



# Dental prostheses and tooth-related factors

Carlo Ercoli<sup>1</sup> | Jack G. Caton<sup>2</sup>

<sup>1</sup>Departments of Periodontics and Prosthodontics, Eastman Institute for Oral Health, University of Rochester, Rochester, NY, USA

<sup>2</sup>Department of Periodontics, Eastman Institute for Oral Health, University of Rochester

## Correspondence

Dr. Carlo Ercoli, Departments of Periodontics and Prosthodontics, Eastman Institute for Oral Health, Suite 257, 625 Elmwood Avenue, Rochester, NY 14620.

Email: carlo\_ercoli@urmc.rochester.edu

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## Abstract

**Objectives:** This narrative review summarizes the current evidence about the role that the fabrication and presence of dental prostheses and tooth-related factors have on the initiation and progression of gingivitis and periodontitis.

**Findings:** Placement of restoration margins within the junctional epithelium and supracrestal connective tissue attachment can be associated with gingival inflammation and, potentially, recession. The presence of fixed prostheses finish lines within the gingival sulcus or the wearing of partial, removable dental prostheses does not cause gingivitis if patients are compliant with self-performed plaque control and periodic maintenance. However, hypersensitivity reactions to the prosthesis dental material can be present. Procedures adopted for the fabrication of dental restorations and fixed prostheses have the potential to cause traumatic loss of periodontal supporting tissues. Tooth anatomic factors, root abnormalities, and fractures can act as plaque-retentive factors and increase the likelihood of gingivitis and periodontitis.

**Conclusions:** Tooth anatomic factors, such as root abnormalities and fractures, and tooth relationships in the dental arch and with the opposing dentition can enhance plaque retention. Restoration margins located within the gingival sulcus do not cause gingivitis if patients are compliant with self-performed plaque control and periodic maintenance. Tooth-supported and/or tooth-retained restorations and their design, fabrication, delivery, and materials have often been associated with plaque retention and loss of attachment. Hypersensitivity reactions can occur to dental materials. Restoration margins placed within the junctional epithelium and supracrestal connective tissue attachment can be associated with inflammation and, potentially, recession. However, the evidence in several of the reviewed areas, especially related to the biologic mechanisms by which these factors affect the periodontium, is not conclusive. This highlights the need for additional well-controlled animal studies to elucidate biologic mechanisms, as well as longitudinal prospective human trials. Adequate periodontal assessment and treatment, appropriate instructions, and motivation in self-performed plaque control and compliance to maintenance protocols appear to be the most important factors to limit or avoid potential negative effects on the periodontium caused by fixed and removable prostheses.

## KEYWORDS

anatomy, classification, dental prostheses, dental restorations, gingivitis, periodontitis, tooth



The anatomy, position, and relationships of teeth within the dental arches are among the factors that have been associated<sup>1</sup> with plaque retention, gingivitis, and periodontitis. Factors related to the presence, design, fabrication, delivery, and materials of tooth-supported prostheses have been suggested to influence the periodontium, generally related to localized increases in plaque accumulation and, less often, to traumatic and allergic reactions to dental materials. This article reviews the role of tooth-related factors and dental prostheses on the initiation and progression of gingivitis and periodontitis.

## MATERIALS AND METHODS

For this narrative review, PubMed database was searched for the time period from 1947 up to April 2017, with the strategy found on Table 1. The following filters were applied to the search results: clinical trial, review, guideline, randomized controlled trial, meta-analysis, systematic reviews, humans, and English. The articles obtained, including those referenced in a previous article,<sup>1</sup> were input into a reference manager software.\* One reviewer (CE) screened titles and abstracts for potential inclusion and discarded duplicates. If title and/or abstract did not provide sufficient information regarding the article content, the article was obtained for review. The selected articles were then obtained in full text and saved as .pdf files in the reference manager database. One reviewer (CE) performed all text reading of the selected publications. When titles of referenced articles, not included in the electronic search, were identified as potentially related to the area of interest of this review, these articles' abstracts were obtained, reviewed for potential inclusion, included in the database, and their full text reviewed.

