has a negative impact on wound healing. Research in animal models showed a reduction in bone mineral density around the implant and bone–implant contact due to smoking.[20] According to ArRejaie et al implant sites showed considerably greater levels of proinflammatory cytokines,[21] probing depths, bleeding, suppuration, and plaque scores in smokers than nonsmokers.[22,23] The peri-implant microbiome also demonstrated an increase in tissue inflammation associated with *Fusobacterium*, *Tannerella*, and *Mogibacterium* caused by smoking.[24]

As reported by Pimentel et al, smoking raised the risk of PI by three times in 147 subjects with 490 implants.[25] A systematic review by Sgolastra et al, however, has reported insufficient evidence of a relationship between smoking and peri-implant health.[26] Even though treatment is not contraindicated in smokers, smokers frequently have less favorable treatment outcomes than nonsmokers.[4] The dentist should advise smokers to stop, and they should make an attempt to educate them about how smoking affects periodontal health and the results of implant therapy.[2] Smoking is reported as a modifier of peri-implant mucositis in the "World Workshop on the Classification of Periodontal and Peri-Implant Diseases and Conditions" consensus report from 2017, though the literature's evidence on the subject is inconclusive as to whether smoking is a potential risk factor or indicator for PI.[4] There is a lack of conclusive evidence to constitute smoking as a risk factor for PI.

Diabetes Mellitus

Diabetes mellitus is a group of metabolic diseases where type-1 diabetes mellitus results from the destruction of β-cells of islets of Langerhans by autoimmunity and type-2 diabetes by insulin resistance.[9] Diabetes has been studied extensively for its impact on the longevity of osseointegrated dental implants. Numerous cellular and vascular responses that increase tissue damage and decrease the healing response have explained the association between poor glycemic control and the progression of periodontitis.[2] In peri-implant tissues, similar pathways are stimulated, resulting in an increased risk of PI in hyperglycemic patients.[27]

Dreyer et al concluded that the risk of PI development is three times more in patients with diabetes mellitus than in patients without diabetes mellitus.[1] When the confounding factor of smoking was removed from the analysis, a 3.39-fold higher risk of PI development was reported in patients with diabetes type-2 than in healthy individuals.[27]

While the preponderance of evidence suggests a correlation between diabetes and PI, contradictory data have also been reported. A recent review failed to demonstrate a higher incidence of implant failure in those with diabetes than nondiabetic patients, although a higher loss of marginal bone was noticed in diabetic patients.[28] In addition, several systematic reviews also found no significant impact of hyperglycemia on PI progression.[9,29] It is inconclusive that diabetes is a potential risk for developing PI.

Other Systemic Conditions

Due to the lack of sufficient evidence, the influence of other systemic conditions in PI development is uncertain. However, few studies indicate a greater prevalence of PI in a patient with cardiovascular disease.[29,30] Too few studies have been done to make any conclusions on the relationship between cardiovascular disease and PI. A 5-year longitudinal study reported considerably elevated parameters like bleeding on probing, probing depth, and loss of marginal bone in obese compared to nonobese patients. It was concluded that obesity is a risk factor for peri-implant disease.[31] Two recent studies also indicated a higher occurrence of PI in those with metabolic syndrome, when compared to nonmetabolic syndrome patients.[32,33] There is limited evidence available to conclude that other systemic conditions (without diabetes) are risk factors/ indicators for the onset of PI.

Autoimmune Diseases

Krennmair et al reported a higher incidence of the crestal bone resorption and bleeding on probing in patients with rheumatoid arthritis.[34] Alsaadi et al demonstrated occurrence of peri-implant disease and early implant failure in patients with Crohn's disease.[35] Another study investigated Sjögren's syndrome patients but was unable to demonstrate an increased prevalence of PI.[36] Due to lack of evidence, further investigation is still needed to clarify the relationship between PI and autoimmune disorders.[37]

Patient's Medications

Recently, PI has been reported to be linked with certain medications. Medications including selective serotonin reuptake inhibitors (SSRIs), bisphosphonates, and proton pump inhibitors (PPIs) have a detrimental effect on bone formation and impair bone metabolism, potentially affecting the osseointegration of dental implants. Patients on SSRIs for depression have been reported to have a high rate of implant failures due to PI.[38,39] Retrospective studies have indicated an impact of osteoporosis and bisphosphonate therapy on bone levels around implants.[40,41] PPIs used to treat Crohn's disease were also reported to be linked with increased peri-implant bone loss.[42] Further investigation required to establish the role of patient's medications on PI.

Stress

Chronic psychological stress may also potentially increase the risk of periodontitis through modifications in healthy behaviors (such as poor oral hygiene, smoking, and an unhealthy diet).[43] It is plausible that similar mechanisms are triggered in the peri-implant tissues and resulting in a higher susceptibility to PI in individuals suffering from chronic psychological stress since periodontitis and PI have similar characteristics. Strooker et al reported that psychological stress is a risk indicator for PI in a cross-sectional cohort study.[43] Makedonova et al also demonstrated psychoemotional stress as a triggering factor for the development of inflammatory complications after dental implant placement.[44] However, there is a paucity of evidence to suggest an association between stress and PI.

Patient Related Habits

A higher risk of implant failure over time has been observed in patients with parafunctional habits (specially bruxism). In a cross-sectional study, Stacchi et al reported a significant association between parafunctional habits and PI.[45] Kadu et al in a systematic review reported that bruxism can cause dental implant failure and is a contributing factor in the development of technical and biological difficulties.[46] In another study, Atieh et al did not find any significant relation between parafunction and peri-implant disease conditions.[47] Due to lack of evidence, the role of patient related habits (parafunctional habits) as a risk factor for PI is still inconclusive.

Genetic Factors

Literature proposed a probable association exists between genetic polymorphisms and the development of PI. However, the prognostic utility of these genetic configurations in recognizing people who are more likely to develop PI is still limited.[8] A recent study showed 1.9 to 2.47-fold more possibility for PI development in those with interleukin-1 polymorphisms[48] however, another investigation found no link between the two.[49] Polymorphism of another pro-inflammatory cytokine, tumor necrosis factor-alpha, was also reported to have five to eight times more risk for PI.[50,51] Nevertheless, a meta-analysis of relevant research found contradictory results.[52] Due to a lack of evidence, the correlation between other genetic polymorphisms and PI is inconclusive.[50] Although available evidence suggests the influence of various gene polymorphisms in PI progression, there is a need for further studies with a larger sample size (►**Table 2**).

