Furcation Morphology Relative to Periodontal Treatment

Furcation Root Surface Anatomy

by
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Recent longitudinal studies of teeth with periodontal breakdown involving the furcation present encouraging results for the prognosis of such teeth.[1-6] Both pocket elimination[3, 5, 6] (sometimes necessitating root resection) and soft tissue readaptation[2, 4] appear to offer a better prognosis than was formerly imagined. In either of these approaches to the problem, the anatomy of the furcal aspects of the roots is likely to influence the result.

If soft tissue healing adjacent to the furcation surface is the objective, the surface must be biologically acceptable and root contour may influence calculus removal and root planing procedures. If pocket elimination has exposed the furcation, root contour may influence post-surgical plaque removal by limiting access for plaque control procedures.

The available literature contains few references to the internal morphology of the furcation and none where quantitative assessment is reported. Wheeler[7] and Everett et al.[8] have emphasized concavity of the furcal aspect of the mesial root in the mandibular first molar but do not mention a corresponding concavity in the distal root.

The present study of furcation morphology in maxillary and mandibular first molar teeth was done to investigate which morphologic features might influence plaque control and root preparation in the area. The modifying role of cementum in altering root contour was also studied.

Materials and Methods

Part One

A random sample of first permanent molar teeth comprising 114 maxillary and 103 mandibular teeth was selected from a collection of extracted teeth kept at The University of Michigan School of Dentistry. These teeth are stored in glycerin and isopropyl alcohol (1:1). Identification was based on crown morphology. Teeth having fused roots, evidence of extraction damage near the furcation, or either caries or restorations extending apical to the cementoenamal junction were excluded from the sample.

The sample is the same as was used by the author in a previously reported study[9] and the mesio-distal length and furcation entrance diameter reported there are used for correlation in the present investigation.

All teeth were sectioned at right angles to the long axis at a level 2 mm apical to the most apical root division as illustrated in Figure 1. A fine carborundum disc was used to make the section except in 22 maxillary and 15 mandibular teeth where a coarser wheel was used. The latter teeth were not used in the second part of the study. The level of section was established using the micrometer screw chuck of a specially constructed tooth sectioning lathe.

The cut tooth surfaces were examined using a dissecting microscope† with a 10× eyepiece and 10/100 mm micrometer disc to give a stated magnification of 6.3×. Measurement by the micrometer disc was calibrated using a 1 cm certified plate. One reticle unit was found equal to 1.065 mm.

The dimensions measured are illustrated in Figures 2 and 3, and the technique of measurement in Figures 4 and 5. For the maxillary teeth they were:

a. concavity of the furcal aspect of the mesiobuccal root,
b. concavity of the furcal aspect of the distobuccal root,
c. concavity of the furcal aspect of the palatal root, and
d. the trigonometric tangent of the angle subtended by the cut edges of the furcal aspects of the buccal roots.

For the mandibular teeth the dimensions measured were:

a. concavity of the furcal aspect of the mesial root,
b. concavity of the furcal aspect of the distal root,
c. minimum mesiodistal distance between the furcal aspects of the roots in the buccal half of the furcation,
d. minimum mesiodistal distance between the furcal aspects of the roots in the lingual half of the furcation, and
e. the maximum mesiodistal dimension of the furcation.

The mean of the minimum distances between the furcal aspects of mesial and distal roots in the buccal and lingual halves of the furcation was calculated for each mandibular tooth in the sample, and subtracted from the maximum mesiodistal dimension of the furcation to give an indication of dimensional difference between the internal furcation and access to it for that tooth.

Reproducibility of measurement was tested by seven repeated measurements of ten maxillary and ten mandibular teeth with a period of at least 4 hours between

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† Olympus Model J. M., Olympus Optical Company Ltd., Japan.

