Management of Furcation-Involved Molars: Recommendation for Treatment and Regeneration

Furcation involvement (FI) is one of the most detrimental factors affecting tooth survival rate over time. Several authors have used the severity of FI for assessing the prognosis of the tooth and the complexity of periodontal disease. While many approaches have been shown to improve the prognosis of furcation-involved teeth, clinical guidelines recommending one treatment or another (based on the horizontal and vertical component of the furcation defects) have not yet been proposed. To this aim, the present article introduces recommendations for the treatment of molars with FI and discusses different treatment options with their potential regenerative approaches. Patient-related factors, together with hard and soft-tissue conditions that may affect the outcomes of periodontal regeneration, are discussed. Int J Periodontics Restorative Dent 2020;40:e137–e146. doi: 10.11607/prd.4341

Periodontitis is a multifactorial chronic disease that affects approximately 42% of the adults in the United States. Its progression and detrimental results on periodontal tissues have been extensively evaluated. When this condition affects multi-rooted teeth exposing the furcation area, the treatment poses additional challenges for the clinician. This is because the unfavorable morphology and restricted-access area that characterize furcation defects limit not only the efficacy of nonsurgical and surgical therapies but also the patient’s self-performed plaque control. Due to these limitations, the progression of the disease in the furcation area exhibits horizontal and/or vertical patterns of destruction that may lead to an increased risk for tooth loss. Therefore, it is not surprising that the severity of furcation involvement (FI) has been used for assessing the prognosis of the tooth and the complexity of periodontal disease. In a recent meta-analysis, Nibali et al showed that the presence of FI increases the risk of tooth loss in molars by two-fold when maintained in supportive periodontal therapy (SPT).

Several surgical approaches have been proposed for the treatment of molars with FI, including guided tissue regeneration (GTR), bicuspidization, tunneling procedure, and root amputation. Car-
er reported a 93% survival rate for molars with FI following root-resective therapy,9 while Bowers et al achieved complete furcation closure in 74% of mandibular molar sites with facial Class II furcations, reporting that 68% of furcation defects were reduced to Class I. These results demonstrated the positive effect of GTR and bone graft in furcation-involved molars.10 In line with these results, the American Academy of Periodontology (AAP) Regeneration Workshop on furcation defects concluded that regeneration is a viable treatment option for molars with Class II FI and that this approach should be considered before performing resective therapy or other treatments.11 However, clinical guidelines recommending one treatment or another have mostly been based upon the horizontal extension of the furcation defect and the morphology of the tooth alone, while guidelines based on the vertical component of the defect and the surrounding soft tissue components have not yet been proposed. Therefore, the aim of this article is to propose recommendations for the treatment of molars with FI and discuss different treatment options with their potential regenerative approaches.

### Materials and Methods

To support the proposal of treatment and regeneration in FI molars, a review of all available literature (until January 2019) was performed across the National Library of Medicine (MEDLINE by PubMed), EMBASE, the Cochrane Library, and the Grey Literature, using the following keywords: “furcation involvement,” “furcation defects,” and “guided tissue regeneration.” In addition, a manual search of related articles, including complete searches of The International Journal of Periodontics & Restorative Dentistry, Journal of Clinical Periodontology, and Journal of Periodontology were performed. A decision tree for furcation management and regeneration was formulated, mainly aimed at treating the buccal furcations of maxillary or mandibular molars, as they show the most realistic and promising treatment outcomes.11

### Table 1 Classifications of Horizontal and Vertical Furcation Defects That Were Used in the Present Article

<table>
<thead>
<tr>
<th>Vertical component of the furcation defect15</th>
<th>Horizontal component of the furcation defect13</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>A</td>
</tr>
<tr>
<td>1</td>
<td>Horizontal loss of periodontal support &lt; 3 mm of the width of the tooth with vertical attachment/bone loss extending to the coronal third of the root.</td>
</tr>
<tr>
<td></td>
<td>B</td>
</tr>
<tr>
<td>2</td>
<td>Horizontal loss of periodontal support ≥ 3 mm of the width of the tooth, but not “through and through,” with vertical attachment/bone loss extending to the coronal third of the root.</td>
</tr>
<tr>
<td></td>
<td>C</td>
</tr>
<tr>
<td>3</td>
<td>Horizontal “through and through” destruction of the periodontal attachment with vertical attachment/bone loss extending to the coronal third of the root.</td>
</tr>
</tbody>
</table>