Implant-Level Risk Factors

Surface Characteristics

Recently there has been an increased interest in the surface characteristics of dental implants on their long-term success. The contemporary dental implant roughened surfaces

Table 2 Genetic factors and peri-implantitis

Study (year)	Sample size	Inferences
García-Delaney et al[49] 2015	27 patients with peri-implantitis (PI) and 27 patients with healthy implants	Interleukin-1 (IL-1) genotypes do not seem to be good predictors of PI
Rakic et al[53] 2015	180 individuals with PI and 189 with healthy peri-implant tissues	Tumor necrosis factor-alpha (TNF-α), was reported to have 5 times more risk for PI
Petkovic-Curcin et al[51] 2017	34 patients with PI and 64 patients with healthy peri-implant tissue	presence of TNF-α genotypes may increase the risk for PI
He et al[48] 2020	144 patients with PI and 174 healthy controls	There was a 1.9- to 2.47-fold more possibility for PI development in those with IL-1 polymorphisms
Zhang et al[54] 2021	2,243 chronic periodontitis patients, 824 aggressive periodontitis patients, 615 PI patients, 795 healthy peri-implant patients, and 3575 healthy controls	No significant association seen between the variant A of the TNF-α (G-308A) polymorphism and PI risk.
Saremi et al[55] 2021	50 patients with PI and 89 periodontally healthy controls	Specific gene polymorphisms of IL-10—819 C/T, IL-10—592 C/A, and IL-1β + 3954 C/T may play a role in the pathogenesis of PI, and increase its risk of occurrence.
Jin et al[56] 2021	1,324 cases with peri-implant disease and 1,808 controls with healthy implants	Functional polymorphisms of IL-1α, IL-1β can be used as predictive markers for peri-implant disease, whereas TNF-α polymorphism was not associated with peri-implant disease.

compared to the original machined surface permits improved osseointegration, instantaneous implant placement, and loading.[2]

The impact of an implant's surface characteristics on PI susceptibility is still up for debate.[2] Dreyer et al reported a higher susceptibility of PI in rough surface implants,[1] whereas another study found no difference between moderately rough and rough surfaces.[57] Moderately rough implants were reported to have a lower risk for PI (implant—5.4% and patient-level 5.9%) in a recent meta-analysis when compared to rough and minimally rough surfaces.[5] A retrospective study of 13 to 32 years found that machined surface implants are highly reliable regarding survival and success.[58] Hybrid implants with a machined collar and a rough periapical surface may help to lower PI risk.[59] In PI, however, a HOP and smoking are regarded to have a higher contribution than implant surface topographies.[8] In a current systematic review, Stavropoulos et al reported a significant negative impact of surface characteristics of modified implants on PI progression as per pre-clinical in vivo experiments analysis, while clinical studies did not support the idea.[60] Due to lack of conclusive evidence, surface characteristics of the implant cannot be established as a risk factor for PI.

Titanium Dissolution Products

Titanium dissolution products might be released into the tissues around the implants during various conditions. Intraorally, saliva can dissolve titanium oxide coating on the exposed dental implants and implant rehabilitations, causing the initiation of corrosion. The release of titanium ions and particles can also be stimulated by microgap at the implant–abutment interface, fluoride presence, and mechanical factors.[61] Pettersson et al reported that patients with PI have a higher amount of dissolved particles of titanium around their dental implants.[62] A study that analyzed the subgingival plaque collected from 15 implants that had been in use for 10 years demonstrated that titanium particles were a major component of the oral microbiome in patients with this peri-implant disease.[63] Although implant corrosion products have been detected in patients with PI, the role of titanium dissolution products is inconclusive due to lack of sufficient evidence.

Prosthetic Design

During the restoration fabrication, the prostheses design and manipulation of peri-implant tissues have a considerable impact on the progression of PI. Inadequate oral hygiene maintenance due to poorly built superstructures leads to a higher chance of peri-implant infections.[2] Plaque deposition is favored by an asymmetrical restoration with a suboptimal emerging profile, with a 4.3-fold increase in the incidence of PI.[64] A deprived marginal fit can also enhance the chance for the development of PI.[2]

Regarding the type of prosthesis, removable implant prostheses were found to have a higher rate of implant problems than single implant crowns. When compared to single crown rehabilitation with implants, full mouth rehabilitations were found to be 16 times more at risk for PI.[21] The risk of PI is also higher if bone-level implants are paired with convex reconstructions at an angle greater than 30 degrees.[64] Platform switching was determined advantageous to peri-implant health when combined with a customized abutment and extraoral cementation of the restoration onto the abutment.[8] A recent clinical study also found that platform switching dramatically lowered the risk of PI.[27] Due to lack of evidence, the role of improper prosthetic design as a risk factor for PI is still inconclusive. However, platform switching can lower the risk of developing PI.

Implant–Abutment Connection

The microgap at the implant–abutment interfaces may facilitate plaque deposition along with bacterial microleakage that can enhance the risk of peri-implant infections.[8] In a systematic analysis, Mishra et al evaluated the sealing ability of different implant–abutment connections. They reported that the internal hexagonal implants (mainly internal conical) were more efficient to prevent microleakage in both static and dynamic loading than any other implants.[65] Mencio et al in a randomized clinical trial of 20 implants (10 in each group) concluded that screw-retained implant connections were more at risk for developing PI than implants with a cemented connection.[66] The implant–abutment connection design does not have an influence on the survival and biologic complication rates. Further research is required to establish the implant–abutment connection as a potential risk factor for PI.

Tissue Phenotype

Peri-implant tissue phenotype comprises the keratinized mucosa width and mucosal thickness. The importance of these two factors in preserving tissue stability around implants is a current topic of interest in implantology. van Eekeren et al reported two to five times less marginal bone resorption in thick soft tissue sites (>2mm) compared to thin soft tissues after implant placement.[67] A strong association between mucosal thickness and peri-implant crestal bone conservation has also been found in several systematic reviews.[68,69] Recent clinical research also indicated that the thin peri-implant phenotype had a considerable association with the severity of PI.[70]

Most human clinical trials demonstrated about 2 mm or more of keratinized mucosa was favorable to prevent mucosal recession and marginal bone resorption. Also, this resulted in a considerable reduction in plaque deposition, inflammation of tissue, and probing depths since individuals experienced less brushing discomfort. A strong association between keratinized tissue width of less than 2 mm and PI was reported in a retrospective analysis.[71] However, in a 5-year retrospective analysis of 87 patients (42 females and 45 males), Lim et al failed to show any association between these two.[72] Although available evidence suggests a possible role of tissue phenotype in PI development, the evidence is still limited.

Excess Cement

The likelihood of residual cement in the tissues around the implant is a major drawback of cemented implant

restorations. Along with plaque retention, excess cement also acts as a foreign substance and thus makes cemented prostheses more susceptible to PI.[8] In a cross-sectional study, gram-negative bacteria were present in larger numbers around cement-retained rehabilitation compared to screw-retained ones.[73] The volume of residual cement is influenced by the emergence profile of a prosthesis. In comparison to convex emergence profiles, concave profiles have substantially higher excess cement on the abutment surface.[74] A systematic review by Staubli et al reported the presence of residual cement in 33 to 100% of cemented restorations with PI.[75] Equigingival abutment margins permit an easier elimination of the cement excess. Following a stringent cementation procedure and early follow-ups after cementation can minimize the risks of excess residual cement.[75] Current evidence suggests that excess cement is a potential risk factor for the onset of PI.