## RESULTS

### Biologic width (BW)

BW has been defined as the cumulative apical–coronal dimensions of the junctional epithelium (JE) and supracrestal connective tissue attachment (SCTA).<sup>2</sup> In a cadaver study, variable supracrestal tissue dimensions (i.e., histologic gingival sulcus [GS], JE, and SCTA) were recorded, with the SCTA exhibiting the most constant average dimension.<sup>3</sup> While JE and SCTA exhibited average dimensions within 0.5 to 1 mm when examined on different tooth surfaces,<sup>4,5</sup> this study<sup>3</sup> and others<sup>6,7</sup> showed that dimensions of JE and SCTA can vary considerably,<sup>8</sup> regardless of the association with other factors such as tooth type,<sup>9</sup> surface,<sup>4,9</sup> biotype,<sup>5</sup> loss of attachment,<sup>3</sup> presence of restorations,<sup>4</sup> and crown elongation,<sup>10</sup> so that it is impossible to clearly define a “fixed” biologic width

dimension.<sup>9</sup> Biologic width dimensions (JE and SCTA) can only be assessed by histology.<sup>3,4,11</sup> Other methods, such as transgingival probing<sup>10,12–14</sup> and parallel profile radiography, can be used to clinically measure the dimensions of the dentogingival unit, but are not appropriate to measure the true biologic width.<sup>6,15</sup> Buccal crown margins placed within the junctional epithelium and supracrestal connective tissue attachment have been associated with recession, and histologic evaluation of these sites demonstrated crestal bone loss and supracrestal connective tissue remodeling within 0 to 8 weeks.<sup>16</sup> However, this limited case series was not designed to correlate the observed histologic changes to plaque indices or other mechanisms that could document, in humans, the biologic rationale for the observed changes. Moreover, in a prospective clinical trial, comparing crowns with interproximal margins placed within varying distances from the alveolar bone crest (groups: I = < 1 mm between crown margin and alveolar crest, II = 1 to 2 mm, and III = > 2 mm) it was observed that, while the presence of supragingival plaque was not different among groups, papillary bleeding index (PBI) was greater in group 1, which was associated with increased probing depths (PD) and a clear encroachment of the crown margins within the supracrestal tissue attachment.<sup>17</sup> Given the limited available evidence in humans, it is not possible to determine if the negative effects on the periodontium associated with restoration margins located within the supracrestal tissue attachment is caused by bacterial plaque, trauma, or a combination of these factors.

### Fixed dental restorations and prostheses

For class II restorations, gingival inflammation is significantly greater around subgingival margins compared with supragingival margins,<sup>18</sup> even when supragingival plaque levels are not significantly different from prerestoration levels.<sup>19</sup> Furthermore, PD around amalgam restorations with subgingival margins were found to be greater than around contralateral unrestored teeth.<sup>20</sup> Direct restorations with overhangs greater than 0.2 mm are associated with crestal bone loss.<sup>21</sup> Unfortunately, a large prevalence of overhanging amalgam restorations were found in several populations associated with increases in bleeding on probing (BOP) and PD which exceeded the values found at sites with well-fitting restorations and unrestored teeth.<sup>22</sup> The correlation between overhanging margins and PD, gingival inflammation,<sup>23,24</sup> and interproximal bone loss<sup>25–27</sup> was greater for larger overhangs.<sup>28</sup> The removal of the overhangs during scaling and root planing causes a resolution of the gingival inflammation<sup>29</sup> and a decrease in PD due to gingival recession (GR)<sup>30</sup> similar to the resolution of gingivitis.<sup>31</sup> From a microbiologic standpoint and similar to indirect restorations,<sup>32</sup> the elimination of amalgam overhangs during periodontal therapy caused a decrease of

\* Thomson Reuters, New York, NY.



