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The Relationships Between Tooth-Supported Fixed Dental Prostheses and Restorations and the Periodontium

Carlo Ercoli, DDS, MBA, FACP[1], Dennis Tarnow, DDS,[2] Carlo E. Poggio, DDS, MS, PhD,[1] Alexandra Tsigarida, DDS, MS,[1] Marco Ferrari, MD, DMD, PhD,[3] Jack G. Caton, DDS, MS,[1] & Konstantinos Chochlidakis, DDS, MS, FACP[1]

[1]Departments of Prosthodontics and Periodontics, Eastman Institute for Oral Health, University of Rochester, Rochester, NY
[2]Department of Periodontics, Columbia University College of Dentistry, New York, NY
[3]Department of Medical Biotechnologies, Division of Fixed Prosthodontics, Dean, University of Siena, Siena, Italy

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Correspondence
Carlo Ercoli, Department of Prosthodontics, Eastman Institute for Oral Health, University of Rochester, 625 Elmwood Avenue, Rochester, NY 14620.
E-mail: Carlo_ercoli@urmc.rochester.edu

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Abstract

Purpose: To search the literature and to critically evaluate the findings on the periodontal outcomes of restorations and tooth-supported fixed prostheses.
Materials and Methods: PubMed was searched according to a systematic methodology, previously reported, but updated to include a larger database. Filters applied were: Case reports, clinical trial, review, guideline, randomized controlled trial, meta-analysis, systematic reviews, and English. A narrative review was then synthesized to discuss periodontal outcomes related to restorations and tooth-supported fixed prostheses. Relevant data was organized into four sections: Direct restorations, indirect restorations, biologic width or supracrestal tissue attachment and tooth preparation/finish line design.
Results: While increased gingival index, bleeding on probing, probing depth and clinical attachment loss have been associated with subgingival restorations, intracrevicular margins do not cause periodontal diseases. Inflammation and bone loss occur, for both direct and indirect restorations, only with large overhangs. Different restorative materials are associated with different clinical responses when placed in the gingival sulcus or within the epithelial and connective tissue attachments. When the connective tissue attachment is removed, histological changes occur causing its apical shift and subsequent re-establishment. Gingival displacement during impression procedures can cause gingival recession. Emergence profile can have a range of values, not associated with periodontal diseases. Periodontal response appears to be clinically not different when compared among different finish line designs.
Conclusions: Contemporary procedures and materials used for the placement and fabrication of tooth-supported restorations and fixed prostheses are compatible with periodontal health when adequate patient education and motivation in self-performed oral hygiene are present. Periodontal diagnostic criteria should be thoroughly reviewed before fixed restorative treatments are planned and executed.

It is well recognized that the anatomy, physiology and pathology of the periodontium can be potentially affected by prosthodontic factors inherent to the planning, design, fabrication, delivery and maintenance of fixed restorations, including tooth-supported prostheses.[1] On the other hand, diagnostic and prognostic periodontal considerations are important factors that can potentially affect the longevity of fixed restorations abutments and the esthetics and longevity of prostheses.[2–4] It is, therefore, important for the clinician to be aware of the current evidence related to the effect that fixed prosthodontic materials and procedures have on the periodontium and conversely understand the periodontal characteristics that may constitute valid prognostic indicators for the success of fixed prosthodontic procedures.

While relationships established in most studies can generally be divided into causation, correlation and association,[5] the main purpose of this review is to build and expand on previous reviews related to the periodontal effects of dental restorations,[1,4,6] include up-to-date clinical and animal evidence, and draw clinically relevant conclusions.[7,8] The primary aim of this review is to provide a comprehensive document on the relationship between restorations and tooth-supported fixed

Table 1 Electronic search strategy used for the study

Topic	Search strategy		Search strategy
Biologic width	("biology"[MeSH Terms] OR "biology"[All Fields] OR "biologic"[All Fields]) AND width[All Fields]	AND	(Periodontitis OR Periodontal Diseases OR Gingivitis OR Gingival Diseases) NOT "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 restoration 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])	AND	(Periodontitis OR Periodontal Diseases OR Gingivitis OR Gingival Diseases) NOT "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])	AND	(Periodontitis OR Periodontal Diseases OR Gingivitis OR Gingival Diseases) NOT "comment"[Publication Type] OR "editorial"[Publication Type] OR "interview"[Publication Type] OR "letter"[Publication Type] OR "news"[Publication Type] OR "newspaper article"[Publication Type])

prostheses and periodontal outcomes that may be useful for the practicing clinician. The secondary aim is to evaluate the available literature and identify knowledge gaps that may stimulate original research.