Occlusal Overload

Although a clear-cut relationship has not been established, occlusal overload could be to blame for the loss of marginal bone without any symptoms of inflammation.[8] A study in an animal model indicated occlusal overload as a stimulating factor for plaque-induced bone resorption in the presence of inflammation.[76] A case report by Merin in 2014 conveyed, osseodisintegration of an implant in the presence of excessive load, and reosseointegration took place as soon as the occlusal load was removed.[77] A retrospective study of 28 full-arch prostheses also demonstrated more amount of crestal bone resorption in the immediately loaded group compared to the delayed loaded group.[78] There is lack of scientific evidence in human studies to establish a role of occlusal overload in the onset of PI.

Implant Materials

Titanium has so far been the preferred material for implant dentistry. However, zirconia ceramic implants have been rapidly gaining popularity for its biocompatibility, low affinity to plaque, and reduced inflammatory processes compared to titanium.[2] A study in an animal model demonstrated significantly reduced inflammation and bone loss in zirconia implant compared to titanium one.[79] Another experimental study on animal also indicated significant difference in marginal bone alterations among zirconia and titanium implants.[80] A systematic review also demonstrated decreased marginal bone loss around zirconia implant.[81]

Dimension of Implants

The dimensions of implant (diameter and length of the implants) may influence the occurrence of peri-implant disease. Dalago et al in a cross-sectional study found a significant higher prevalence of PI in short implants ($<$9 mm).[13] Yi et al reported that patients treated with narrow and long implant demonstrated greater marginal bone loss.[82] A retrospective analysis indicated that compared to regular diameter implants, narrow diameter implants were associated with greater bone loss during the first 3 years following implantation.[83] Another retrospective cohort study demonstrated a negative correlation between implant diameter and crestal bone loss, with a diameter increase of 1 mm being correlated with a crestal bone level decrease of approximately 0.11 mm.[41] A systematic review demonstrated higher crestal bone loss and lower survival rate associated with narrow diameter implants compared to wide diameter implants.[84] Due to the lack of sufficient evidence, the influence of dimension of implants in PI development is uncertain.

Jaw Location of Implants

It has been postulated that the implant's anatomic location may serve as a potential indicator of the onset of peri-implant bone loss. Previous retrospective studies found that the maxillary region had a higher likelihood of implant loss and a greater number of risk variables.[85,86] Serino and Turri also reported a higher prevalence of PI in the maxillary anterior region.[87] The authors concluded a possible role of the quality of the bone in the development of peri-implant inflammation and resultant bone loss. Since maxilla contains a larger medullary area and more vascular and cellular components, it is more prone to develop PI especially in smokers.[87] In a retrospective cohort study, French et al analyzed 4,591 maxillary and mandibular implants, over time, and demonstrated greater marginal bone loss in anterior implants compared to posterior implants.[41]

Implant Position

The long-term function and aesthetics of the implant are influenced by the dental implant's spatial position into the bone. It enables efficient plaque management to reduce peri-implant inflammation.[2] A malpositioned implant is more prone to develop PI. It might be due to the violation of the physiological hard and soft tissue boundaries. Additionally, it leads to improperly contoured prostheses that are difficult to clean.[88] Also, mucosal recession is more likely to occur in fixtures that are positioned outside the skeletal envelope. This causes exposure of the fixture's rough surface and increases the risk of PI by increasing plaque retention.[89] Moreover, the risk of developing PI is also increased by 8.5 times when an implant is positioned 6 mm or more apical to the cementoenamel junction of the neighboring teeth.[12]

Sinus Lift Techniques

Sinus floor elevation may be a secure and dependable choice to improve the amount of available bone height for implant implantation when appropriate intermaxillary relationship is retained.[45] But this procedure may enhance the occurrence of post-treatment complications. There is insufficient data in the literature to assess the prevalence of PI in sites with augmented maxillary sinuses. A retrospective study reported that implants placed in sites that received maxillary sinus augmentation exhibited more marginal bone loss than implants placed in pristine bone, although marginal bone loss mainly occurred during the first 12 months after functional loading.[90] Stacchi et al demonstrated that sinus elevation with lateral approach and one-stage sinus floor

elevation significantly correlated with the occurrence of PI.[45] Krennmair et al reported an increased crestal bone level alteration over time for implants placed in staged maxillary sinus augmentation.[11] The available data is insufficient to conclude the role of sinus floor elevation in development of PI.

In this review, the related studies for each risk factor were reviewed in order to draw the conclusion **(►Table 3).** It can

Table 3 Studies regarding risk factors for peri-implantitis

Author	Type of study	Interpretation
History of periodontitis		
Dalago et al 2017[13]	Cross-sectional study	History of periodontitis (HOP) is a potential risk factor for the development of peri-implantitis (PI)
Kumar et al 2018[12]	Retrospective analysis	Periodontitis on the teeth near the implant at the time of implant restoration was a significant predictor of PI in the future
Ferreira et al 2018[10]	Systematic review	Based on the analysis of cohort studies, PI was associated with the HOP
Dreyer et al 2018[1]	Systematic review	The history or presence of periodontitis was identified as a risk factor for PI on a medium-high level of evidence
Arunyanak et al 2019[14]	Cross-sectional study	Patients with HOP were 2.2-2.5 times more prone to develop a PI
Gunpinar et al 2020	Cross-sectional study	Patient with history of periodontitis or active periodontitis were more likely to develop PI
Stacchi et al 2021[45]	Cross-sectional study	HOP demonstrated its well-known role as a risk factor for peri-implant diseases
Oral hygiene and maintenance therapy		
Serino and Ström 2009[16]	Cross-sectional study	There was a 3.8-fold more risk of PI development in patients with improper oral hygiene compared to subjects with proper oral hygiene
Canullo et al 2016	Cross-sectional study	Inadequate oral hygiene in patients with dental implant was associated with a higher prevalence of PI
Monje et al 2016[19]	Systematic review	Peri-implant maintenance therapy is significantly associated with prevention of PI
Atieh et al 2019[17]	Retrospective analysis	Inadequate supportive maintenance care was a risk predictor for PI in patients with implant-supported restorations
Costa et al 2019[18]	Prospective study	There was an increased microbial load and higher occurrence of PI due to a lack of routine maintenance
Lin et al 2019	Systematic review	Supportive treatment during maintenance phase after implant therapy can potentially improve peri-implant health in terms of survival rate, and development of peri-implant diseases.
Smoking		
Sgolastra et al 2015[26]	Systematic review	There was insufficient evidence available to suggest any relationship between smoking and PI
Turri et al 2016	Systematic review	Smoking can be considered as a biologic associated factor for PI
Chun-Teh Lee et al 2017	Systematic Review	Percentage of smoking subjects was positively associated with implant-based PI prevalence
Dreyer et al 2018[1]	Systematic review	The smoking history was identified as a risk factor for PI on a medium-high level of evidence
Pimentel et al 2018[25]	Cross-sectional study	Smoking raised the risk of PI by three times in subjects with implants
ArRejaie et al 2019[21]	Cross-sectional study	Implant sites showed considerably greater levels of proinflammatory cytokines, probing depths, bleeding, suppuration, and plaque scores in smokers than nonsmokers
Costa et al 2022	Cross-sectional study	The occurrence of PI among current smoker was high