When presenting their clinical recommendation, the present authors combined the horizontal and the vertical components for describing the furcation defects (eg, A1, B3, C2).
Management of Furcation-Involved Molars

Based upon the evidence available in the literature and the clinical experience of the authors, the following factors were considered for formulating the presented decision tree: (1) furcation defects considering both horizontal and vertical attachment loss; (2) level of the interproximal bone; (3) accessibility of the area for patient oral hygiene; (4) residual attachment of the roots; and (5) tooth anatomy (eg, root trunk length, root length, divergence of the roots). Based on the severity of the horizontal or vertical attachment loss, several classifications for furcation involvement have been proposed.

While FI has been often classified based on the horizontal attachment loss, a 10-year retrospective study by Tonetti et al recently demonstrated that the residual periodontal attachment, evaluated as the loss of vertical component, is a reliable predictor of survival of molars with Class II horizontal FI. Nibali et al showed that after surgical treatment and SPT for at least 5 years, both the horizontal and vertical FI were associated with an increased risk for tooth loss. Therefore, the present authors considered the combination of the horizontal (grades 1, 2, and 3) and vertical (subclasses A, B, and C) furcation components in this newly formulated decision tree (Table 1 and Fig 1). The goal for treatment of FI is to clean the furcation and to facilitate patients' oral hygiene. Bearing in mind that nonsurgical periodontal therapy (NSPT) constantly presents the first step following the diagnosis of a furcation defect, the diagnosis of FI has to be confirmed after at least 6 weeks following NSPT. Indeed, a correct diagnosis is vital for establishing an adequate treatment plan. If the area is accessible for oral
hygiene, a molar with a Class A1 FI can be maintained with NSPT. If the treatment is aimed at improving the patients’ oral hygiene and obtaining access for debridement, then the suggested treatment is an open-flap procedure with furcation-plasty using finishing burs to remove root irregularities and widen the furcation entrance. Similarly, open-flap debridement plus furcation-plasty is recommended in A2 and B1 furcations when a regenerative approach is not favorable (interproximal bone not being coronal to the furcation defect). In line with these recommendations, Al-Shammari et al reported a significant improvement for patient access during oral hygiene measures after open-flap debridement with furcation-plasty in grade 1 and shallow grade 2 horizontal furcation defects. However, when the interproximal bone is coronal to the furcation defect, regeneration should be recommended. In fact, as stated by the 2015 AAP Regeneration Workshop, periodontal regeneration should always be considered the treatment of choice whenever possible. It was also concluded that extensive clinical and histologic evidence is available supporting the efficacy of periodontal regeneration in Class II FIs in mandibular molars, while Class I FIs are typically maintained by nonsurgical therapies; however, in some cases, regeneration of Class I furcation defects can provide additional benefits, in particular when the furcation is combined with vertical attachment loss or when the defect extends to the middle third of the root (Class B1 FI). Although Class II furcation defects are considered the most suitable cases to be treated with periodontal regeneration, not all defects are candidates for regeneration. Based on the level of the interproximal bone compared to the furcation defect, B2 furcation defects can be treated with regenerative therapy or tunneling (in cases with patients exhibiting with adequate oral hygiene). However, regeneration is not recommended in C2 furcation defects. Tonetti et al showed that the vertical component played a key role in the survival rate of molars with Class II FIs. In particular, molars with Class C2 FIs had a 10-year survival rate of 23% with active periodontal therapy followed by SPT (which involves the infection control phase, oral hygiene instructions, scaling and root planing with or without antibiotics, and conservative periodontal surgery). Therefore, the authors suggest that Class C2 FIs be managed by active periodontal therapy and regular SPT.