Materials and methods

This review utilized a systematic search strategy modified from a previous article[1] to also include case series and case reports as well as preclinical data from animal studies. Medical Subject Headings (MeSH) and keywords were used, in collaboration with an experienced librarian, to devise the search strategy in PubMed (Table 1). Filters applied were: Case reports, clinical trial, review, guideline, randomized controlled trial, meta-analysis, systematic reviews, and English. Similar to a previously reported methodology,[1] "the articles obtained were input into a reference manager software (Endnotes X9, Thomson Reuters). Titles and abstracts were screened for potential inclusion and duplicates discarded. 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. Text reading of the selected publications was performed and when titles of referenced articles, not included in the electronic search, were identified as 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." While a systematic methodology for appraising the selected literature was not used,[9,10] when multiple articles reached similar conclusions, only those with a higher level of evidence were included. Data is organized to discuss, in relation to periodontal outcomes, the following four main topics: Direct restorations, indirect restorations, biologic width or supracrestal tissue attachment and tooth preparation/finish line design.

Results

Direct restorations

Factors that have been reported to potentially affect the periodontium include: Intrasulcular position of the restoration margin, overhangs, dental material characteristics, gingival displacement procedures, periodontal phenotype, emergence profile (EP), and biologic width (supracrestal tissue attachment).[1] To avoid duplication, this section will describe the first three factors, while the others will be discussed later in the manuscript.

Intracrevicular position of the margin

In cross-sectional studies, class II amalgam restorations with intracrevicular margins have been associated with increased prevalence of gingivitis and periodontitis compared to supragingival margins or contralateral teeth. In these cases, periodontal parameters that have been shown to be increased include gingival index (GI), bleeding on probing (BoP), probing depth (PD), and clinical attachment loss (CAL).[11–13]

Even though direct subgingival restorations may present with statistically significant greater PD and CAL compared to supragingival restorations,[11,12,14,15] the clinical significance of this finding remains unclear. Indeed, in a 26-year longitudinal study (from 1969 to 1995), while CAL increased for teeth with subgingival restoration margins, a similar pattern and

magnitude of CAL was observed for control teeth.[16] Only three recalls (1973, 1975, 1988) showed differences in CAL sufficient to reach the stated level of significance ($p<.05$), and even in these cases, the CAL difference was never greater than 0.46 mm.

In these instances, in the presence of gingival inflammation, the reliability and validity of clinical probing measurements in relation to histologic characteristics should also be questioned. In fact, it has been demonstrated that, in inflamed marginal tissues, the tip of the periodontal probe stops in a more apical position compared to sites where gingival inflammation is absent.[17–22] This is likely due to histologic tissue changes (relative increase in cellularity and decrease in collagen fibers) which accompany gingival inflammation.[23]

Overhangs

Amalgam restorations overhanging margins are unfortunately relatively common.[24,25] They are associated with inflammation, BoP, increased PD [26–28] and interproximal bone loss,[15,29] but only when overhang dimensions are greater than 0.2 mm.[30–32] Removal of the overhanging margin is accompanied by a decrease in gingival inflammation, decreased PD and gingival recession.[33–35]

Dental materials

While in vitro studies show that several ions can affect cell function and the release of inflammatory mediators,[36,37] their clinical effect on gingivitis and periodontitis is unclear.[1] From a clinical standpoint, a study examining 28,796 proximal restorations, found that CAL and PD $\geq$4 mm were present in 1.5% and 4.8% of the sites, respectively. However, compared to sound tooth surfaces, only amalgam restorations were associated with increased PD and CAL, while composite materials were not.[38] This finding is further supported by a clinical and histologic study that clearly showed that intracrevicular composite restorations are compatible with gingival health, provided that epithelial and connective tissue attachments[1,4] are respected and periodontal supportive therapy is implemented.[39] Therefore, contrary to other materials,[11–14,40] adhesive composite materials, when used for subgingival restorations, appear to elicit a periodontal response that is similar to periodontal tissues behavior around unrestored teeth.[41–49] In addition, it has been shown that adhesive materials can be successfully used, in a subgingival location,[50,51] including during periodontal plastic surgery, without causing gingivitis and periodontitis.[52–60]

To summarize, increased GI, BoP, PD, and CAL are associated with amalgam restorations intracrevicular margins while inflammation and bone loss occur only if large overhangs are present. In addition, the reliability and validity of periodontal probing (PD, CAL) in the presence of gingival inflammation is questionable.