(*Continued*)

Table 3 (*Continued*)

Author	Type of study	Interpretation
Diabetes mellitus		
Naujokat et al 2016	Systematic review	Patients with poorly controlled diabetes suffer from impaired osseointegration, elevated risk of PI, and higher level of implant failure
Monje et al 2017[27]	Systematic review	When the confounding factor of smoking was removed from the analysis, a 3.39-fold higher risk of PI development was reported in patients with diabetes type-2 than in healthy individuals
Dreyer et al 2018[1]	Systematic review	The risk of PI development was three times more in patients with diabetes mellitus than in patients without diabetes mellitus
Meza Maurício et al 2019[28]	Systematic review	diabetes mellitus/hyperglycemia seems to be associated with a high risk of PI
Al Ansari et al 2022	Systematic review and meta-analysis	When compared to non-diabetic patients, diabetes patients have a statistically significant higher risk of implant failure and marginal bone loss
Other systemic conditions		
Krennmair et al 2016[30]	Prospective-cohort study	Cardiovascular diseases are potential risk factor for PI
Alkhudhairy et al 2018[31]	Longitudinal prospective clinical trial	Compared to non-obese patients, individuals with obesity demonstrated a significantly higher pocket depth and bone loss
Ting et al 2018[29]	Systematic review	Patients with cardiovascular diseases have a higher risk of developing PI
Papi et al 2019[32]	Cross-sectional study	Patients affected by metabolic syndrome showed a greater prevalence of peri-implant diseases.
Di Murro et al 2019[33]	Case–control study	There was a statistically significant higher prevalence of peri-implant diseases in patients with metabolic syndrome compared to healthy patients.
Autoimmune diseases		
Alsaadi et al 2008[35]	Cross-sectional study	Occurrence of peri-implant disease and early implant failure in patients with Crohn's disease.
Krennmair et al 2010[34]	Retrospective clinical follow-up study	There was higher incidence of the crestal bone resorption and bleeding on probing in patients with rheumatoid arthritis.
Korfage et al 2016[36]	Retrospective analysis	No significant difference in the prevalence of peri-implant disease between patients with Sjögren's syndrome and healthy individuals.
Patient medications		
Deepa et al 2018[38]	Retrospective study	Patients on selective serotonin reuptake inhibitors for depression have a high rate of implant failures due to PI
Mayta-Tovalino et al 2019[40]	Retrospective study	Patient on bisphosphonate therapy had comparatively higher level of peri-implant bone loss than healthy individuals.
French et al 2019[41]	Retrospective cohort study	Marginal bone loss was significantly higher in patients on bisphosphonate therapy.
Ursomanno et al 019[42]	Retrospective study	Proton pump inhibitors used to treat Crohn's disease were reported to be linked with increased peri-implant bone loss.
Stress		
Makedonova et al 2021[44]	Cross-sectional study	The presence of psychoemotional stress can be a triggering factor for the development of inflammatory complications after dental implantation.
Strooker et al 2022[43]	Cross-sectional cohort study	Presence of psychological stress is a risk indicator for PI

Table 3 (*Continued*)

Author	Type of study	Interpretation
Patient related habits		
Kadu et al 2020[46]	Systematic review	Bruxism can cause dental implant failure and is a contributing factor in the development of technical and biological difficulties.
Stacchi et al 2021[45]	Cross-sectional study	There was a significant association between parafunctional habits and PI
Atieh et al 2022[47]	Retrospective analysis	There was no significant relation between parafunctions and peri-implant disease conditions.
Genetic factors		
García-Delaney et al 2015[49]	Case–control study	IL-1 genotypes do not seem to be good predictors of PI
Rakic et al 2015[53]	Case–control study	Tumor necrosis factor-alpha (TNF-α), was reported to have 5 times more risk for PI
Petkovic-Curcin et al 2017[51]	Case–control study	Presence of TNF-α genotypes may increase the risk for PI
He et al 2020[48]	Case–control study	There was 1.9- to 2.47-fold more possibility for PI development in those with interleukin-1(IL-1) polymorphisms
Zhang et al 2021[54]	Systematic review and meta-analysis	No significant association seen between the variant A of the TNF-α (G-308A) polymorphism and PI risk
Leila Saremi et al 2021[55]	Case–control study	Specific gene polymorphisms of IL-10—819 C/T, IL-10—592 C/A, and IL-1β + 3954 C/T may play a role in the pathogenesis of PI, and increase its risk of occurrence
Jin et al 2021[56]	Systematic review and meta-analysis	Functional polymorphisms of IL-1α, IL-1β can be used as predictive markers for peri-implant disease, whereas TNF-α polymorphism was not associated with peri-implant disease
Cardoso et al 2022	Systematic review and meta-analysis	Individuals with the polymorphism in the IL-1B +3954 gene have a higher risk for the development of PI
Surface characteristics		
Dvorak et al 2011[57]	Cross-sectional study	There was no significant difference in PI among implant with moderately rough and rough surfaces
Spinato et al 2017[59]	Preliminary study	Hybrid implants with a machined collar and a rough periapical surface may help to lower PI risk
Dreyer et al 2018[1]	Systematic review	Rough surface implant had a higher susceptibility for development of PI
Rakic et al 2018[5]	Systematic review and meta-analysis	Moderately rough implants have a lower risk for PI compared to rough and minimally rough surfaces
Simion et al 2018[58]	Retrospective study	Machined surface implants are highly reliable regarding survival and success
Stavropoulos et al 2021[60]	Systematic review	Surface characteristics of modified implants had a significant negative impact on PI progression
Titanium dissolution products		
Daubert et al 2018[63]	Cross-sectional study	Titanium particles were a major component of the oral microbiome in patients with peri-implant disease
Suárez-López Del Amo et al 2018	Systematic review	PI sites presented a higher number of particles compared to healthy implants
Pettersson et al 2019[62]	Cross-sectional study	Patients with PI had a higher amount of dissolved particles of titanium around their dental implants
Rakic et al 2022	Cross-sectional study	Titanium particles were identified in all PI specimens as free metal bodies interspersed within granulation tissue. However, presence of macrophages or multinucleated giant cells engulfing the Titanium particles were not identified in any specimen
Freitag et al 2023	Systematic review	Titanium particles from implant may affect the onset and progression of PI

(*Continued*)

Table 3 (*Continued*)

