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REVIEW ARTICLE

Hemisection

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ABSTRACT

Resective therapy has been utilized in the treatment of furcation defects for over 100 years. This review article emphasis on the predisposing factors, indications, contraindications, diagnosis and treatment protocol for hemisection of mandibular molars.

Keywords: Distal root, Furcation defects, Hemisection, Mesial root, Mandibular molar, Periodontal disease.

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INTRODUCTION

Furcation is an area of complex anatomic morphology[1] that may be difficult or impossible to debride by routine periodontal instrumentation.[2] The progress of inflammatory periodontal disease, if unabated, ultimately results in attachment loss in this furcation or trifurcation areas of the multirooted teeth.[3] Higher mortality and compromised prognosis for molars with furcal involvement have been reported in several retrospective studies of tooth loss. Additionally, reduced efficacy of periodontal therapy has been consistently found in multirooted teeth with furcal involvement, regardless of treatment modality employed.[4] Reasons for compromised results in furcation areas include the lack of proper access for instrumentation due to furcation anatomy and consequently a persistence of pathogenic microbial flora.[5]

The dental pulp and the periodontium are closely related to and the pathways of communications between these structures often determine the progress of disease in these tissues. Understanding the inter-relationship between endodontic and periodontal disease is crucial for correct diagnosis, prognosis and treatment decision making. The main pathways for communication between the pulp and periodontium are dentinal tubules, lateral and accessory canals and the apical foramen. It follows that once the dental pulp is infected; such endodontic-periodontal communications may result in either destruction of the inter-radicular periodontium or interfere with the healing response of either periodontal or endodontic procedures and may complicate the prognosis.[6]

Resective therapy has been utilized in the treatment of furcation defects for over 100 years. Guided tissue regeneration procedures have been effective in the treatment and long term maintenance of furcation defects.[7] Regenerative procedures are not effective for all furcation defects like mesial and distal class II and III maxillary furcation defects.[8,9] Therefore resective procedures including hemisection remain important procedures in treating these periodontal defects.

Classification of Furcation Involvement

Furcation is defined as the anatomic area of a multirooted tooh where the roots diverge and furcation invasion refers to pathologic resorption of bone within a furcation (American Academy of Periodontology 1992).[10] Several classification of furcation involvement based on degree of horizontal and/or vertical probe penetration have been developed (Table 1). The guidelines for periodontal therapy produced by the American Academy of Periodontology in 1992 list as respective treatment of multirooted teeth only root resection and tooth hemisection. In the current literature there is no uniformity in terms used. Root amputation, root resection root separation and hemisection are frequently used terms. These are generally used as follows:[11]

Hemisection is defined as the removal of half of a tooth performed by sectioning the tooth and removing one root. It is frequently used with reference to lower molar.

Root amputation is characterized as removal of a root without removal of the overhanging portion of the crown.

Root resection generally indicates the removal of a root without any information on the crown of the tooth.

Root separation is indicated as the sectioning of the root complex and the maintenance of all the roots. Carnevale et al more recently[12] have used the term root resection as the sectioning of a mandibular or maxillary molar with the removal of one or two roots regardless of how the crown is treated. Conversely, the term root separation was used to indicate sectioning of a mandibular molar or of the two remaining roots of maxillary molar after one has been removed. The same authors further simplified the terms. Root separation was defined as the sectioning of the root complex and the maintenance of all roots. Root resection, conversely was used to indicate the sectioning and the removal of one or two roots of a multirooted tooth.[13]