Furthermore, different restorative materials are associated with different periodontal reactions,[61] with adhesive materials eliciting a periodontal response similar to unrestored tooth structure especially when patient are enrolled in a supportive periodontal maintenance program.

Indirect restorations

Periodontal outcomes around indirect fixed restorations are related, but not limited to, the intracrevicular positioning of the restoration margin, presence of overhangs, gingival displacement procedures, periodontal phenotype, and EP.

Intracrevicular position of the margin

Similar to direct restorations, cross-sectional studies of indirect restorations with intracrevicular margins have been associated with increased GI, PI, PD, BoP, and CAL compared to supragingival margins.[14,62–69] However, longitudinal studies of patients, motivated, instructed on self-performed plaque removal and periodically maintained,[70–71] did not show any detrimental periodontal outcome for restorations with intracrevicular margin design.[72–79]

In addition to the aforementioned periodontal parameters, gingival recession has been, at times, associated with intracrevicular margin.[1] However, when intracrevicular crown margins are adopted, it is important to assess the temporal onset of gingival recession, as longitudinal studies have shown that recession can occur before the delivery of the definitive prosthesis.[80,81]

These studies support the concept that the nominal margin location (intracrevicular) may "be less of a contributing etiologic factor than the prosthetic materials and procedures required to design and record the margin position."[1] In addition, characteristics of the periodontal phenotype, later described, may also play a role in the occurrence of gingival recession associated with intracrevicular crown margins.[4]

Overhangs

Like direct restorations, only overhanging margins $\geq$0.5 mm are associated with increases in GI, gingival crevicular fluid (GCF) flow and bone loss, while overhangs $\leq$0.2 mm are compatible with periodontal health.[28,82]

Gingival displacement

Gingival margin changes have been associated with fixed prosthodontic procedures.[80,81,83–90] They can be linked to a variety of factors, including crown preparation and margin position,[80,91–93] gingival displacement and impressions,[81,84,94] provisional prostheses,[95] and luting agents.[96]

During impression making for fixed prostheses with intracrevicular margins, gingival displacement procedures aim to achieve a temporary and reversible gingival displacement, exert minimal and reversible trauma to the periodontium, and ensure that the recorded impression margin or marginal area is identifiable by the laboratory technologist.[81,97–100]

Several materials and methods are available for gingival displacement[101–104] and they can be broadly grouped into tissue displacement [81,94,100,103,105–108] and tissue removal methods.[94,100,109–115] While paste materials may be deemed less traumatic than retraction cords[116] and surgical tissue removal,[84] no material or method has been proven ideal.[101–102] Specifically, it appears that cordless systems, while allowing a dry field during impression, may, in some patients, fail to achieve the same amount of tissue displacement as other

methods[117,118] and not allow adequate reading of the impression by the laboratory technologist.[81] On the other hand, excessive forces applied during gingival displacement may cause trauma to the epithelial and connective tissue attachments[94,119] potentially causing gingival recession,[81,84] a relatively common condition[120–121] more often found in individuals with a thin periodontal phenotype.[4,122–124]

Periodontal phenotype

Mucogingival conditions have been associated with the occurrence of recession, defined as an apical shift of the gingival margin caused by different conditions/pathologies and accompanied by attachment loss.[4] Specifically, periodontal phenotype, a combination of gingival phenotype (defined as the gingival thickness,[125] and keratinized tissue width),[2] and bone morphotype (defined as the thickness of the buccal bone plate)[4,124,126] appears to be associated with the occurrence of gingival recession.[122–124,127,128]

While periodontal health can be maintained around natural teeth regardless of the periodontal phenotype,[4] periodontal parameters, such as GI, can increase when intracrevicular prosthesis margins are adopted for teeth with less than 2 mm of keratinized tissue apico-coronal width.[2] However, studies evaluating the influence of prosthesis-related factors (including finish line designs, prosthetic material, gingival displacement methods and materials, EP) on the occurrence of gingivitis and periodontitis with different periodontal phenotypes are still lacking.