Author	Type of study	Interpretation
Prosthetic design		
Rammelsberg et al 2017	Prospective study	Removable implant prostheses have a higher rate of implant problems than single implant crowns
Dalago et al 2017[13]	Cross-sectional study	Compared to single crown rehabilitation with implants, full mouth rehabilitations were found to be 16 times more at risk for PI
Monje et al 2017[27]	Systematic review	Platform switching lowered the risk of peri-implantitis
Katafuchi et al 2018[64]	Cross sectional study	Plaque deposition is favored by an asymmetrical restoration with a sub-optimal emerging profile, with a 4.3-fold increase in the incidence of PI
Yi et al 2020[82]	Cross-sectional study	Over-contoured implant prosthesis is a critical local confounder for PI
Implant-abutment connection		
Romanos et al 2014	Randomized clinical trial	Implants with internal conical connections demonstrated less crestal bone loss than implants with internal clearance-fit connections
De Medeiros et al 2016	Systematic review	Osseointegrated dental implants with internal connections exhibited lower marginal bone loss than implants with external connections
Mishra et al 2017[65]	Systematic review	The internal hexagonal implants (mainly internal conical) were more efficient in preventing microleakage in both static and dynamic loading than any other implants
Mencio et al 2017[66]	Randomized clinical trial	Screw-retained implant connections were more at risk for developing PI than implants with a cemented connection
Lemos et al 2018	Systematic review	Internal connections had lower marginal bone loss when compared to external connections
Caricasulo et al 2018	Systematic review	In the short-medium term, internal conical connection seems to be better to maintain the peri-implant crestal bone level
Javier Sanz-Esporrin et al 2020	Preclinical in vivo investigations	Compared to implants with platform switching connections, radiographic bone loss during the induction phase was noticeably higher in implants with matched abutments
Tissue phenotype		
Suárez-López Del Amo et al 2016[68]	Systematic review	Implants placed with an initially thicker peri-implant soft tissue have less radiographic MBL in the short term
Souza et al 2016	Cohort study	Implant sites with a narrow band of keratinized mucosa ($<$2 mm) were more prone to peri-implant inflammatory conditions
van Eekeren et al 2017[67]	Randomized clinical trial	Marginal bone resorption was 2-5 times less in thick gingival tissue site ($>$2 mm) compared to thin soft tissues after implant placement
Thoma et al 2018	Systematic review	Gain of mucosal thickness resulted in significant less marginal bone loss over time
Perussolo et al 2018	Prospective follow-up study	Presence of a keratinized mucosa $\geq$ 2 mm around implants are beneficial for maintaining peri-implant health
Isler et al 2019[70]	Cross-sectional study	The thin peri-implant phenotype had a considerable association with the severity of PI
Wada et al 2019[71]	Retrospective analysis	A strong association reported between keratinized tissue width of less than 2 mm and PI was reported in a retrospective analysis
Lim et al 2019[72]	Retrospective analysis	A minimal correlation was found between peri-implant disease and the width of keratinized mucosa around dental implants

Table 3 (*Continued*)

Author	Type of study	Interpretation
Excess cement		
Wilson et al 2009	Prospective clinical study	Along with plaque retention, excess cement also acts as a foreign substance and thus makes cemented prostheses more susceptible to PI
Korsch et al 2015	Retrospective follow-up study	A higher prevalence of peri-implant inflammation and a greater degree of peri-implant bone loss are caused by cements that have a tendency to leave more undetected excess
Kotsakis et al 2016	Cross-sectional study	When appropriate selection and removal of cement is performed, cement-retention is not a risk indicator for peri-implant diseases
Staubli et al 2017[75]	Systematic review	Presence of residual cement was reported cement 33% to 100% of cemented restorations with PI
Ramón-Morales et al 2019[73]	Cross-sectional study	Gram-negative bacteria were present in larger numbers around cement-retained rehabilitation compared to screw-retained ones
Occlusal overload		
Kozlovsky et al 2007[76]	Animal study	Occlusal overload is a stimulating factor for plaque-induced bone resorption in the presence of inflammation
Chambrone et al 2010	Systematic review	Occlusal overload may lead to loss of crestal bone in the presence of plaque
Merin 2014[77]	Case report	Presence of excessive load was associated with osseodisintegration of implant, and reosseointegration took place as soon as the occlusal load was removed
Kumar et al 2017[78]	Retrospective analysis	More amount of crestal bone resorption in the immediately loaded group compared to the delayed loaded group
Bertolini et al 2019	Systematic review	There might be an association between occlusal overloading and peri-implant bone loss when pathologic overload is applied prior osseointegration
Implant materials		
Thoma et al 2016[80]	Animal study	There was a significant difference in marginal bone alterations among zirconia and titanium implants
Pieralli et al 2017[81]	Systematic review	Zirconia implant had a promising affect regarding marginal bone loss
Roehling et al 2019[79]	Animal study	Zirconia implant had significantly reduced ligature-induced inflammation and bone loss compared to titanium one
Dimension of implants		
Zweers et al 2015[83]	Retrospective analysis	In comparison to regular diameter implants, narrow diameter implants were associated with greater bone loss during the first three years following implantation
Dalago et al 2017[13]	Cross-sectional study	PI was more prevalent in implants with short length ($<$9 mm)
Schiegnitz and Al-Nawas 2018[84]	Systematic review	Narrow diameter implants were associated with higher crestal bone loss and lower survival rate compared to wide diameter implants
French et al 2019[41]	Retrospective analysis	There was a negative correlation between implant diameter and crestal bone loss, with a diameter increase of 1 mm being correlated with a decrease of approximately 0.11 mm in crestal bone level
Yi et al 2020[82]	Cross-sectional study	Patients treated with narrow and long length implant group showed greater marginal bone loss
Jaw location of implants		
Serino and Turri 2011[87]	Retrospective analysis	There was a higher prevalence of PI in the maxilla, particularly in anterior region

(*Continued*)

Table 3 (*Continued*)

Author	Type of study	Interpretation
French et al 2019[41]	Retrospective analysis	Greater marginal bone loss was reported in anterior implants compared to posterior implants
Chang 2020[85]	Retrospective analysis	The maxillary region had a higher likelihood of implant loss and a greater number of risk variables
Wu et al 2021[86]	Retrospective analysis	Peri-implant diseases are more prevalent in maxilla
Implant position		
Canullo et al 2015	Retrospective study	Implant malposition was reported as a risk predictor for peri-implant diseases
Romandini et al 2021	Cross-sectional study	Implant malposition was significantly associated with PI
Romandini et al 2021	Cross-sectional study	Implant malposition was indicated as a significant risk factor of peri-implant soft tissue dehiscence
Sinus lift techniques		
Galindo-Moreno et al 2014[90]	Retrospective study	Implants placed in sites that received maxillary sinus augmentation exhibited more marginal bone loss than implants placed in pristine bone
Krennmair et al 2019[11]	Prospective cohort study	Crestal bone level alteration was increased over time for implants placed in staged maxillary sinus augmentation
Stacchi et al 2021[45]	Cross-sectional study	Sinus elevation with lateral approach, and one-stage sinus floor elevation significantly correlated with the occurrence of PI

be summarized from the various aspects of this review that some risk factors such as the HOP, poor oral hygiene and lack of maintenance therapy, and excess cement are supported by scientific evidence, whereas other factors although perceived as relevant by researchers, however, there is a paucity of evidence to indicate a definite role (►**Table 4**).

