

## Implant-based factor as possible risk for peri-implantitis

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**Abstract:** Peri-implantitis is currently a topic of major interest in implantology. Considered one of the main reasons of late implant failure, there is an emerged concern whether implant characteristics could trigger inflammatory lesion and loss of supporting bone. The purpose of this narrative review is to provide an evidence based overview on the influence of implant-based factors in the occurrence of peri-implantitis. A literature review was conducted addressing the following topics: implant surface topography; implant location; occlusal overload; time in function; prosthesis-associated factors (rehabilitation extension, excess of cement and implant-abutment connection); and metal particle release. Although existing data suggests that some implant-based factors may increase the risk of peri-implantitis, the evidence is still limited to consider them a true risk factor for peri-implantitis. In conclusion, further evidences are required to a better understanding of the influence of implant-based factors in the occurrence of peri-implantitis. Large population-based studies including concomitant analyses of implant- and patient-based factors are required to provide strong evidence of a possible association with peri-implantitis in a higher probability. The identification of these factors is essential for the establishment of strategies to prevent peri-implantitis.

**Keywords:** Peri-Implantitis; Dental Implants; Protheses and Implants; Dental Implant-Abutment Design.

## Introduction

Dental implants have been reported to have high rates of long-term survival,<sup>1,2,3,4</sup> and hence have become a widely used treatment modality for oral rehabilitation. Therefore, greater emphasis is now placed on understanding the risk factors that may influence the long-term success of osseointegrated implants. Peri-implantitis is considered the major biological complication associated with late implant loss.<sup>2,5,6</sup>

A myriad of possible risk factors for peri-implantitis could be associated with the dental implant characteristics itself. However, there is a lack of definitive literature corroborating implant-based factors as possible risk for peri-implantitis. Few studies are concentrated in major points related to the implant characteristics.

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Implant surface topography represents one characteristic that could be considered as a possible implant-based risk factor for peri-implantitis. The first modern implants as we know were introduced to the public by P-I Brånemark in 1978, a two-stage threaded machined titanium root-form implant,<sup>7</sup> being the implant shoulder positioned at the bone level, leading to a submucosal healing, and requiring a further surgical procedure to insert the abutment connection. Few years later, in 1985, Andre Schroeder and the ITI Group introduced the ITI implant system by Straumann Company, with an exclusive plasma-sprayed surface, reducing the time required to achieve osseointegration.<sup>8</sup> Although it was also a cylindrical implant it was designed to be placed in a one-stage operation with the implant presenting a soft tissue interface, allowing a transmucosal healing. A variety of implants were introduced after the original Brånemark implant, associating or not different modifications based on the initial concept. The tapered form implant, platform switch, different connections like cone morse or hexagons were also developed associated with countless abutments designs. However, it's unclear how these modifications may possible act as risk factors associated with the development or progression of peri-implantitis. Beside these, other implant-based factors that will be also addressed in the present review include: implant location, occlusal overload, time in function, prosthetic factors (rehabilitation extension, excess of cement and implant-abutment connection) and metal particle release. The purpose of this review is to provide an evidenced-based overview on the influence of implant-based factors on the onset and progression of peri-implantitis.

### **Implant surface topography**

Implant surface topography has a significant effect on the osseointegration and success of titanium implants and encompasses macroscopic,<sup>9</sup> microscopic and nanometric characteristics. Along with these lines, implant surfaces have been modified over the last decades to enhance the rate and extent of bone formation to achieve more predictable osseointegration. Ultimately, implementation of treated surfaces has been shown to promote increased implant stability during healing,

greater bone-to-implant contact, improved long-term treatment outcomes and allowed expanding treatment possibilities in more challenging clinical cases, such as immediate placement and immediate loading.<sup>10,11</sup>

Implant surface modifications have evolved from simple changes of the oxide surface to precise nanoscale modifications capable of modulating critical steps of osseointegration. Following fibrin clot adhesion, blood-derived cells and mesenchymal stem cells interact with implant surfaces in an orchestrated manner that results in bone formation in direct contact with the implant surface.<sup>12,13,14</sup> In this scenario, implant surface microscopic and nanometric roughness may improve the osseointegration process via several mechanisms. For instance, improvements in surface roughness increase implant surface area, result in formation of a more extensive and complex fibrin scaffold,<sup>15</sup> increased adhesion, proliferation and osteoblastic differentiation of mesenchymal stem cells and promotes greater matrix mineralization.<sup>16</sup>