It is therefore important that future studies aiming to assess the periodontal response to fixed prostheses include a comprehensive pre-operative periodontal assessment.[128,129]

Emergence profile

One of the prerequisites of any restorative treatment is the establishment and maintenance of periodontal health. Several prosthodontic parameters have been described in the literature including the design of the apical third of a restoration, generally defined as the emergence profile (EP).[130]

Several theories have been proposed to support different designs of the EP.[131] Among these theories, the so-called gingival protection theory postulated that the contour of the apical third of the restoration should ensure mechanical protection of the gingival margin from food impaction, offer gingival stimulation and provide self-cleansing contours. This largely anecdotal theory has since been abandoned, as the resultant contour has been suggested to only lead to increased plaque accumulation.[131]

Other authors have instead advocated the selection of a flat EP in order to minimize detriment to the periodontium,[132–137] however, the evidence, in this regard, is quite limited.

Animal studies (canine model) supporting the adoption of under contoured EP showed that, when EP is increased by 2 mm,[138] an increased inflammatory response is noted. Other authors, though, showed no differences with a similar animal model.[139,140] While it is often difficult to reconcile study outcomes with different experimental methodologies, it is worth noting than the latter studies[139,140] incorporated periodic oral hygiene procedures (once/daily), while no oral hygiene measures were mentioned in the former one.[138]

In humans, the placement of an overhanging acrylic filling, located 5 mm from the gingival margin, caused an increase in GI in approximately 2/3 of the study subjects.[141] Similarly, increased PI values were found surrounding crowns where bucco-lingual dimension of the height of contour was increased as compared to unrestored contralateral teeth.[142]

These two studies,[141,142] though, while often quoted in review articles[131,132,134,135,143] to advocate against overcontouring, are not relevant to discuss EP as over contoured restorations located 5 or more millimeters from the gingival margin[141] or the bucco-lingual dimension of the height of contour[142] are not the same as the EP.[130]

Other human studies[144] with a small sample size,[145,146] showed that under or overcontoured direct and indirect restorations of 0.5-1 mm, had no effect on GI, PI, bleeding index (BI), interproximal bone levels, and gingival inflammation when patients practiced oral hygiene.

It is therefore evident that the level of evidence supporting a specific prosthetic EP is quite low. It may, therefore, be helpful to examine normative values for EP and angle related to healthy or periodontally diseased natural dentition.[147]

The emergence angle is defined as "the angle between the average tangent of the transitional contour relative to the long axis of a tooth."[130] For unrestored maxillary anterior teeth, this angle has been shown to have a mean value of 15°,[148–150] with a range of values, though, from 0° to 69°.[150,151]

Unrestored maxillary anterior teeth do not show a correlation between the emergence angle and PI, GI, and CAL values.[151] For crowned teeth, subgingival emergence angle was associated with increased PD and CAL, but only on the lingual surface.[151]

Consequently, it appears that periodontal health is associated with relatively large variations of EP and emergence angle values. Based on this normative data, it could be prudent to suggest that a range of values, for EP angles, can also be used for indirect prosthetic restorations,[151–153] especially when self-performed plaque removal and supportive periodontal therapy is established.[67,73,129,144–146,154,155]

In summary, cross-sectional studies of indirect restorations with subgingival margins show association with increases in GI, BoP, PD and CAL; however, longitudinal studies suggest that periodontal health can be preserved in motivated and well-maintained patients.

Gingival displacement (and other prosthodontic procedures) can cause gingival recession so it is important to assess periodontal phenotype prior to the initiation of fixed prosthodontic procedures. Furthermore, while bone loss and inflammation can occur only if larger overhangs are present, the EP can have a range of values, not associated with periodontal diseases.

Supracrestal tissue attachment (biologic width)

The term "biologic width"[156] refers to the epithelial and connective tissue attachments coronal to the periodontal ligament proper [1,4] and describes the variable histologic dimensions of the components of this part of the periodontium.[157–162]

Clinical and histologic evidence suggests that crown margins that are placed within the epithelial and connective tissue attachments are associated with buccal gingival recession, CAL, and bone loss.[163] Similarly, in a prospective clinical trial of premolar teeth, margins placed within 1 mm of the interproximal bone were associated with increase in papillary bleeding index (PBI) and PD.[164] However, other studies, investigating the placement of resin-modified glass ionomer restorations within the connective and epithelial attachment apparatus,[50] found that the clinical response of the periodontal tissues was characterized by almost complete absence of inflammation, BoP and PD > 3 mm. Histologically, healthy, non-infiltrated epithelium and connective tissues were seen juxtaposed to the restorative material. [51]

While these studies[51,163,164] describe the available human evidence related to the relation between restoration margins and epithelial and connective tissue attachments, it is important to include additional histological information, mostly from animal studies.