**TABLE 1** Electronic search strategy used for the study

Topic	Search strategy	AND	Search strategy
Biologic width	("biology"[MeSH Terms] OR "biology"[All Fields] OR "biologic"[All Fields]) AND width[All Fields]		(Periodontitis OR Periodontal Diseases OR Gingivitis OR Gingival Diseases) NOT ("case reports"[Publication Type] OR "comment"[Publication Type] OR "editorial"[Publication Type] OR "interview"[Publication Type] OR "letter"[Publication Type] OR "news"[Publication Type] OR "newspaper article"[Publication Type])
Fixed dental restorations and prostheses	("Crowns"[Mesh:NoExp] OR "Dental Prosthesis Design"[Mesh:NoExp] OR "Dental Restoration Failure"[Mesh] OR "Dental Restoration, Permanent" [Mesh:NoExp] OR "Dental Veneers"[Mesh])		(Periodontitis OR Periodontal Diseases OR Gingivitis OR Gingival Diseases) NOT ("case reports"[Publication Type] OR "comment"[Publication Type] OR "editorial"[Publication Type] OR "interview"[Publication Type] OR "letter"[Publication Type] OR "news"[Publication Type] OR "newspaper article"[Publication Type])
Dental materials	("dental materials"[Pharmacological Action] OR "dental materials"[MeSH Terms] OR "dental materials"[All Fields]) NOT ("dental implants"[MeSH Terms] OR "dental implants"[All Fields] OR "dental implant"[All Fields] OR "dental prosthesis, implant-supported"[MeSH Terms] OR "implant-supported dental prosthesis"[All Fields] OR "dental prosthesis, implant supported"[All Fields])		(Periodontitis OR Periodontal Diseases OR Gingivitis OR Gingival Diseases) NOT ("case reports"[Publication Type] OR "comment"[Publication Type] OR "editorial"[Publication Type] OR "interview"[Publication Type] OR "letter"[Publication Type] OR "news"[Publication Type] OR "newspaper article"[Publication Type])
Removable dental prostheses	("Dentures"[MeSH] OR "Dental Clasps"[MeSH])		(Periodontitis OR Periodontal Diseases OR Gingivitis OR Gingival Diseases) NOT ("case reports"[Publication Type] OR "comment"[Publication Type] OR "editorial"[Publication Type] OR "interview"[Publication Type] OR "letter"[Publication Type] OR "news"[Publication Type] OR "newspaper article"[Publication Type])
Enamel pearls	Enamel pearl [All Field]		(Periodontitis OR Periodontal Diseases OR Gingivitis OR Gingival Diseases) NOT ("case reports"[Publication Type] OR "comment"[Publication Type] OR "editorial"[Publication Type] OR "interview"[Publication Type] OR "letter"[Publication Type] OR "news"[Publication Type] OR "newspaper article"[Publication Type])
Cervical enamel projections	("neck"[MeSH Terms] OR "neck"[All Fields] OR "cervical"[All Fields]) AND ("dental enamel"[MeSH Terms] OR ("dental"[All Fields] AND "enamel"[All Fields]) OR "dental enamel"[All Fields] OR "enamel"[All Fields]) AND ("projection"[MeSH Terms] OR "projection"[All Fields] OR "projections"[All Fields] OR "forecasting"[MeSH Terms] OR "forecasting"[All Fields])		(Periodontitis OR Periodontal Diseases OR Gingivitis OR Gingival Diseases) NOT ("case reports"[Publication Type] OR "comment"[Publication Type] OR "editorial"[Publication Type] OR "interview"[Publication Type] OR "letter"[Publication Type] OR "news"[Publication Type] OR "newspaper article"[Publication Type])

(Continues)



TABLE 1 (Continued)