Although surface modification was implemented to improve the clinical success of dental implants, the high incidence of complications on first launched rough-surface coated implants led to the hypothesis that these implants could be more prone to peri-implantitis. This initial hypothesis was further strengthened by data showing that rough implants facilitate initial biofilm formation and may impact biofilm composition.<sup>17</sup> Using bone loss as a surrogate parameter for peri-implantitis, a recent systematic review demonstrated that peri-implant bone loss around minimally rough implants (0.86 mm) was significantly less than the one around moderately rough (1.01 mm) and rough implants (1.04 mm), with no significant differences between moderately rough and rough implant systems.<sup>10</sup> According to the same study, the prevalence of peri-implant bone loss greater than 2 mm was higher for implants with rough (18%) and moderately rough surfaces (20%) than for implants with minimally rough surfaces (14%).

Implants with acid-etched surfaces showed high survival and success rates after 8-10 years of function in a retrospective study. Forty-four patients who received 183 implants were evaluated. Only 5 implants were lost during this period (2.7%) and 20 implants were diagnosis with peri-implantitis (11%).<sup>18</sup>

It is important to highlight that most studies evaluating the impact of implant surface characteristics on the development and/or progression of peri-implantitis, compared implants differing in their design and prosthetic connection. Only three retrospective studies have compared the incidence of marginal bone loss and peri-implant disease in implants differing in surface topography, but with equal design.<sup>19,20,21</sup> Altogether, a meta-analysis of these three studies revealed that minimally rough implants have less bone loss than moderately rough implants.<sup>10</sup>

In conclusion, although existing data suggests that rough and moderately rough implants might have a higher risk to peri-implantitis, well designed long-term prospective clinical trials are needed to validate or refute these findings.

### Implant Location

Considerable cross-sectional studies have reported on a correlation between implant site (maxilla/mandible or anterior/posterior) and the prevalence or risk factor for peri-implant diseases. Employing a variety of statistical analysis, different inclusion and exclusion criteria, and disease definition, implant maxillary sites were suggested as statistically significant risk indicators,<sup>22,23,24,25</sup> while controversial data is also available.<sup>26,27,28,29</sup> For peri-implantitis, even when significant association with location is identified, there is still questionable evidence whether upper jaw<sup>22,23,24,26</sup> is considered the most prevalent region for peri-implantitis or lower jaw,<sup>25</sup> as well as anterior<sup>24,26</sup> and posterior sites.<sup>27,29,30</sup> In fact, bone component is denser in mandibles and anterior areas and osseous volume tends to become thinner and more porous directly proportional to age. This correlation is most likely related to the bone quality, difficult access to perform oral hygiene, and occlusal load, intrinsic to the different regions of the oral cavity.

Peri-implant health is rather more associated to the periodontal condition of the remaining teeth close to the dental implant than to implant location in the jaw. Recently, the periodontal status of the adjacent and contralateral teeth to the implants with and without peri-implantitis was compared.<sup>31</sup> The results suggested that the peri-implant health status is associated to the health periodontal condition of the

tooth adjacent to the implant. Correspondingly, the presence of peri-implantitis affected the periodontal measurements of the tooth adjacent to these involved implants.<sup>31</sup> Furthermore, a cross-sectional study demonstrated that implant placement at a depth of 6 mm or more from the cement-enamel junction of the adjacent tooth was a strong predictor for peri-implantitis (OR 8.5) as well as the presence of gingivitis and periodontitis on the adjoining teeth at the time of implant restoration (OR 8.0).<sup>32</sup>

There is currently no conclusive evidence that implant location constitutes a risk indicator for the onset or progression of peri-implantitis.