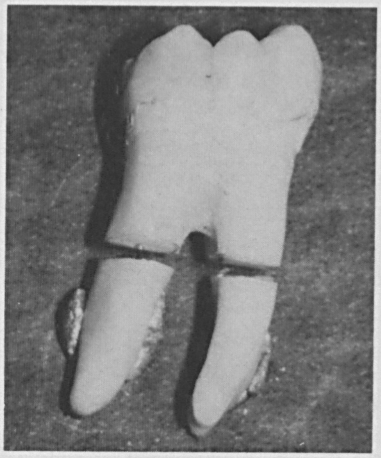

FIGURE 1. *Plane of section of mandibular first molar tooth 2 mm apical to the furcation.*

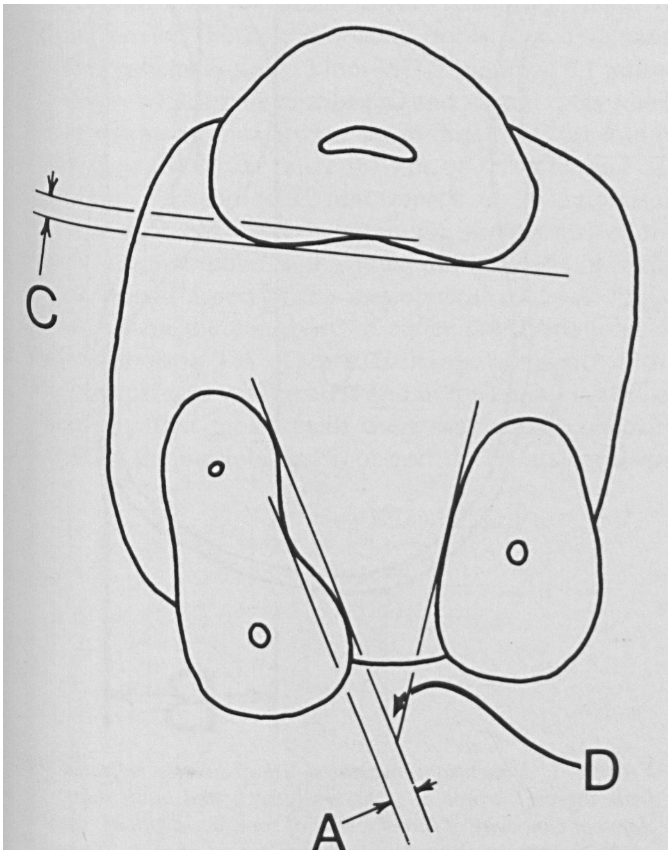

FIGURE 2. *Dimensions measured on transversely sectioned maxillary first molar teeth.* A—*Depth of concavity of mesio-buccal root,* C—*Concavity of palatal root,* D—*angle between furcal aspects of buccal roots (trigonometric tangent measured). The concavity of the distobuccal root was also measured but is not illustrated here.*

successive measurements of the same tooth. A reproducibility of 95% was obtained for measurement of root concavity in maxillary and mandibular teeth, with no difference greater than 0.1 reticle unit. Measurement of the trigonometric tangent of the angle subtended by the furcal aspects of the buccal roots of the maxillary molars was found to be 91% consistent with five differences of 0.1 and one of 0.3. In the mandibular teeth a reproducibility of 87% was obtained for measurement of root separation (both maximal and minimal) with no difference greater than 0.1 reticle unit.

Part Two

In the second part of the study only those teeth sectioned using fine carborundum discs were considered. This left a sample of 92 maxillary and 85 mandibular first molar teeth. The cut surfaces were examined using the same dissecting microscope with the light source now