Topic	Search strategy		Search strategy
Developmental grooves	grooves[All Fields]	AND	(Periodontitis OR Periodontal Diseases OR Gingivitis OR Gingival Diseases) NOT (“case reports”[Publication Type] OR “comment”[Publication Type] OR “editorial”[Publication Type] OR “interview”[Publication Type] OR “letter”[Publication Type] OR “news”[Publication Type] OR “newspaper article”[Publication Type])
Tooth and root fractures	“tooth fractures”[MeSH Terms] OR (“tooth”[All Fields] AND “fractures”[All Fields]) OR “tooth fractures”[All Fields]	AND	(Periodontitis OR Periodontal Diseases OR Gingivitis OR Gingival Diseases) NOT (“case reports”[Publication Type] OR “comment”[Publication Type] OR “editorial”[Publication Type] OR “interview”[Publication Type] OR “letter”[Publication Type] OR “news”[Publication Type] OR “newspaper article”[Publication Type])
Root resorption	“Tooth Root/pathology”[MAJR] AND Root Resorption/pathology	AND	(Periodontitis OR Periodontal Diseases OR Gingivitis OR Gingival Diseases) NOT (“case reports”[Publication Type] OR “comment”[Publication Type] OR “editorial”[Publication Type] OR “interview”[Publication Type] OR “letter”[Publication Type] OR “news”[Publication Type] OR “newspaper article”[Publication Type])
Tooth position	(“malocclusion”[MeSH Terms] OR “malocclusion”[All Fields]) AND (“tooth”[MeSH Terms] OR “tooth”[All Fields]) AND position[All Fields]	AND	(Periodontitis OR Periodontal Diseases OR Gingivitis OR Gingival Diseases) NOT (“case reports”[Publication Type] OR “comment”[Publication Type] OR “editorial”[Publication Type] OR “interview”[Publication Type] OR “letter”[Publication Type] OR “news”[Publication Type] OR “newspaper article”[Publication Type])
Root proximity	(“tooth root”[MeSH Terms] OR (“tooth”[All Fields] AND “root”[All Fields]) OR “tooth root”[All Fields]) AND proximity[All Fields]	AND	(Periodontitis OR Periodontal Diseases OR Gingivitis OR Gingival Diseases) NOT (“case reports”[Publication Type] OR “comment”[Publication Type] OR “editorial”[Publication Type] OR “interview”[Publication Type] OR “letter”[Publication Type] OR “news”[Publication Type] OR “newspaper article”[Publication Type])
Open contacts	“Diastema”[MAJR] OR Open contacts	AND	(Periodontitis OR Periodontal Diseases OR Gingivitis OR Gingival Diseases) NOT (“case reports”[Publication Type] OR “comment”[Publication Type] OR “editorial”[Publication Type] OR “interview”[Publication Type] OR “letter”[Publication Type] OR “news”[Publication Type] OR “newspaper article”[Publication Type])



*Aggregatibacter actinomycetemcomitans* and increase of *Streptococcus mutans*.<sup>33</sup>

For indirect restorations, overhangs between 0.5 and 1 mm are associated with an increase in gingival inflammation<sup>29</sup> and a more apical crestal bone level, while overhangs of less than 0.2 mm are not.<sup>32,34</sup> Other studies showed that subgingival margins were associated with increased signs of gingival inflammation<sup>35–42</sup> and, at times, increases in PD.<sup>43–47</sup>

A clear association is found between periodontal health and patient compliance with self-performed plaque control and periodontal maintenance after prosthodontic therapy with fixed dental prostheses.<sup>47–49</sup> In a prospective clinical trial where patients were instructed and motivated on adequate measures of self-performed plaque control, plaque levels and gingival inflammation were not significantly different between teeth that received crowns and controls.<sup>50</sup> Similarly, in a cohort of patients who were seen for periodontal maintenance every 1 to 6 months, no difference in plaque and gingival indices were found between crowned and non-crowned teeth regardless of the position of the crown margins,<sup>51</sup> a finding also reported by other studies.<sup>52–54</sup>