Table 4 Risk factors for peri-implantitis (based on evidence)

Risk factors supported by scientific evidence	Requiring further scientific evidence
1. History of periodontitis 2. Poor oral hygiene and lack of maintenance therapy 3. Excess cement	1. Smoking 2. Diabetes mellitus 3. Other systemic conditions 4. Genetic factors 5. Autoimmune diseases 6. Patient's medications 7. Stress 8. Patient related habits 9. Surface characteristics 10. Titanium dissolution products 11. Prosthetic design 12. Implant-abutment connection 13. Tissue phenotype 14. Occlusal overload 15. Implant materials 16. Dimension of implants 17. Jaw location of implants 18. Implant position 19. Sinus lift techniques

Conclusions

The identification of risk factors and reducing the risk are important in treatment planning for implants. This will help clinicians to design a tailor-made supportive therapy based on patients' needs, thus reducing the incidence of disease. Awareness, understanding of the risk factors, and appropriate selection of implants and prostheses along with patient education and motivation are crucial for successful long-term outcomes.

Conflict of Interest
None declared.

References

1 Dreyer H, Grischke J, Tiede C, et al. Epidemiology and risk factors of peri-implantitis: a systematic review. J Periodontal Res 2018; 53(05):657–681
2 Hashim D, Cionca N. A comprehensive review of peri-implantitis risk factors. Curr Oral Health Rep 2020;27:1–2
3 Caton JG, Armitage G, Berglundh T, et al. A new classification scheme for periodontal and peri-implant diseases and conditions - introduction and key changes from the 1999 classification. J Periodontol 2018;89(Suppl 1):S1–S8
4 Berglundh T, Armitage G, Araujo MG, et al. Peri-implant diseases and conditions: Consensus report of workgroup 4 of the 2017 World Workshop on the Classification of Periodontal and Peri-Implant Diseases and Conditions. J Periodontol 2018;89(Suppl 1): S313–S318
5 Rakic M, Galindo-Moreno P, Monje A, et al. How frequent does peri-implantitis occur? A systematic review and meta-analysis. Clin Oral Investig 2018;22(04):1805–1816
6 Renvert S, Persson GR, Pirih FQ, Camargo PM. Peri-implant health, peri-implant mucositis, and peri-implantitis: case definitions and

diagnostic considerations. J Clin Periodontol 2018;45(Suppl 20): S278–S285
7 Lasserre JF, Brecx MC, Toma S. Oral microbes, biofilms and their role in periodontal and peri-implant diseases. Materials (Basel) 2018;11(10):22
8 Maney P, Schiavo JH, Mascarenhas F, Dragonas P. Risk factors for peri-implantitis. Curr Oral Health Rep 2020;30:1–5
9 Schwarz F, Derks J, Monje A, Wang HL. Peri-implantitis. J Clin Periodontol 2018;45(Suppl 20):S246–S266
10 Ferreira SD, Martins CC, Amaral SA, et al. Periodontitis as a risk factor for peri-implantitis: systematic review and meta-analysis of observational studies. J Dent 2018;79:1–10
11 Krennmair S, Hunger S, Forstner T, Malek M, Krennmair G, Stimmelmayr M. Implant health and factors affecting peri-implant marginal bone alteration for implants placed in staged maxillary sinus augmentation: a 5-year prospective study. Clin Implant Dent Relat Res 2019;21(01):32–41
12 Kumar PS, Dabdoub SM, Hegde R, Ranganathan N, Mariotti A. Site-level risk predictors of peri-implantitis: a retrospective analysis. J Clin Periodontol 2018;45(05):597–604
13 Dalago HR, Schuldt Filho G, Rodrigues MA, Renvert S, Bianchini MA. Risk indicators for peri-implantitis. A cross-sectional study with 916 implants. Clin Oral Implants Res 2017;28(02):144–150
14 Arunyanak SP, Sophon N, Tangsathian T, Supanimitkul K, Suwanwichit T, Kungsadalpipob K. The effect of factors related to periodontal status toward peri-implantitis. Clin Oral Implants Res 2019;30(08):791–799
15 Renvert S, Quirynen M. Risk indicators for peri-implantitis. A narrative review. Clin Oral Implants Res 2015;26(Suppl 11):15–44
16 Serino G, Ström C. Peri-implantitis in partially edentulous patients: association with inadequate plaque control. Clin Oral Implants Res 2009;20(02):169–174
17 Atieh MA, Pang JK, Lian K, et al. Predicting peri-implant disease: Chi-square automatic interaction detection (CHAID) decision tree analysis of risk indicators. J Periodontol 2019;90(08):834–846
18 Costa FO, Ferreira SD, Cortelli JR, Lima RPE, Cortelli SC, Cota LOM. Microbiological profile associated with peri-implant diseases in individuals with and without preventive maintenance therapy: a 5-year follow-up. Clin Oral Investig 2019;23(08):3161–3171
19 Monje A, Aranda L, Diaz KT, et al. Impact of maintenance therapy for the prevention of peri-implant diseases: a systematic review and meta-analysis. J Dent Res 2016;95(04):372–379
20 Javed F, Kellesarian SV, Abduljabbar T, et al. Influence of involuntary cigarette smoke inhalation on osseointegration: a systematic review and meta-analysis of preclinical studies. Int J Oral Maxillofac Implants 2018;47(06):764–772
21 ArRejaie AS, Al-Aali KA, Alrabiah M, et al. Proinflammatory cytokine levels and peri-implant parameters among cigarette smokers, individuals vaping electronic cigarettes, and non-smokers. J Periodontol 2019;90(04):367–374
22 Gürlek Ö, Gümüş P, Buduneli N. Smokers have a higher risk of inflammatory peri-implant disease than non-smokers. Oral Dis 2018;24(1-2):30–32
23 Fransson C, Wennström J, Berglundh T. Clinical characteristics at implants with a history of progressive bone loss. Clin Oral Implants Res 2008;19(02):142–147
24 Pimentel SP, Fontes M, Ribeiro FV, et al. Smoking habit modulates peri-implant microbiome: a case-control study. J Periodontal Res 2018;53(06):983–991
25 Pimentel SP, Shiota R, Cirano FR, et al. Occurrence of peri-implant diseases and risk indicators at the patient and implant levels: a multilevel cross-sectional study. J Periodontol 2018;89(09): 1091–1100
26 Sgolastra F, Petrucci A, Severino M, Gatto R, Monaco A. Smoking and the risk of peri-implantitis. A systematic review and meta-analysis. Clin Oral Implants Res 2015;26(04):e62–e67
27 Monje A, Catena A, Borgnakke WS. Association between diabetes mellitus/hyperglycaemia and peri-implant diseases: systematic review and meta-analysis. J Clin Periodontol 2017;44(06): 636–648
28 Meza Maurício J, Miranda TS, Almeida ML, Silva HD, Figueiredo LC, Duarte PM. An umbrella review on the effects of diabetes on implant failure and peri-implant diseases. Braz Oral Res 2019;33 (suppl 1):e070
29 Ting M, Craig J, Balkin BE, Suzuki JB. Peri-implantitis: a comprehensive overview of systematic reviews. J Oral Implantol 2018;44 (03):225–247
30 Krennmair S, Weinländer M, Forstner T, Krennmair G, Stimmelmayr M. Factors affecting peri-implant bone resorption in four implant supported mandibular full-arch restorations: a 3-year prospective study. J Clin Periodontol 2016;43(01):92–101
31 Alkhudhairy F, Vohra F, Al-Kheraif AA, Akram Z. Comparison of clinical and radiographic peri-implant parameters among obese and non-obese patients: a 5-year study. Clin Implant Dent Relat Res 2018;20(05):756–762
32 Papi P, Di Murro B, Pranno N, et al. Prevalence of peri-implant diseases among an Italian population of patients with metabolic syndrome: a cross-sectional study. J Periodontol 2019;90(12): 1374–1382
33 Di Murro B, Papi P, Letizia C, Pompa G. The prevalence of peri-implant diseases in patients with metabolic syndrome: a case-control study on an Italian population sample. Minerva Stomatol 2019;68(04):143–149
34 Krennmair G, Seemann R, Piehslinger E. Dental implants in patients with rheumatoid arthritis: clinical outcome and peri-implant findings. J Clin Periodontol 2010;37(10):928–936
35 Alsaadi G, Quirynen M, Michiles K, Teughels W, Komárek A, van Steenberghe D. Impact of local and systemic factors on the incidence of failures up to abutment connection with modified surface oral implants. J Clin Periodontol 2008;35 (01):51–57
36 Korfage A, Raghoebar GM, Arends S, et al. Dental implants in patients with Sjögren's syndrome. Clin Implant Dent Relat Res 2016;18(05):937–945
37 Guobis Z, Pacauskiene I, Astramskaite I. General diseases influence on peri-implantitis development: a systematic review. J Oral Maxillofac Res 2016;7(03):e5
38 Deepa MK, Mujawar K, Dhillon K, Jadhav P, Das I, Singla YK. Prognostic implication of selective serotonin reuptake inhibitors in osseointegration of dental implants: a 5-year retrospective study. J Contemp Dent Pract 2018;19(07):842–846
39 Meyle J, Casado P, Fourmousis I, Kumar P, Quirynen M, Salvi GE. General genetic and acquired risk factors, and prevalence of peri-implant diseases - consensus report of working group 1. Int Dent J 2019;69 Suppl 2(Suppl 2):3–6
40 Mayta-Tovalino F, Mendoza-Martiarena Y, Romero-Tapia P, et al. An 11-year retrospective research study of the predictive factors of peri-implantitis and implant failure: analytic-multicentric study of 1279 implants in Peru. Int J Dent 2019;2019:3527872
41 French D, Grandin HM, Ofec R. Retrospective cohort study of 4,591 dental implants: analysis of risk indicators for bone loss and prevalence of peri-implant mucositis and peri-implantitis. J Periodontol 2019;90(07):691–700
42 Ursomanno Korf BL, Cohen RE, Levine MJ, Yerke LM. Treatment of Crohn's disease and ulcerative colitis with proton pump inhibitors: effect on bone loss at dental implants. Inflamm Bowel Dis 2019;25:S30–S1
43 Strooker H, de Waal YCM, Bildt MM. Psychological risk indicators for peri-implantitis: a cross-sectional study. J Clin Periodontol 2022;49(10):980–987
44 Makedonova Y, Mihalchenko D, Gavrikova L, Dyachenko S, Naumova V, Veremeenko S. THE role of psychoemotional stress in the development of inflammatory post-prosthetic complications. Archiv EuroMedica. 2021;11(03):86–89
45 Stacchi C, Troiano G, Rapani A, et al. Factors influencing the prevalence of peri-implantitis in implants inserted in augmented