Table 1: Classifications of furcation involvement

Glickman (1953)	Grade I: pocket formation into the flute, but intact inter-radicular bone (incipient) Grade II: loss of inter-radicular bone and pocket formation, but not extending through to the opposite side Grade III: through-and-through lesion Grade IV: through-and-through lesion with gingival recession, leading to clearly visible furcation area
Goldman (1958)	Grade I: incipient Grade II: *cul de sac* Grade III: through-and-through
Hamp et al (1975)	Degree I: horizontal loss of periodontal tissue support less than 3 mm Degree II: horizontal loss of support >3 mm, but not encompassing the total width of the furcation Degree III: horizontal through-and-through destruction of the periodontal tissue in the furcation
Ramfjord and Ash (1979)	Class I: beginning involvement. Tissue destruction <2 mm (<1/3 of tooth width) into the furcation Class II: *cul de sac*. >2 mm (>1/3 of tooth width), but not through-and-through. Class III: through-and-through involvement
Tarnow and Fletcher (1984)	Subclassification based on the degree of vertical involvement Subclass A: 0-3 mm Subclass B: 4-6 mm Subclass C: $\geq$7 mm
Eskow and Kapin Fedi (1985)	Same subclasses as Tarnow and Fletcher (1984), but thirds instead of 3 mm units are used Combined the Glickman and hamp classification: same Glickman grades I through IV, but grade II furcations are subdivided into degree I (< 3 mm) or degree II (> 3 mm)
Ricchetti (1982)	Class I: 1 mm of horizontal measurement; the root furrow Class Ia: 1-2 mm of horizontal invasion; earliest damage Class II: 2-4 mm of horizontal invasion Class IIa: 4-6 mm of horizontal invasion Class III: >6 mm of horizontal invasion

Predisposing Factors for Furcation Involvement

Numerous anatomical factors predispose the molar teeth to furcation involvement. Recognizing these factors is crucial for the treatment of the furcation, regardless of the treatment modality. These include (1) accumulation of bacterial plaque as result of difficult access for oral hygiene procedures, (2) aberrant root morphology, (3) enamel projections or pearls, (4) presence of accessory canals, (5) length of the root trunk, (6) location of the root separation relative to the root trunk.[14]

Accumulation of Plaque

Apical extension of attachment loss in the inter-radicular space caused by bacterial plaque pathogens is the common cause of furcation involvement. Any restorative or other iatrogenic factor that enhances plaque accumulation or prevents the performance of optimal oral hygiene procedures results in chronic local inflammation, which in turn is associated with attachment loss and ultimately the degree of invasion of the inter-radicular space.

Aberrant Root Forms

Examining sectioned molar teeth, Bower[15] demonstrated that on mandibular first molar teeth a concavity was found on the furcation aspect in almost all roots. A deeper concavity was present on the mesial root than in the distal root. On maxillary first molars, the furcal aspect of the root was concave in 94% of mesiobuccal roots, 31% of disto-buccal roots, and 17% of palatal roots. In these locations, the deepest concavity was in the furcation aspect of the mesiobuccal root. The complexity in the root anatomy of multirooted teeth implies that, even after root resection, the resected tooth will likely have nonflat, and frequently concave, residual root surface topography.

Enamel Projections

An enamel projection is an extension of the cervical enamel margin either toward or into the root furcation area (Fig. 1). Masters and Hoskins[16] studied the prevalence of cervical enamel projections in extracted molars. Cervical enamel projections were found on 29% of the buccal surfaces of mandibular molars and 17% of maxillary molars. The authors proposed a classification of cervical enamel projection into three grades according to the extension of the projections, with a grade III cervical enamel projection extending directly into the furcation. Although the frequency of enamel projections is very high, enamel projections are often difficult to detect in the nondiseased dentition. Atkinson[17] was the first to suggest a possible correlation between enamel projections and furcation lesions. Hou and Tsai[18] showed a close relationship between the presence of enamel projections and furcation involvement by

Table 2: Anatomical features of maxillary and mandibular 1st molars

	*Maxillary 1st molar**	*Mandibular 1st molar*†
Furcation entrance	M: 3.6 mm B: 4.2 mm D: 4.8 mm	B: 2.4 mm L: 2.5 mm
Root separation	MB: 5.0 mm DB: 5.5 mm	B: 3.0 mm L: 4.0 mm
Furcation roof	4.6 mm	4.6 mm
Root depression	M: 0.3 mm (94%) D: 0.1 mm (31%) P: 0.1 mm (17%)	M: 0.7 mm (100%) D: 0.5 mm (99%)
Root surface area (% total RSA)	DB: 91 mm^2 (19%) MB: 118 mm^2 (25%) P: 115 mm^2 (24%) Root trunk: 153 mm^2 (32%)	M: 162 mm^2 (37%) D: 142 mm^2 (32%) Root trunk: 134 mm^2 (31%)