While porcelain veneers were not associated with changes in plaque levels and gingival inflammation for as long as 7 years after delivery,<sup>55–59</sup> gingival recession can be a common consequence of other fixed prosthodontic therapies.<sup>60–62</sup> Prosthodontic procedures required for the fabrication of fixed prostheses can negatively affect the periodontium. Procedures and/or materials such as crown preparation, gingival displacement during impression,<sup>63,64</sup> impressions, provisional prostheses,<sup>65</sup> and luting agents<sup>66</sup> may be contributing factors for the development of gingivitis, gingival recession, and periodontitis. The placement of provisional crowns causes an increase in plaque retention regardless of the resin material used for the prosthesis.<sup>65</sup> In another study<sup>67</sup> where all crown margins were designed in a subgingival location during crown preparation, only 82% of them were still located subgingivally at crown delivery. This suggests that the actual crown margin location was less of a contributing etiologic factor affecting the occurrence and magnitude of recession than the prosthetic procedures required to design and record the crown margin position. In a short-term randomized, multicenter, controlled trial, different methods of gingival displacement produced different magnitudes and frequency distributions of gingival recession, and most of the recession occurred before final crown delivery.<sup>68</sup> The anatomy of the periodontium of teeth receiving crowns should be evaluated to minimize the likelihood of gingival recession because the presence of an initial shallow PD and narrow band of gingiva negatively influenced the level of periodontal attachment after crown delivery.<sup>69</sup> These studies point out the critical importance of including a complete periodontal assessment prior to prosthodontic manipulations when studying the response of the periodontium to indirect restorations.<sup>60</sup>

The available literature supports the conclusion that a direct restoration with subgingival margins can be associated with localized gingivitis and increases in PD. A direct or indirect restoration with overhanging margins can be associated with localized gingivitis, increase in PD, and interproximal bone loss, especially for larger overhangs. These changes are likely caused by the overhang acting as a plaque-retentive factor and causing a qualitative shift toward a subgingival cultivable microflora more characteristic of periodontitis.

From cross-sectional studies, it can be concluded, especially when self-performed plaque control and periodontal maintenance measures are not mentioned, that an indirect restoration subgingival margin is associated with gingivitis. However, in longitudinal studies, where self-performed plaque control and periodontal maintenance measures are described and patient compliance is achieved, subgingival prosthesis margins do not appear to act as plaque-retentive factors that cause gingivitis. Based on the available evidence, it appears that plaque control by the patient and compliance with periodontal maintenance is of paramount importance to maintain the health of the periodontium when subgingival margins are adopted in the prosthetic design. Permanent changes to the periodontium, such as gingival recession, could occur when subgingival margins are adopted for prosthesis design; however, they appear to be mostly related to trauma to the periodontium exerted by the procedures, instruments, and materials required to place and record the margins in a subgingival location, rather than the nominal position of the margin.

## Dental materials

Different dental materials, their surface characteristics, and location in relation to the gingiva have been associated with variable periodontal responses.<sup>70–73</sup> However, this response could be potentially affected, not only by the type of material, but also by the surface characteristics, such as surface-free energy and roughness, among others, that act as confounding variables. For the latter, a minimum roughness threshold ( $R_a < 0.2 \mu\text{m}$ ) has been suggested, with increases in plaque retention expected above this threshold, but no reduction for lower  $R_a$  values.<sup>74</sup> Similarly, when different alloys were used to fabricate onlays<sup>75</sup> and other types of prostheses,<sup>50</sup> they showed similar levels of plaque and gingival inflammation. Roughness changes, resulting from polishing, scaling, or patient-related factors are material-specific and data on resultant plaque accumulation as a function of the change in  $R_a$  is scarce.<sup>76</sup> Teeth restored with a variety of dental materials, when compared with enamel, had similar plaque levels, gingival inflammation, interleukin (IL)-1 $\alpha$ , IL-1 $\beta$ , and IL-1ra levels, but most important, in a 10-day gingivitis experiment, showed no difference for the same parameters.<sup>49,77</sup> Similar clinical gingival reactions in periodontally healthy patients



were also seen when comparing class V restorations of composite resin or calcium aluminate/silicate material.<sup>78–82</sup> These findings appear also valid when different restorative materials are used to rebuild part of the tooth anatomy during mucogingival surgical procedures.<sup>83–88</sup> Therefore, available evidence demonstrates that different dental materials act similarly to enamel as plaque-retentive factors to initiate gingivitis.