For the epithelial attachment, histological evidence shows that tooth preparation finish lines that encroached on the epithelial attachment, but were not covered by a crown margin, experienced a reattachment of the junctional epithelium.[100,119,165]

For the connective tissue attachment, histological data related to crown lengthening, instrumentation/tooth preparation extending to the bone level, and the periodontal reactions to the placement of different restorative materials within the supracrestal tissue attachment are relevant to this review.

After crown lengthening procedures, the junctional epithelium (JE) migrates to the apical level of root planing and a newly formed, approximately 1-mm wide, supracrestal connective tissue attachment forms in the area where a similar apico-coronal extent of crestal bone has been resorbed.[166] The same histological changes occur when tooth preparation, regardless of preparation design (chamfer, shoulder, feather-edge), is extended to the bone level and complete removal of the supracrestal connective tissue attachment is, therefore, achieved with rotary instruments.[155,167] Periodontal health is re-established after these histologic changes have occurred and tissues have healed.[168]

The preparation and placement of dental restorations within the connective tissue attachment is also accompanied by similar histologic changes as described above, but material-specific marginal tissue reactions.

Specifically, Tal et al[169] and Parma-Benfenati et al,[170,171] with very similar methodologies, placed amalgam class V restorations in dogs, after the reflection of full or partial thickness flaps, respectively. The apical margin of the restoration was located at the crestal bone level, within the area previously occupied by the connective tissue attachment. Clinically, these sites showed severe gingival inflammation, redness, edema, and BoP. Histology showed apical migration of the epithelium with ulcerations and underlying inflammatory infiltrate, crestal bone loss for approximately 1 mm and newly formed, tooth-inserted connective tissue fibers apical to the restoration, essentially recreating a new connective tissue attachment. Bone resorption was more pronounced in thin buccal bone areas.[171]

Similar histologic findings were reported, with the same methodology, by Santamaria et al.[57] In this study, resin modified glass ionomer (RMGI) restorations were placed on the buccal surfaces of canines with their apical margin located at the level of the bone crest. Histology showed a migration of the JE to the apical level of cavity preparation, a healthy epithelium facing the restoration, a reestablishment of approximately 1 mm of connective tissue attachment apical to the JE and crestal bone resorption to accommodate this newly formed supracrestal tissue attachment. The clinical findings, however, largely differed from those of Tal et al[169] and Parma-Benfenati et al[170,171] since no gingival inflammation was present and periodontal clinical parameters (PD, BoP, and gingival recession) were no different than control sites.

These studies show that the placement of an amalgam or RMGI restoration within the supracrestal connective tissue compartment is followed by a re-establishment of connective tissue attachment, apical to the restoration, made possible by and accompanied with, crestal bone resorption. The marginal tissue reactions, though, appear to be influenced by the type of restorative material and, likely, its physical and chemical characteristics.

These findings are also supported by other clinical and histological animal evidence that demonstrated that RMGI materials placed within the connective tissue attachment are associated with less pronounced marginal inflammatory reactions[172,173] than amalgam. They also agree with other studies showing that epithelial and connective tissues health can be established and maintained in close proximity to restorative materials.[51,174–176] This animal evidence appears to support the previously discussed clinical findings.[51,163,164]

More recently, the concept of "cervical margin relocation"(CMR) or "proximal box/margin elevation" has been proposed for the restoration of proximal carious lesion that extend within the connective tissue attachment.[177–179] This technique suggests avoiding a crown lengthening procedure by placing a direct composite restoration extending within the connective tissue attachment. The composite material is then prepared to incorporate a coronal, supragingival finish line for the placement of another direct or indirect restoration. While a number of in-vitro studies have been published,[180] only one human comparative study is available in the literature and shows, compared to control sites, an increase in BoP when CMR is adopted, however with no difference in PI and GI scores compared to controls.[181] No histological evidence is available to characterize the tissue response to CMR.

Taken together, temporary detachment of the junctional epithelium is followed by reattachment in areas not covered by restoration margins. When the supracrestal connective tissue attachment is removed, histological changes occur causing its apical shift and subsequent re-establishment. Similar histological changes occur with the placement of a restoration within the supracrestal connective tissue attachment. However, the marginal tissue reaction appears to be determined by the type of restorative material.