Less favorable situations include severe horizontal defects combined with vertical attachment loss extending to the middle or apical third of the root. Class B3 FIs can be treated with: (1) tunneling for improving the access to the furcation for proper oral hygiene or (2) removing the affected part of the tooth by performing either root resection (where only the root is removed) or hemisection (where a root with its corresponding crown is removed). The attachment and anatomy of the two roots, including crown/root ratio, together with patient’s compliance and motivation play an important role in determining the most appropriate approach. When the residual attachment of both roots is inadequate, tooth extraction should be considered. In Class A3 FIs, when a favorable root attachment is present, it is recommended to separate the crown from their respective portions by performing a bicuspidalization procedure to eliminate the furcation area. Bicuspidalization treatment can also be applied to Class B2 defects when tunneling is not recommended due to poor patient oral hygiene. In any case of a Class III FI, the residual attachment around each root dictates whether the tooth should be saved (hemisection or root amputation) (Fig 2) or extracted. In a 10-year longitudinal study, Carnevale et al reported a 93% survival rate of root-resected teeth. Similar results were also observed by Fugazzotto. Molars with a Class C3 FI present the most advanced condition to treat, with unfavorable or hopeless prognoses. Among the factors affecting the decision of maintaining or extracting a tooth, the residual attachment around the roots, the root trunk length, the crown/root ratio, and the morphology of the roots have to be considered, as well as patients’ systemic conditions. Figure 1 illustrates the proposed decision tree for the management of an FI.

### Periodontal Regeneration of Furcation Defects in Molars

The predictability of periodontal regeneration has been extensively demonstrated. Long-term data support the superiority of regenerative techniques over flap surgery alone,
leading clinicians to consider periodontal regeneration as the treatment of choice when indicated.\textsuperscript{21}

As recommended by the 2015 AAP Regeneration Workshop,\textsuperscript{11} a periodontal regeneration procedure should be attempted for furcation types A2, B1, and B2 when the interproximal bone is coronal to

---

**Fig 2** (a) A 65-year-old woman presented with deep probing depths mesial to the maxillary left first premolar and first molar with Class III furcation involvement of the mesiopalatal furcation of the first molar. (b) A periapical radiograph was taken following endodontic treatment of the palatal and distal roots and extraction of the mesial root of the first molar. (c to h) Osseosective surgery was performed around the first molar with simultaneous connective tissue graft at the buccal aspect of the first molar to mimic the presence of the mesial root. (i and j) Healing following osseous resective surgery and soft tissue augmentation with the cemented crown on the first molar. (k and l) Radiographic view 7 years later.
the defect. Nonetheless, it has been shown that patient selection is key for the periodontal regeneration outcomes. Factors such as poor oral hygiene, low compliance, and smoking habits can negatively impact the success of regeneration. In these situations, flap surgery without the use of bone graft, membranes, or biologic agents might be a better approach if NSPT is not effective. When the patient is a good candidate for periodontal regeneration, the anatomy of the furcation defect dictates the amount of periodontal tissue that can be regenerated. While occlusion and mobility can be controlled with occlusion adjustments and temporary splinting of the teeth before surgery, root configuration, the distance from the bone crest to the root of the furcation, and interproximal bone height present limitations for the complete closure of the furcation. Bowers et al found that when treating mandibular Class II furcations with bone graft and expanded polytetrafluoroethylene membrane, the best outcomes were achieved in nonsmoking patients and when the interproximal bone height was at either the same level or coronal to the roof of the furcation. Similarly, a lower rate of furcation closure was observed in defects with vertical or horizontal bone loss ≥ 5 mm, high divergence of roots at creatal bone, and in large distances between the roof of the furcation and the bone crest and base of the defect. Thus, regeneration of the furcation is not contraindicated in these clinical scenarios; however, a partial closure of the furcation—rather than complete—should be expected. It is a necessity to consider the soft tissue component of the furcation-involved molars in the presurgical evaluation. As recently highlighted by Pilloni and Rojas, the soft tissue component is an influential factor in the treatment of furcation defects.