Metal ions and metal particles can also be released from dental alloys and can be found locally within plaque, the periodontium, and in several organs and tissues. While several of these ions (nickel [Ni], palladium [Pd], copper [Cu], titanium [Ti] among others) have been shown, via *in vitro* studies, to potentially affect cell count, viability, function, and the release of inflammatory mediators, their influence on gingivitis and periodontitis is largely unclear.<sup>89</sup> Metal ions and particles, especially Ni and Pd, have also been associated with hypersensitivity reactions which might clinically appear as gingivitis, localized in the area of gingival contact with the dental material that does not respond to adequate measures of plaque control, and contact stomatitis, often with a lichenoid-type appearance.<sup>90–93</sup> For patients who have shown allergic reactions to dental alloys, very limited evidence suggests that the replacement of these prostheses with zirconia-based prostheses was associated with a resolution of the allergic reaction.<sup>94</sup>

## Removable dental prostheses

In cross-sectional studies, where no information is present on the level of self-performed plaque control and periodontal maintenance or where clearly heterogeneous baseline periodontal conditions are present,<sup>95</sup> partial removable dental prostheses (RDPs) have been associated with increased prevalence of caries, gingivitis, and periodontitis.<sup>96–100</sup> A study has shown no changes in PD, but increases in plaque levels and gingival inflammation in patients wearing RDPs.<sup>101</sup> Other authors have reported that when the patient was adequately instructed on self-performed plaque control and seen at frequent periodic maintenance visits, there was a decrease in plaque levels and gingival inflammation.<sup>102</sup> A recent study showed no difference in PD, BOP, gingival recession, microbial count, and species between teeth that supported RDPs and teeth that did not.<sup>103</sup> Longitudinal studies of distal extension RDPs indicate that a favorable periodontal prognosis may be expected provided the following conditions are satisfied: 1) periodontal disease, if present, is treated and an adequate preprosthetic plaque control regimen established; 2) periodontal health and oral hygiene are maintained through self-performed plaque control measures<sup>104</sup> and periodic maintenance appointments,<sup>105</sup> and 3) patient's motivation is reinforced to enhance compliance to self-performed plaque control and periodontal maintenance.<sup>106–112</sup> Therefore, we can conclude that, if plaque control is established, the prostheses are correctly designed and regularly checked, and indicated

maintenance procedures are performed, RDPs do not cause greater plaque accumulation, periodontal loss of attachment, or increased mobility.<sup>113–118</sup> On the other hand, if patients do not adequately perform plaque control and attend periodic maintenance appointments, removable dental prostheses, including overdentures,<sup>118–127</sup> could act as plaque-retentive factors and indirectly cause gingivitis and periodontitis. In addition, especially distal extension RDPs, when not properly maintained and relined, have the potential to apply greater forces and torque to the abutment teeth, causing a traumatic increase in mobility.<sup>107</sup>

## Tooth anatomy and position

### Cervical enamel projections (CEP) and enamel pearls (EP)

Tooth anatomic factors, such as CEP and EP, have been associated with furcation invasion, increased PD, and loss of clinical attachment.<sup>128,129</sup> The extent of CEP extension toward the furcation area can be classified into three classes, with grade I described as “distinct change in cemento-enamel junction (CEJ) attitude with enamel projecting toward the furcation;” grade II, “the CEP approaching the furcation, but not actually making contact with it;” and grade III, “CEP extending into the furcation proper.”<sup>130</sup> Prevalence of CEP for all extracted teeth varies, depending on the report, from 25% to 35.5% and 8% to 17% in mandibular and maxillary molars, respectively.<sup>130–135</sup> When controlling for the presence of furcation invasion (FI), CEP were found in 82.5% and 17.5% of molars with and without FI, respectively,<sup>136</sup> with prevalence for CEP associated with FI ranging from 63.2% to 90%<sup>130,137,138</sup> and only one study finding no greater significant association between CEP compared with FI.<sup>134</sup> While the prevalence of grade III CEP varies in the literature from 4.3% to 6.3%, these types of CEP might be more detrimental to the furcation periodontal tissues than grade I and II CEP.<sup>136,139</sup>