*Bower (1979), Gher & Dunlap (1985); †Bower (1979), Dunlap & Gher (1985)

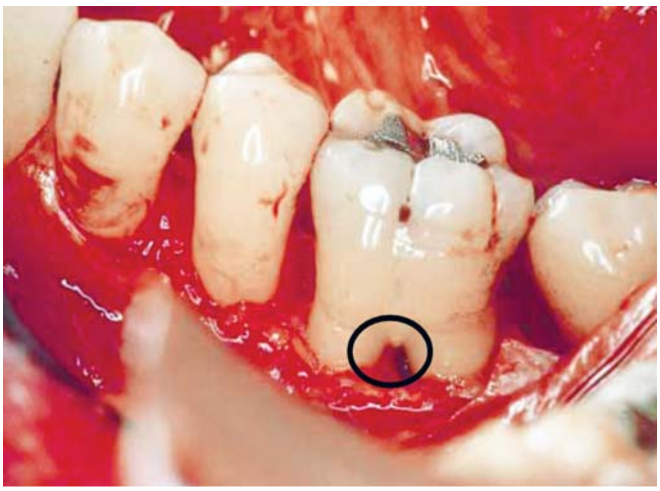

Fig. 1: Class II furcation involvement—an enamel projection is evident

demonstrating that 63% of the 87 furcally involved molars studied had enamel projections or furcation ridges; these were particularly observed in first and second molars. They also found significant differences in the mean pocket depth, clinical attachment loss and plaque index scores between first and second molars with and without enamel projections and furcation ridges. Cervical enamel projections are therefore considered to be a local cofactor in causing furcation lesions.

Accessory Pulp Canals

Histological studies on extracted human molars have demonstrated the presence of accessory canals, especially in the furcation region. Bender and Seltzer[19] found that accessory canals and foramina were in greater numbers in the furcation regions of premolars and molars. Burch and Hulen[20] demonstrated the presence of accessory foramina in 76% of the furcations examined. Vertucci and Williams (1974),[21] reported that 45% of the mandibular first molars in their study had accessory canals extending into the furcation area. Frequently, more than one canal was detected at the trifurcation or bifurcation area. It follows that, once the pulp is infected, such endodontic-periodontal communications may result in either destruction of the inter-radicular periodontium or interfere with the healing response of either periodontal or endodontic procedures. Likewise, chemical root conditioning of the furcation area may induce an alteration in pulpal health.[22]

Size and Location of the Furcation

Larger teeth do not necessarily have large furcation entrance diameters. Bower[1] found that the mesiodistal widths at the cementoenamel junction of both maxillary and mandibular first molars had very low correlation with their furcation entrance diameters (Table 2). Likewise, the buccal furcation entrance diameter of the mandibular first molar was smaller than that of the lingual first molar. He also demonstrated that the buccal furcation entrance diameter of the maxillary first molars is smaller than either the mesiopalatal or disto-palatal. Of clinical relevance is the fact that the average furcation entrance diameter is smaller than the tips of conventional hand instruments. Therefore, successful treatment of molars with furcation involvement depends upon the size and accessibility of the instrumentation that can remove or control local causative factors and possibly alter the morphology of the furcation.

Etiology and Contributing Factors

Newell[23] in 1998 mentioned certain etiologic factors associated with the development of furcation defects apart from the previously mentioned anatomic factors.