Tooth preparation and finish line design

Tooth preparation design principles have included preservation of tooth structure, retention and resistance forms, structural durability, marginal integrity and preservation of the periodontium.[136,137,165] Tooth preparation finish line design has long been one of the factors suggested to affect the integrity and health of the periodontium.

The finish line of a tooth preparation is defined as the junction of prepared and unprepared tooth structure with the margin of a restorative material.[130] In fixed prosthodontics, it can assume several configurations including shoulder, chamfer, bevel, feather-edge, knife-edge or combinations. Finish line characteristics including marginal accuracy,[182–186] tooth structure preservation,[136] periodontal attachment,[94,100,165] prosthetic material property,[187] and EP and angles[188] have been considered important for the periodontium.

While a cast restoration could potentially be designed with any type of finish line, information related to all-ceramic restorations can vary. Historically, given the limited mechanical properties of early ceramic materials and the need to optimize ceramic materials clinical application,[136,137,189] tooth preparation requirements for all-ceramic crowns suggested the adoption of a shoulder or deep chamfer and the avoidance of beveled, knife-edge or feather-edge preparation designs.[190–195] While this information was applicable to ceramic materials with limited mechanical properties, it may be less relevant today given the availability of high-strength and high-toughness ceramic materials.[187,196] Recent clinical studies, suggest that both lithium disilicate[197–201] and zirconia crowns[202–204] have a favorable prognosis when fabricated with a featheredge margin design.

An objection to the adoption of a featheredge finish line design has been the necessity to add material bulk in the most apical part of the crown or retainer, therefore leading to negative periodontal outcomes due to the almost unavoidable marginal overhang and/or an over contoured EP.[136] While, from a microscopic standpoint, the marginal portion of the restoration could technically be considered an overhang, it is quite plausible that its dimensions would be below the 0.2 mm threshold previously identified as necessary for periodontal damage.[28,82] However, while it is suggested that featheredge margin design with lithium disilicate[197–201] and zirconia materials[202–204] are compatible with favorable restorative and periodontal prognoses, careful attention to margin design is important during prosthesis fabrication.

In summary, as previously discussed, periodontal health appears compatible with a range of values for EP[151] and when a featheredge finish line design is adopted.[93,197,203,205–208]

Limited comparative evidence related to periodontal outcomes of different finish line designs is however available, generally showing only minor differences for BoP and recession.[91,92]

Discussion

This review sought to evaluate the literature on the effects that prostheses have on periodontal outcomes, but differently from previous works,[1,6] it exclusively focused on fixed, tooth-supported dental prostheses and restorations. It evaluated, not only evidence from human studies, but included, where applicable, information from animal histology that was helpful to elucidate the role that prosthetic restorations have on the periodontium.[165–167,170,171] In addition, periodontal characteristics that can potentially affect the longevity of fixed restorations abutments and the esthetics and longevity of prostheses were discussed.[2,4,124]

The primary aim of this review was to provide a document on the relationship between fixed prostheses and periodontal outcomes that may useful for the practicing clinician. However, in keeping with this intent, it is helpful, in order to adequately discuss the findings, that the limitations of this review be readily presented.

A systematic and reproducible methodology was used to search the available literature and identify relevant information, yet the selection, extraction, appraisal and presentation of the included evidence was not performed according to established criteria for systematic reviews. This was motivated by the heterogeneity of the included studies.[9,10] Therefore, it is possible, while the authors have made every effort to objectively evaluate the available literature, that the current review be biased by selective reporting.

While this can be considered a weakness of the present study, it was decided, at the outset of this review, that the intended audience was the practicing clinician. The review, therefore, sought to provide useful information, albeit from heterogeneous study designs, that may allow a readily applicable, clinical understanding of the relationships between fixed restorations and prostheses and the periodontium. Therefore, the presentation of the data was organized in four clinically relevant sections. Evidence provided in one section was, often, helpful for a more thorough understanding of information provided later in the review. Therefore, in attempting to avoid duplications, yet providing a clinically cohesive presentation of the results, the authors used the conclusions from each section to better frame the discussion for later sections of the manuscript and build upon already discussed, relevant information.

One search engine, PubMed, was used for the literature search, therefore, it is possible that selection biases have occurred.[9] In an attempt to minimize this possibility, a group of experienced periodontists and prosthodontists was included among the authors. In addition, a manual search of the references of the included articles was done to identify additional studies and minimize selection bias.