Enamel pearls are generally spheroidal in shape, occur in roughly 1% to 5.7% of all molar teeth,<sup>140–142</sup> vary in dimension from 0.3 to 2 mm, and occur most often isolated on a tooth, potentially localized in the furcation area of molars.<sup>133,142–144</sup> EP can act as a plaque-retentive factor when periodontitis progresses to the point that they become part of the subgingival microbial ecosystem.

### Developmental grooves

The most frequent developmental groove appears to be the palatal groove, most often located in the maxillary lateral incisor with a prevalence of 1% to 8.5% at the subject level and 2.2% at the tooth level.<sup>145</sup> Forty-three percent of grooves do not extend more than 5 mm apical to the CEJ and only 10% are present 10 mm or more apical the CEJ.<sup>146</sup> The mechanism suggested for developmental grooves to initiate



periodontal disease is related to plaque retention that causes localized gingivitis and periodontitis.<sup>133,145,147-150</sup> Grooves are also present on other teeth<sup>151,152</sup> and mostly in the interproximal areas, with few of these grooves extending to the tooth apex.<sup>153</sup>

## Tooth and root fractures

### Tooth fractures

If tooth fractures occur coronal to the gingival margin and do not extend to parts of the tooth surrounded by periodontal tissues, they do not initiate gingivitis or periodontitis, unless the surface characteristics of the fracture area predispose to greater plaque retention.

### Root fractures

Root fractures can be classified based on the trajectory of the fracture (vertical, transverse, or oblique), their extent (complete or incomplete), location (apical, midroot, or cervical regions) and on the healing/repair mode.<sup>154</sup> While fractures located within the midroot and apical regions were shown in a 10-year study to have a very favorable prognosis (78% and 89% tooth survival, respectively), fractures located within the cervical one-third of the root had a significantly worse prognosis for tooth retention (33%).<sup>154-156</sup> Since fractures located within the cervical third of a root have a more likely possibility of being colonized by subgingival plaque, they can act as plaque-retentive factors and indirectly cause gingivitis and periodontitis. In addition, they can directly traumatize the surrounding periodontium due to mobility of the fractured tooth surfaces. Limited short-term evidence suggests that fractures located within the anatomic crown or slightly into the cervical third of the root can be successfully repaired with adhesive techniques and that periodontal parameters, such as plaque index, gingival index (GI), PD, and clinical attachment level, are not different than control teeth.<sup>157-159</sup> Vertical root fractures are defined as longitudinal fractures that might begin on the internal canal wall and extend outward to the external root surface. They occur most often on endodontically treated teeth, although they can be present on non-endodontically treated teeth, especially molars and premolars, as a result of apical extensions of coronal tooth fractures.<sup>160</sup> A localized pocket, with loss of attachment and bone is usually associated with the fractured tooth<sup>161</sup> and extends to variable lengths along the fracture line.<sup>162,163</sup> Narrow, deep, V- or U-shaped osseous defects are generally seen during surgical exposure of the fractured area with bone resorption and inflammation related to bacterial infection from the gingival margin and root canal system.<sup>164,165</sup>

### Root resorption

Root resorption can be classified into surface, inflammatory, replacement resorption,<sup>166,167</sup> and depending on its location,

as internal or external, cervical or apical.<sup>168,169</sup> When root resorption is located within the cervical third of the root, it can easily communicate with the subgingival microbial ecosystem. Plaque retention at such sites can cause gingivitis and periodontitis. Cemental tears are localized areas of cementum detachment from the underlying dentin and can potentially lead to localized periodontal breakdown, although the biologic mechanism involved has not been elucidated.<sup>170,171</sup>