Trauma from Occlusion

Glickman et al (1961)[24] reported that furcations are some of the more susceptible areas of the periodontium to excessive occlusal forces, and suggested the periodontal fiber orientation in furcation areas facilitated a more rapid spread of inflammation and accounted for the increased susceptibility to occlusal forces. Wang et al (1994),[25] reported that teeth with mobility and furcation involvement were more likely to lose attachment and to be extracted. Waerhaug (1980),[26] however, has suggested that increased mobility is a late symptom, rather than the cause of furcation defects. Although some controversy still exists, trauma from occlusion is a suspect etiologic/contributing factor in isolated furcation defects. The heavy occlusal load on molar teeth may render them susceptible to increased bone loss in the furcation areas if inflammation is present.

Vertical Root Fractures

Lommel et al (1978),[27] reported that vertical root fractures are associated with rapid, localized alveolar bone loss. Furcation defects can result if the fracture extends into the furcation area. A poor prognosis is often given in these situations.

Iatrogenic Factors

Overhanging restorations present iatrogenic predisposing factors that may lead to furcation involvement. Wang et al (1993),[28] in a study of 134 maintenance patients reported that molars with a crown or a proximal restoration had a significantly higher percentage of furcation involvement than nonrestored teeth. While only 39.1% of molars without restorations had furcation involvement, 52.8% of molars with class II restorations and 63.3% of molars with crowns were found to have furcation involvement.

Diagnosis of Furcation Invasion

Diagnosing furcation invasion is best accomplished using a combination of radiographs, periodontal probing with a curved explorer or Nabers probe and bone sounding (Kalkwarf and Reinhardt 1988).[29]

Indications and Contraindications of Hemisection

When root removal is indicated in a mandibular molar because of a vertical root fracture, therapeutic misadventure, or pathologic resorptive process, hemisection is usually the treatment of choice. Due to the difficulties noted above in attempting to perform a root amputation procedure on mandibular molars, removal of one- half of the tooth is more predictable treatment procedure. The ideal situation for performing a hemisection procedure is when one-half of a mandibular second molar can be retained to occlude with and prevent the supraeruption of a maxillary second molar. The root and crown structure that is retained can be restored as a premolar. This procedure is indicated only if the remaining root has adequate periodontal support, a favorable crown root ratio and the remaining crown can be restored (Tables 3 and 4).[30]

Mesial *vs* Distal Root Amputation

The mesial root usually is slightly wider buccolingually. Near the gingival third the mesial root curves mesially but then slopes distally to its apex. A depression on the distal portion of the mesial root is present and a similar but smaller depression is present on the mesial aspect. This gives the root a figure-eight shape in cross-section. The distal root is less curved than the mesial root but it has a definite distal apical inclination. Because of these depressions and a greater curvature of the mesial root, this root probably has more resistance to stress than does the distal root and thus may be a better choice for retention. However, a key factor in such a decision must be the endodontic manipulation of the root canals because the two canals of the mesial root are much more difficult to prepare and fill than the single canal of the distal root. A variant of the mandibular molar has two distinct distal roots, and such occurrence may be verified by radiographs from the mesial and distal angles. The additional root is lingual to the larger distobuccal root and is often curved. Because of the curvature of the distolingual root when present and the excellent retention that it offers,

Table 3: Indications for root resection and separation treatment
Periodontal indications
• Severe bone loss affecting one or more roots untreatable with regenerative procedures
• Class II or III furcation invasions or involvements
• Severe recession or dehiscence of a root
Endodontic or conservative indications
• Inability to successfully treat and fill a canal
• Root fracture or root perforation
• Severe root resorption
• Root decay
Prosthetic indications
• Severe root proximity inadequate for a proper embrasure space
• Root trunk fracture or decay with invasion of the biological width

Table 4: Contraindications to root resection and separation treatment

General contraindications to periodontal surgery
- Systemic factors
- Poor oral hygiene

Factors associated with local anatomy
- Fused roots
- Unfavorable tissue architecture

Endodontic factors
- Retained root endodontically untreatable
- Excessive endodontic instrumentation of retained roots
- Excessive deepening of pulp chamber floor

Restorative factors
- Internal root decay
- Presence of a cemented post in the remaining root

Strategic considerations
- Consider adjacent teeth available for conventional prosthetic restoration
- Consider removable prosthesis
- Consider implants

it is usually best to amputate the single mesial root and retain the two distal roots to relieve a periodontal condition.