### Occlusal overload

Peri-implant tissues facing overload damage and plaque-induced inflammation present different histological features, where minimal inflammatory infiltrate is observed on the first. For this reason, a specific histopathogenic mechanism associated to overload implants has been suggested.<sup>33,34,35,36</sup> Defining whether an implant is under excessive load or not is crucial to consider it as a risk factor/indicator for peri-implantitis. There is a lack of consensual parameters to standardize these investigations for the pathway of overload integrated implants.<sup>37</sup> In a classic study in dogs, it was demonstrated that lateral static load with controlled forces does not increase the risk for peri-implant marginal bone loss.<sup>38</sup> This conclusion has been expanded for occlusal load in latter investigations.<sup>36,39,40,41,42</sup> Occlusal load, when controlled and associated with implants with no biofilm accumulation results in increased bone density and bone-implant contact, but in the presence of plaque, it may contribute to bone loss.<sup>39,40,42,43</sup> Several clinical studies have also reported a relationship between overload and bone loss around dental implants,<sup>44,45,46,47,48,49</sup> but most of these studies highlighted the presence of microorganisms as the key causative factor or did not investigate a possible correlation with poor oral hygiene, the occurrence of parafunctional habits, and other factors related to prostheses.

Clinical signs of occlusal overload, such as abutment fracture, loss of retention, chipping and dynamic occlusal measurements, were observed in a higher frequency at peri-implantitis sites

(27 out of 98 implants) than in healthy peri-implant condition (3 out of 204 implants), with an OR of 18.7.<sup>50</sup> In addition, the presence of wear facets on the implant supported crowns was associated with peri-implantitis (OR 2.4).<sup>26</sup> Although these previous data have suggested a relationship between occlusal overload and peri-implantitis, further evidences are required to confirm the occlusal influence in the onset and progression of peri-implantitis. In a recent cross-sectional study, the association of occlusal interference with peri-implantitis was not significant after adjustment for other patient and implant-level variables included in the multivariate analysis.<sup>51</sup>

### **Time in function**

Time in function as a risk factor for peri-implantitis is also a controversial issue in the literature. Previous cross-sectional studies indicated that time in function is associated with the occurrence of peri-implantitis.<sup>51,52,53,54</sup> The percentage of peri-implantitis was higher in individuals with implants with more than 10 years in function (38.4%) than in those with lower time in function (17.6%).<sup>53</sup> In addition, a significant positive correlation was observed between peri-implantitis and time of loading,<sup>52</sup> and the probability of peri-implantitis was two times higher for implants loaded for 5 years or more.<sup>51</sup> On the other hand, other studies reported no association between implant time in function and peri-implantitis.<sup>22,55,56</sup>

The effectiveness of implant therapy was evaluated in a Swedish population. It was verified that early implant loss occurred in 4.4% of patients and 1.4% of implants, while 4.2% of the patients and 2.0% of the implants presented with late implant loss after around 9 years of loading. In this study, the loss of dental implants was assessed in a large and randomly selected patient sample (early loss: 2,765 patients and 11,311 implants; late loss: 596 patients and 2,367 implants).<sup>57</sup>

In fact, peri-implantitis could be considered a time-dependent condition, but there is no evidence to support a cause-and-effect relationship.

### **Prosthesis-associated factors**

According to the literature, among all prosthesis-associated factors considered possible

risk indicators for peri-implantitis only three are considered relevant, including: prosthetic rehabilitation extension,<sup>26,58</sup> excess of cement,<sup>59,60,61,62,63,64,65,66,67,68,69,70,71</sup> and implant-abutment connection type.<sup>72,73,74,75,76,77,78,79,80,81,82,83</sup>

#### **Prosthetic rehabilitation extension**

Studies have demonstrated that implants supporting fixed bridges, removable superstructures or total rehabilitation displayed a higher risk for peri-implant disease.<sup>26,58</sup> The difficulty to perform adequate oral hygiene around implants supporting these types of prosthetic rehabilitation is likely to justify the higher occurrence of peri-implantitis. Furthermore, it is important to highlight that full-mouth rehabilitations are likely related to patients with previous experience of periodontal disease, while single crown rehabilitations are usually alternative treatments for root fractures or endodontic failures.

#### **Excess of cement**

Although using a variety of different case definitions, observational studies found a positive relationship between the presence of excess cement and the occurrence of mucositis and peri-implantitis.<sup>59,60,61,62,63</sup> This association may be explained by the rough surface of the residual cement that facilitate microorganism retention and biofilm formation.<sup>62,64</sup> However, a considerable variation can be observed among the studies on the percentage of diseased implant sites exhibiting excess cement<sup>59,60,61,62,63</sup> and several studies did not find higher occurrence of peri-implantitis in cement-retained implant-supported restorations than in screw-retained restorations<sup>51,52,57,65,66</sup>. Furthermore, the mode of retention of implant-supported crowns does not appear to affect clinical and immune-inflammatory parameters.<sup>65,67</sup>