No attempt was made to contact authors of the included studies. While this could have provided additional information related to their study, helped clarify some inconsistencies, and better inform this review, it was deemed not feasible given the wide temporal span of the included studies and the fact that many authors are no longer alive. Therefore, every effort was made to evaluate the included articles by carefully reading the entire text.

The secondary aim was to evaluate the available literature and identify knowledge gaps that may stimulate additional original research.

While recognizing the outstanding contributions of many landmark studies and the role that several authors have played

in shaping our current understanding of the relationships between tooth-supported fixed prostheses and the periodontium, some results need to be framed within their historic period and discussed in light of new evidence related to materials and technologies.[40] As an example, studies that used provisional acrylic resin crowns to investigate periodontal responses to fixed prostheses, while at times providing valuable histologic evidence, may not be adequate to describe the clinical reaction of the periodontium to currently used ceramic materials.[100,165] Similarly, studies investigating the role of crowns marginal accuracy cannot be generalized from findings on provisional acrylic crowns.

Different materials are also used for a variety of prosthetic procedures. It appears evident, for example, that while some provisional materials[40] and amalgam intracrevicular margins are associated with plaque and inflamed marginal periodontal tissues, adhesive materials, such as composite and RMGI, behave similarly to natural tooth structure when placed in the gingival sulcus.[38,39,73] It is therefore not appropriate to generalize findings across material types as different materials appears to elicit differential periodontal responses.

Measurement methodologies used to define periodontal outcomes need also discussion in this context. While histology represents the gold standard to assess quantitative changes of the periodontium, such as attachment loss, it is common, in clinical studies, to use surrogate measures, such as clinical attachment loss. In a clinical situation where gingival inflammation is present and especially when assessing small differences between groups, the validity of the CAL measurements to reflect true histological changes may be questioned.[17–20]

Data analysis and interpretation is another area of interest. Statistical significance is important and points to a separation of the data based on a specified level of chance, however it is, at times, misinterpreted or misquoted to reflect clinical significance.[7] LeFort defined clinical significance as "the extent of change, whether the change makes a real difference to subject lives, how long the effects last, consumer acceptability, cost-effectiveness, and ease of implementation."[8] With this in mind, a statistical significant difference based, though, on a small clinical difference, assumes limited clinical relevance. It is therefore important to consider statistical study results not at face value, but relate them to the appropriate clinical context. A similar analogy can be made between association studies and actual causation.[5]

For some studies, a more in-depth description of the study methodologies and limitations was included in this manuscript, rather than a mere reporting of the conclusions. This exhaustive approach was selected for instances in which the appraised evidence appeared, to the authors, less than settled or when a more detailed review could better inform the reader about the rationale of our conclusions.

While it is important to recognize these methodological limitations, it appears clear that periodontal health around fixed restorations and tooth-supported fixed prostheses abutments is less a function of specific prosthodontic interventions than self-performed plaque control and periodontal maintenance.[41–43,70,72,73] As such, it is important that adequate patient education and motivation be part of every fixed prosthodontic treatment plan and precede the actual delivery of treatment.

Moreover, the specific characteristics of the periodontium, such as the phenotype, need to be evaluated before the commencement of prosthodontic therapy, especially when studying the response of the periodontium to tooth-supported fixed restorations, so that adequate prosthodontic prognosis can be associated with periodontal diagnostic characteristics.[2,124]

Conclusions

While increases in GI, BoP, PD, CAL are generally associated with direct amalgam and indirect restorations with intracrevicular margins, longitudinal studies, where oral hygiene is maintained and motivated, do not show association between intracrevicular margins and increased periodontal parameters, especially for adhesive materials.

In addition, EPs, designed within natural range values and irrespective of finish line design, are not associated with periodontal diseases and only larger overhangs are associated with bone loss and inflammation in both direct and indirect restorations.

Gingival displacement trauma can cause gingival recession; therefore it is important to assess periodontal phenotype prior to the initiation of fixed prosthodontic procedures. In this sense, temporary detachment of the junctional epithelium is followed by reattachment in areas not covered by restoration margins; however, when supracrestal connective tissue attachment is removed, histologic changes do occur and cause an apical shift and reestablishment of the connective tissue attachment. While these histologic changes occur irrespective of the adopted dental material, the marginal tissue reactions appear to be determined by the type of restorative material.

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