Endodontic Treatment before or after Amputation

It is most desirable to amputate a periodontally involved root after the canals of the roots that are to remain have been sealed. In some cases the periodontal defect is quite severe, and it is not certain that the affected tooth can be retained under any circumstances until the area is surgically exposed. So, its incorrect to put the patient through the treatment time and expense of canal fillings on all roots prior to surgery. Weine[31] has suggested that in such cases pulp in the involved tooth be extripated and the canals measured prior to the surgical appointment. This further verifies that the root to be retained are negotiable and treatable at a later date. It is very undesirable to have a retained root that proves to be untreatable endodontically when amputation procedures on the same tooth have already been performed. Following this initial endodontic treatment the access is sealed temporarily with ZOE or Cavit. Under certain circumstances amputation need is virtually impossible to ascertain prior to surgery. In these instances it is better to perform the amputation immediately with the vital pulp and perform endodontic emergency treatment at the surgical appointment itself. The emergency endodontic treatment will relieve the patient of pain arising due to the exposure of the pulp which may be acutely inflamed or it may prevent a severe exacerbation of a chronically inflamed pulp (due to periodontal disease) due to the trauma caused during amputation. The close relationship between the pulp and the periodontal structures may adversely affect the healing of the periodontal condition due to the inflamed status of the pulp. Also, it might be more difficult to perform the endodontic therapy with a severe contamination of the pulp by the way of the open site due to the amputation.

Clinical Protocol for Hemisection

Treatment planning is critical when evaluating mandibular molars for root amputation. Some outstanding successes, however, are seen involving hemisection and placement of a three-unit fixed partial denture. The most common method of root amputation involving mandibular molar teeth is a hemisection. A terminal second mandibular molar is ideally suited for hemisection, provided there is opposing occlusion and adequate bone support for the remaining root. The remaining root and crown structure is restored as a premolar. The root to be retained undergoes endodontic therapy. A post is placed in the retained root, if indicated, or a coronal–radicular core is placed. Following set of the core material, a sharp cowhorn explorer is used to identify the location of the buccal and lingual furcations. Depending on the degree of periodontal bone loss and the thickness of the trunk of the tooth, a mucoperiosteal flap may or may not need to be raised. The coronal sectioning should be done with a fissure bur or a small tapered diamond stone in a high-speed handpiece under rubber dam isolation. This prevents debris from accumulating in the mucobuccal fold and possibly getting under the soft tissue flap once its reflected or into the open extraction socket. A surgical operating microscope will be advantageous in this surgical procedure as it enhances view of the surgical treatment field, reduces need for multiple radiographs and facilitates documentation of treatment. The cut should then be initiated on the buccal surface and should section the tooth at the expense of the portion of the crown that is scheduled to be removed. Sufficient proximal furcal floor should be left on the portion of the tooth to be retained to establish a restorative finish line as well as sufficient crown for retention. Once the resection has reached the furcation area, the rubber dam is removed and the final separation of the roots is completed with a fissure or tapered diamond bur. An elevator should then be placed between the two halves of the crown and gently rotated to determine if the separation is complete. Once this has been verified, the pathologic root is gently removed with forceps or eased out with an elevator. Sterile gauze should be packed into the socket while the final contouring of the remaining coronal tooth structure is completed. This will prevent particles of tooth and restorative material from gaining entrance into the open socket. After all coronal contouring is completed, the gauze packing should be removed and, if a flap was elevated, it should be repositioned and stabilized with sutures.