maxillary sinuses: a multicenter cross-sectional study. J Periodontol 2021;92(08):1117–1125
46 Kadu A, Khare VV, Dawood T, Abbad N, Ranjeri S, Elagib MF. Impact of bruxism on dental implant: a systematic review & meta-analysis. Eur J Mol Clin Med 2020;7(11): 6498–6508
47 Atieh MA, Almutairi Z, Amir-Rad F, et al. A retrospective analysis of biological complications of dental implants. Int J Dent 2022; 2022:1545748
48 He K, Jian F, He T, Tang H, Huang B, Wei N. Analysis of the association of TNF-α, IL-1A, and IL-1B polymorphisms with peri-implantitis in a Chinese non-smoking population. Clin Oral Investig 2020;24(02):693–699
49 García-Delaney C, Sánchez-Garcés MÁ, Figueiredo R, Sánchez-Torres A, Gay-Escoda C. Clinical significance of interleukin-1 genotype in smoking patients as a predictor of peri-implantitis: a case-control study. Med Oral Patol Oral Cir Bucal 2015;20(06): e737–e743
50 Eguia Del Valle A, López-Vicente J, Martínez-Conde R, Aguirre-Zorzano LA. Current understanding of genetic polymorphisms as biomarkers for risk of biological complications in implantology. J Clin Exp Dent 2018;10(10):e1029–e1039
51 Petkovic-Curcin A, Zeljic K, Cikota-Aleksic B, Dakovic D, Tatic Z, Magic Z. Association of cytokine gene polymorphism with peri-implantitis risk. Int J Oral Maxillofac Implants 2017;32(05): e241–e248
52 Mo YY, Zeng XT, Weng H, Cen Y, Zhao Q, Wen X. Association between tumor necrosis factor-alpha G-308A polymorphism and dental peri-implant disease risk: a meta-analysis. Medicine (Baltimore) 2016;95(35):e4425
53 Rakic M, Petkovic-Curcin A, Struillou X, Matic S, Stamatovic N, Vojvodic D. CD14 and TNFα single nucleotide polymorphisms are candidates for genetic biomarkers of peri-implantitis. Clin Oral Investig 2015;19(04):791–801
54 Zhang X, Zhu X, Sun W. Association between tumor necrosis factor-α (G-308A) polymorphism and chronic periodontitis, aggressive periodontitis, and peri-implantitis: a meta-analysis. J Evid Based Dent Pract 2021;21(03):101528
55 Saremi L, Shafizadeh M, Esmaeilzadeh E, et al. Assessment of IL-10, IL-1ß and TNF-α gene polymorphisms in patients with peri-implantitis and healthy controls. Mol Biol Rep 2021;48(03): 2285–2290
56 Jin Q, Teng F, Cheng Z. Association between common polymorphisms in IL-1 and TNFα and risk of peri-implant disease: a meta-analysis. PLoS One 2021;16(10):e0258138
57 Dvorak G, Arnhart C, Heuberer S, Huber CD, Watzek G, Gruber R. Peri-implantitis and late implant failures in postmenopausal women: a cross-sectional study. J Clin Periodontol 2011;38(10): 950–955
58 Simion M, Nevins M, Rasperini G, Tironi F. A 13- to 32-year retrospective study of bone stability for machined dental implants. Int J Periodont Restor Dent 2018;38(04):489–493
59 Spinato S, Bernardello F, Sassatelli P, Zaffe D. Hybrid implants in healthy and periodontally compromised patients: a preliminary clinical and radiographic study. Int J Periodont Restor Dent 2017; 37(02):195–202
60 Stavropoulos A, Bertl K, Winning L, Polyzois I. What is the influence of implant surface characteristics and/or implant material on the incidence and progression of peri-implantitis? A systematic literature review. Clin Oral Implants Res 2021;32 (Suppl 21):203–229
61 Delgado-Ruiz R, Romanos G. Potential causes of titanium particle and ion release in implant dentistry: a systematic review. Int J Mol Sci 2018;19(11):3585
62 Pettersson M, Pettersson J, Johansson A, Molin Thorén M. Titanium release in peri-implantitis. J Oral Rehabil 2019;46(02): 179–188
63 Daubert D, Pozhitkov A, McLean J, Kotsakis G. Titanium as a modifier of the peri-implant microbiome structure. Clin Implant Dent Relat Res 2018;20(06):945–953
64 Katafuchi M, Weinstein BF, Leroux BG, Chen YW, Daubert DM. Restoration contour is a risk indicator for peri-implantitis: a cross-sectional radiographic analysis. J Clin Periodontol 2018; 45(02):225–232
65 Mishra SK, Chowdhary R, Kumari S. Microleakage at the different implant abutment interface: a systematic review. J Clin Diagn Res 2017;11(06):ZE10–ZE15
66 Mencio F, De Angelis F, Papi P, Rosella D, Pompa G, Di Carlo S. A randomized clinical trial about presence of pathogenic microflora and risk of peri-implantitis: comparison of two different types of implant-abutment connections. Eur Rev Med Pharmacol Sci 2017; 21(07):1443–1451
67 van Eekeren P, van Elsas P, Tahmaseb A, Wismeijer D. The influence of initial mucosal thickness on crestal bone change in similar macrogeometrical implants: a prospective randomized clinical trial. Clin Oral Implants Res 2017;28(02):214–218
68 Suárez-López Del Amo F, Lin GH, Monje A, Galindo-Moreno P, Wang HL. Influence of soft tissue thickness on peri-implant marginal bone loss: a systematic review and meta-analysis. J Periodontol 2016;87(06):690–699
69 Thoma DS, Naenni N, Figuero E, et al. Effects of soft tissue augmentation procedures on peri-implant health or disease: a systematic review and meta-analysis. Clin Oral Implants Res 2018;29(Suppl 15):32–49
70 Isler SC, Uraz A, Kaymaz O, Cetiner D. An evaluation of the relationship between peri-implant soft tissue biotype and the severity of peri-implantitis: a cross-sectional study. Int J Oral Maxillofac Implants 2019;34(01):187–196
71 Wada M, Mameno T, Onodera Y, Matsuda H, Daimon K, Ikebe K. Prevalence of peri-implant disease and risk indicators in a Japanese population with at least 3 years in function-a multicentre retrospective study. Clin Oral Implants Res 2019;30(02):111–120
72 Lim HC, Wiedemeier DB, Hämmerle CHF, Thoma DS. The amount of keratinized mucosa may not influence peri-implant health in compliant patients: a retrospective 5-year analysis. J Clin Periodontol 2019;46(03):354–362
73 Ramón-Morales CA, Ramón-Morales OM, Ardila CM. Gram-negative enteric rods/Pseudomonas colonization in mucositis and peri-implantitis of implants restored with cemented and screwed reconstructions: a cross-sectional study. Clin Implant Dent Relat Res 2019;21(05):946–952
74 Sancho-Puchades M, Crameri D, Özcan M, et al. The influence of the emergence profile on the amount of undetected cement excess after delivery of cement-retained implant reconstructions. Clin Oral Implants Res 2017;28(12):1515–1522
75 Staubli N, Walter C, Schmidt JC, Weiger R, Zitzmann NU. Excess cement and the risk of peri-implant disease - a systematic review. Clin Oral Implants Res 2017;28(10):1278–1290
76 Kozlovsky A, Tal H, Laufer BZ, et al. Impact of implant overloading on the peri-implant bone in inflamed and non-inflamed peri-implant mucosa. Clin Oral Implants Res 2007;18(05):601–610
77 Merin RL. Repair of peri-implant bone loss after occlusal adjustment: a case report. J Am Dent Assoc 2014;145(10):1058–1062
78 Kumar KA. Outcome assessment of all-on-four and all-on-six implant restoration in edentulous patients in Indian population. Int J Oral Maxillofac Surg 2017;46:97
79 Roehling S, Gahlert M, Janner S, Meng B, Woelfler H, Cochran DL. Ligature-induced peri-implant bone loss around loaded zirconia and titanium implants. Int J Oral Maxillofac Implants 2019;34 (02):357–365
80 Thoma DS, Benic GI, Muñoz F, et al. Marginal bone-level alterations of loaded zirconia and titanium dental implants: an experimental study in the dog mandible. Clin Oral Implants Res 2016;27(04):412–420