Regenerative therapy is not suggested in a molar with a recession type (RT) 3 gingival recession (GR), where the amount of interproximal attachment loss is greater than the buccal attachment loss. Depending on the depth and width of the recession defects, complete or partial root coverage may be achieved together with periodontal regeneration in FI molars presenting with a GR of RT1 or RT2. Having at least 2 mm of keratinized tissue width (KTW) is considered fundamental for flap advancing and outcomes of root coverage. When KTW is < 1 mm and the vestibule is shallow, performing a free gingival graft 4 months prior to the regeneration is suggested for increasing KTW, soft tissue thickness, and vestibular depth. When KTW is 1 to 2 mm, the regenerative therapy of the furcation defects should be performed together with a connective tissue graft (CTG). It has been shown that a CTG is able to induce keratinization of the underlying epithelial layer and to increase soft tissue thickness. The CTG acts as a biologic filler that facilitates flap repositioning and adaptation to the root surface, resulting in an increased soft tissue thickness as well. In presence of an adequate KTW (≥ 2 mm), soft tissue thickness (if ≤ 1 mm) can also be increased with an acellular dermal matrix (ADM) or a xenogeneic collagen matrix (XCM). When CTG or substitutes are used for increasing KTW or soft tissue thickness, the present authors suggest using bone grafts with biologic agents (enamel matrix derivatives [EMD]), fibroblast growth factors, or platelet-derived growth factors) without a membrane (Figs 3 and 4). The importance of tissue thickness on the regenerative outcomes of FI molars has been demonstrated by Anderegg et al, who after 6 months found a recession depth increase of 2.1 mm when tissue thickness was ≤ 1 mm, compared to a 0.6-mm increase when tissue thickness was > 1 mm. Both ADM and XCM act as scaffolds encouraging the migration and proliferation of adjacent cells; however, they lack cellular components and therefore are most likely only effective in increasing tissue thickness, not augmentation of KTW. In a preclinical study, it was shown that ADM was as effective as a conventional membrane in the regeneration of mandibular Class II furcations but with a superior increase in keratinized tissue thickness. In the presence of tissue thickness > 1 mm, the regenerative approach can be performed using GTR (bone graft + resorbable membrane) and/or biologic agents. In a multicenter randomized clinical trial, Meyle et al showed that EMDs and GTR were equally effective in obtaining clinical improvements in mandibular molars with buccal Class II FI, while less postoperative recession, pain, and swelling were observed in molars treated with EMD. Figure 5 depicts the decision tree for furcation regeneration.
Discussion

This paper aimed to provide clinical recommendations for the management of molars with FI, as the authors are aware that the involvement of the furcation area creates additional difficulties for the predictable treatment of periodontal disease. It is not surprising to find that the lower survival rate in molars with FI is due to the anatomy of the defect and the challenge it creates for optimal plaque control. By considering the extent of the horizontal component of the defect and their related vertical components, Tonetti et al has shown it is possible to achieve long-term success with active periodontal treatment and regular SPT. Using a statistical model, Schwendicke et al showed that retaining molars was more cost-effective than replacing them with dental implants. Therefore, providing a rationale for the treatment of molars with furcation involvement in different scenarios is fundamental. Aichelmann-Reidy et al proposed a decision tree for the treatment of furcation defects based on systemic and local anatomical conditions. Later on, several studies focused on the importance of the vertical aspect of furcation defects and tooth survival. Therefore, the present authors’ decision tree was based on previous literature as well as the clinical experience of the authors. Thus, it is important to note that case selection, patient behavior and compliance, tooth morphology, and the characteristics of hard tissues (bone levels and root morphology) and soft tissues (eg, amount of

Fig 3 A Class B2 furcation defect was treated with a regenerative approach, including bone graft, connective tissue graft (CTG), and fibroblast growth factor (FGF-2). (a) Baseline periapical radiograph. (b) A full-thickness flap was raised and the defect degranulated. (c) Xenogeneic bone graft mixed with FGF-2 was applied in the furcation defect, and CTG harvested from the palate was sutured over it. (d) Clinical and (e) radiograph views 7 months later. Note the increased soft tissue thickness.
keratinized gingiva, tissue phenotype, vestibular depth) are all factors that should be carefully examined before choosing the proper treatment approach.\textsuperscript{5,30} Within the limitations of the present article, it has to be mentioned that the described recommendations for management of furcation defects are based upon the clinical experience of the authors and therefore may need to be confirmed in further clinical studies.

\textbf{Conclusions}

The present article provides clinical guidelines for treating furcation defects based on the literature and the authors’ clinical expertise. In par-
ticular, favorable and unfavorable conditions for periodontal regeneration were discussed, including the importance of patient selection, defect morphology, and the soft tissue component.

Acknowledgments

This paper was partially supported by the University of Michigan Periodontal Graduate Student Research Fund. The authors declare no conflicts of interest.

References


Fig 5 Decision tree for the regeneration of furcation defects. FMPS = full-mouth plaque score; FMBS = full-mouth bleeding score; CEP = cervical enamel projection; RT = recession type; CTG = connective tissue graft; FGG = free gingival graft; GTR = guided tissue regeneration; ADM = acellular dermal matrix; CM = collagen membrane.