Restorative Phase

Once the healing of the socket has progressed to a point that the coronal portion of the socket is completely covered, restorative procedures can be initiated. However, Marin et al[32] have suggested that the restoration be performed prior to amputation, taking care that the build-up is retentive in each single root. Access cavity and coronal third of the canal is modified by creating lateral slots to obtain undercuts in the apicocoronal or mesiodistal direction. It is generally suggested to accomplish crown build-up with a chemically cured composite, by using dentin adhesive to improve retention of the material. Use of a post will decrease fracture resistance of a tooth and therefore post should be incorporated in the foundation restoration only when adequate retention will not be provided by the residual tooth structures. Whenever, it is deemed necessary to place a post, recent clinical studies[33] indicated that a prefabricated parallel sided was less likely to result in root or restoration fracture compared with a custom fabricated tapered post. In this respect, Torbjorner et al[34] studied 788 parallel (para-post) and tapered posts over a 4- to 5-year observation period. The cumulative failure rate was 8% for the para-post group and 15% for the taper post group. Prosthodontic research has disputed the belief that specific foundation restorations reinforce endodontically treated teeth. Various foundation materials and techniques have been directly tested for retention and resistance to fracture. However, the differences are of limited clinical significance because full-coverage crowns, which have been shown to negate these differences,[35] are usually placed on top of these crown build-ups and therefore afford some protection to these foundations. The marginal area of a complete crown that extends onto the tooth structure apical to the foundation material creates a ferrule effect. This is considered a critical component in the reconstruction of a root-resected tooth and for the prevention of technical complications in particular. It appears from tooth-loading characteristics that, clinically, the buccal and lingual ferrule locations would be most critical for the prevention of fracture. Less than 1.5 mm of this ferrule effect increases the risk of failure.[35] Therefore, the type of core material and whether a post is used may not be as important as the length of the apical extent of the crown preparation.[36] The type of margin of the full coverage restoration is also significant. Given the limited width of the residual roots, tooth structure–saving knife-edge finishing lines are frequently required to avoid excessive removal of residual root structure. This finish line is of particular significance in the cervical extension area whenever, the clinician wishes to obtain a ferrule effect. Such a finish line will require metal margins of the full coverage restoration. In addition to this Newell[23] suggested an occlusal scheme with a narrow occlusal table and reduced cuspal inclines to minimize excessive occlusal loads.

Tooth Contour after Hemisection

The morphology of the portion of the tooth remaining after root separation and resection therapy is of primary importance for the subsequent maintenance of the tooth. Schmitt and Brown[37] suggest that the preparation of the crown must be 'barreled in' to follow the profile of the root complex. This procedure when in presence of root concavities or shallow class II furcations requires that the preparation of the crown follows the root contour by eliminating the furcation roof and thus creating a concave shape of the root trunk and crown. Such a shape may not offer an ideal surface for oral hygiene procedures; patients should therefore pay special attention to these areas. In contrast to this solution, Di Febo et al[38] suggest a 'combined preparation' to modifying the emergence profile. This procedure has the objective of creating convex surfaces that are more conducive to effective oral hygiene procedures. It must be carried out during surgery; in fact, root shape has to be modified at the emergence from bone. The root profile is modified by preparing a chamfer on the convex portion of the root, without touching the concave portions, thereby flattening the tooth's surface. In performing this preparation, the location of the filled root canal and pulp chamber should carefully be taken into account. In fact, when this technique is used it is of paramount importance not to excessively reduce the dentinal wall in order to decrease the risk of root fracture. To this end, great care has also to be taken not to over-instrument the root canal during the endodontic phase. Also, this technique requires the final preparation of the tooth to be a knife-edge preparation. In fact the paucity of the residual root structure will not allow for any other finish line. According to the authors flat surfaces obtained with 'combined preparation' allow for easy plaque control and better maintenance of periodontal health.

CONCLUSION

The results of several studies report a success rates ranging[30] from 62 to 100% with a follow- up periods of 1 to 23 years. The combined data from these studies indicates an overall success rate of approximately 88% can be expected when this procedure is performed. The long-term prognosis for teeth with hemisection will depend upon a number of factors:

1. Quality of root canal therapy in the retained roots or root
2. The contouring and quality of the final restoration
3. The ability to maintain the health of the supporting periodontal soft and hard tissues. Any of the following factors may alter the prognosis of the retained portion of the tooth.

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