81 Pieralli S, Kohal RJ, Jung RE, Vach K, Spies BC. Clinical outcomes of zirconia dental implants: a systematic review. J Dent Res 2017;96 (01):38–46
82 Yi Y, Koo KT, Schwarz F, Ben Amara H, Heo SJ. Association of prosthetic features and peri-implantitis: a cross-sectional study. J Clin Periodontol 2020;47(03):392–403
83 Zweers J, van Doornik A, Hogendorf EA, Quirynen M, Van der Weijden GA. Clinical and radiographic evaluation of narrow- vs. regular-diameter dental implants: a 3-year follow-up. A retrospective study. Clin Oral Implants Res 2015;26(02):149–156
84 Schiegnitz E, Al-Nawas B. Narrow-diameter implants: A systematic review and meta-analysis. Clin Oral Implants Res 2018;29 (Suppl 16):21–40
85 Chang LC. Risk factors associated with early failure of maxillary versus mandibular implants: a retrospective study. Int J Oral Implantol (New Malden) 2020;13(01):55–63
86 Wu X, Chen S, Ji W, Shi B. The risk factors of early implant failure: a retrospective study of 6113 implants. Clin Implant Dent Relat Res 2021;23(03):280–288
87 Serino G, Turri A. Extent and location of bone loss at dental implants in patients with peri-implantitis. J Biomech 2011;44 (02):267–271
88 Kröger A, Hülsmann C, Fickl S, et al. The severity of human peri-implantitis lesions correlates with the level of submucosal microbial dysbiosis. J Clin Periodontol 2018;45(12):1498–1509
89 Giovannoli JL, Roccuzzo M, Albouy JP, Duffau F, Lin GH, Serino G. Local risk indicators - consensus report of working group 2. Int Dent J 2019;69 Suppl 2(Suppl 2):7–11
90 Galindo-Moreno P, Fernández-Jiménez A, Avila-Ortiz G, Silvestre FJ, Hernández-Cortés P, Wang HL. Marginal bone loss around implants placed in maxillary native bone or grafted sinuses: a retrospective cohort study. Clin Oral Implants Res 2014;25(03):378–384