The excess cement appears to have influence of the cementation margin level, the deeper the subgingival interface implant-abutment, the greater amount of undetected cement was discovered.<sup>63,68</sup> Authors have suggested that cements containing zinc may lead to fewer negative tissue reactions,<sup>70,69</sup> apparently zinc-based cements demonstrate the highest solubility when compared to other types.<sup>70</sup> A recent systematic review recommends the use of zinc oxide eugenol cements in patients with a history of periodontitis instead of resin cements.<sup>71</sup>

The excess cement may be considered an iatrogenic factor that may influence the onset and progression of peri-implantitis. The signs and symptoms of inflammation recede after removal of excess cement.<sup>60,61,62</sup> Then, with appropriate cement selection and detailed attention to removal excess of cement, cemented-retained restorations are not a risk indicator for peri-implantitis.<sup>66</sup>

### Type of implant-abutment connection

Several studies have reported that platform switching system is associated with reduced marginal bone loss around implants.<sup>72,73,74,75,76,77,78</sup> The crestal bone stability is justified by the inward shifting of the implant-abutment junction that transfers the peri-implant microbiota and the inflammatory cell infiltrate away from the adjacent crestal bone and creates a space for biologic width formation.<sup>79,80,81</sup> In addition, platform switching decreases the forces concentration in the crestal bone-implant interface during occlusal loading.<sup>82</sup> However, scarce information is available in the literature concerning the impact of different platform designs on peri-implant diseases. In a cross-sectional study with a small sample size (25 patients and 64 implants), the prevalence of mucositis and peri-implantitis after one year of loading for platform switching was 90% and 15.6%, respectively, and 81.2% and 15.6% for conventional implants. These differences were not statistically significant.<sup>83</sup> Recently, it was verified that implants with platform switching have 82% lower probability of developing peri-implantitis than conventionally restored implants.<sup>51</sup>

In conclusion, further evidences are required to confirm the previously discussed prosthesis-associated factors as risk/indicator factors for peri-implantitis.

### Metal particle release

In the field of medicine, primarily in orthopedics, metal particles release has been intensively studied as a potential risk factor for implants failure.<sup>84,85,86,87</sup> Correspondingly, in implant dentistry, titanium particles dispersed in adjacent tissue of implants are also considered foreign bodies and may provoke negative effects.<sup>88</sup> Independent studies have detected the presence of metal particles in soft tissue samples from peri-implantitis sites.<sup>88,89,90,91,92,93,94</sup> Although

investigations might not confirm the relationship between titanium content within tissue and peri-implant inflammation, these findings may have a significant importance since several studies have reported negative effects of implant debris on cells and tissue.<sup>91,95,96,97,98,99,100,101,102</sup> Recent studies suggested the stimulation of osteoclast activity and exacerbated proinflammatory response in the presence of titanium-based particles and ions.<sup>91,98</sup> Researchers also detected genotoxic and cytotoxic potential of nanometric metal particles,<sup>99,101</sup> and their ability to produce morphological changes in neutrophils and macrophages and activate DNA damage response in oral epithelial cells.<sup>102,103</sup> However, there is not sufficient evidence to support whether metal content has a significant impact or not in the immune response.<sup>104,105</sup>

Adversely to orthopedic prosthesis, which are placed in a closed site, dental implants are exposed to many intrinsic factors related to the oral cavity. Plausible causes for metal particle release are related to mechanical and chemical principles: wear particles generated during implant placement surgery,<sup>106</sup> implant-abutment connection under force transmission,<sup>107,108,109</sup> and tribocorrosion, this last is a result of the combined effect of wear (micromotion) and corrosion substances present in the oral cavity (e.g., lactic acid, fluoride, citric acid).<sup>110,111,112</sup> The mechanism responsible for metal particles and ions release remains unclear, just as the possible local impact of that content on implant-associated tissue.<sup>113,114</sup> At this moment, the available evidence does not allow an assessment of metal particles as a risk factor for peri-implantitis.

## Conclusion

Further evidences are required to a better understanding of the influence of implant-based factors in the occurrence of peri-implantitis. In fact, large population-based studies including concomitant analyses of implant- and patient-based factors are required to identify the factors significantly associated with higher probability of peri-implantitis. The identification of these factors is essential for the establishment of strategies to prevent peri-implantitis and for the effective prognostic of dental implants success.

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