### Tooth position

Cross-bite,<sup>172,173</sup> misalignment/rotation of a tooth,<sup>174</sup> and crowding of the maxillary<sup>175</sup> and mandibular anterior sextant<sup>176</sup> have been shown to be associated with increased plaque retention<sup>176</sup> and gingivitis, greater PD, and bone<sup>177</sup> and clinical attachment loss.<sup>178</sup> However, other studies assessing the effect of crowding on the periodontium did not find an association with plaque retention and gingivitis.<sup>179-181</sup> Tooth position and periodontal biotype and their interaction<sup>182</sup> can also be factors that influence the likelihood of mucogingival deformities, as it has been shown that a thin periodontal biotype has a significantly thinner labial bone plate, narrower gingival width, and greater apico-coronal distance between the CEJ and the alveolar crest.<sup>183</sup> In subjects who exhibit trauma related to tooth brushing<sup>184-187</sup> or tooth malposition within the alveolar process,<sup>187,188</sup> a greater risk for gingival recession can be present. Tooth anatomy, and specifically the shape of the tooth and their approximation, have been shown to affect the height of the interproximal papilla.<sup>189</sup>

### Root proximity

Root proximity (RP) in the maxilla is most prevalent between the first and second molar and between the central and lateral incisors; in the mandible, it is generally seen between the central and lateral incisors.<sup>190,191</sup> However, RP has been defined and measured in different ways in the literature, therefore producing inconsistent conclusions on its effect on the periodontium.<sup>192,193</sup> More recently, however, a longitudinal 10-year clinical study concluded that, while an interproximal root distance (IRD) of mandibular central and lateral incisors > 0.8 mm was not associated with a more apical position of the interproximal bone, an IRD > 0.8 mm was associated, even when controlled for age, smoking, plaque, and calculus, with interproximal crestal bone loss, and sites with IRDs < 0.6 mm were 28% and 56% more likely to lose > 0.5 mm and > 1.0 mm of bone during 10 years, respectively.<sup>194</sup> Based on the limited evidence, we are not able to conclude which are the biologic mechanisms underlying this increased bone loss.<sup>194</sup> To standardize the location and magnitude of RP, a classification has been proposed that defines the location of the measured site of RP (cervical, middle, or apical third of the root) and divides the severity of the RP into type 1: > 0.5 to ≤0.8 mm; type 2: > 0.3 to ≤0.5 mm; type 3: ≤0.3 mm.<sup>190</sup>



## Open contacts

The presence of adequate proximal tooth contacts is considered important to prevent food impaction between teeth.<sup>195</sup> From a periodontal standpoint, while the presence of open contacts was not a factor directly associated with increased GI and PD, the statistically greater occurrence of food impaction at sites with open contacts was associated with increased PD in these areas.<sup>196,197</sup>

## CONCLUSIONS

Tooth anatomic factors, root abnormalities and fractures, and tooth relationships in the dental arch and with the opposing dentition can enhance plaque retention. Restoration margins located within the gingival sulcus do not cause gingivitis if patients are compliant with self-performed plaque control and periodic maintenance. Tooth-supported and/or tooth-retained restorations and their design, fabrication, delivery, and materials have often been associated with plaque retention and loss of attachment. Hypersensitivity reactions can occur to dental materials. Restorations margins placed within the junctional epithelium and supracrestal connective tissue attachment can be associated with inflammation and, potentially, recession. However, the evidence in several of these areas, especially related to the biologic mechanisms by which these factors affect the periodontium, is inconclusive. This highlights the need for additional well-controlled animal studies to elucidate biologic mechanisms, as well as longitudinal, prospective human trials. Adequate periodontal assessment and treatment, instructions and motivation in self-performed plaque control, and compliance with maintenance protocols appear to be the most important factors to limit or avoid potential negative effects on the periodontium associated with fixed and removable prostheses.

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