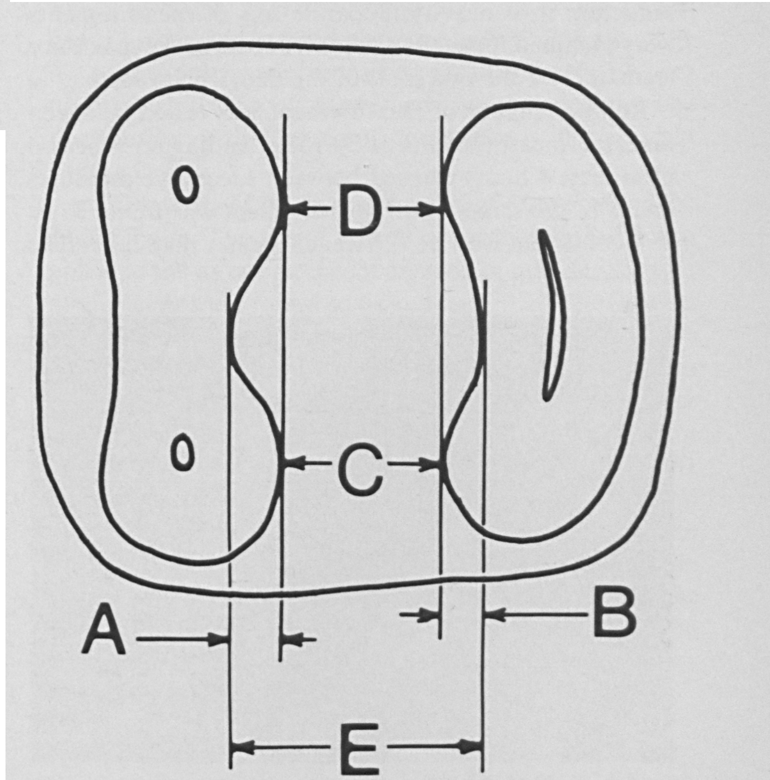

FIGURE 3. *Dimensions measured on transversely sectioned mandibular first molar teeth.* A—*depth of concavity of mesial root,* B—*depth of concavity of distal root,* C—*minimum mesiodistal distance between the roots in the buccal half of the furcation,* D—*minimum mesiodistal distance between the roots in the lingual half of the furcation,* E—*maximum mesiodistal dimension of the furcation.*

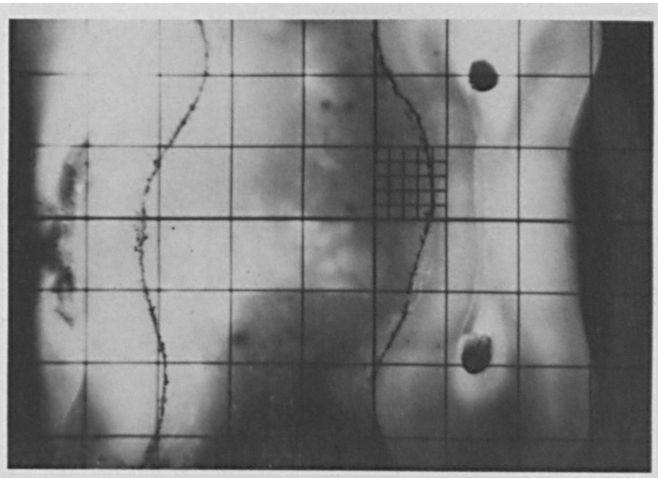

FIGURE 4. *Use of reticle to measure concavity of the furcal aspect of the mesial root of a mandibular first molar tooth.*

directed along the optical axis of the microscope and normal to the cut tooth surface. Differences in the optical properties of cut dentine and cementum allowed identification of the dentinocemental junction (DCJ) (Fig. 6). The concavity of the root surface and of the DCJ together with the thickness of the cementum between them were measured as illustrated in Figure 7.

The net effect of cementum on concavity of the DCJ was calculated by subtraction of the root concavity from the DCJ concavity. A positive result indicates an overall reduction in concavity. Separate sets of measurements were obtained for each of the three roots of the maxillary teeth and for the two roots of the mandibular teeth.

Reproducibility of measurement was tested by seven repeated measurements of 30 roots, and again a period of at least 4 hours elapsed between successive measurements of the same tooth. Measurement was found to be 95% consistent with no difference greater than 0.1 reticle unit.

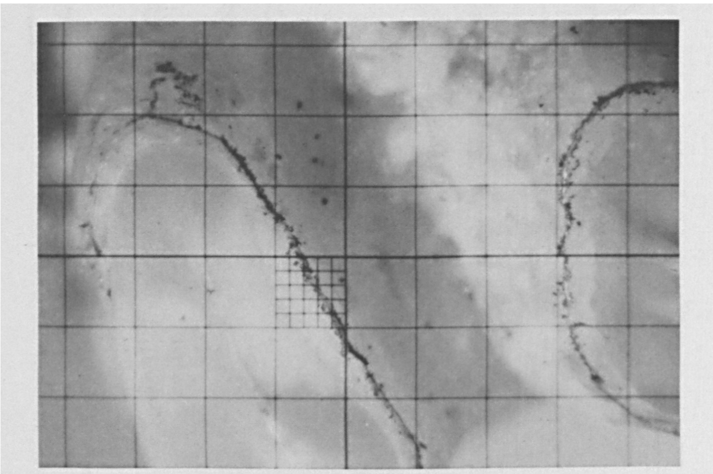

FIGURE 5. *Use of reticle to determine the trigonometric tangent of the angle between the furcal aspects of a maxillary first molar tooth.*

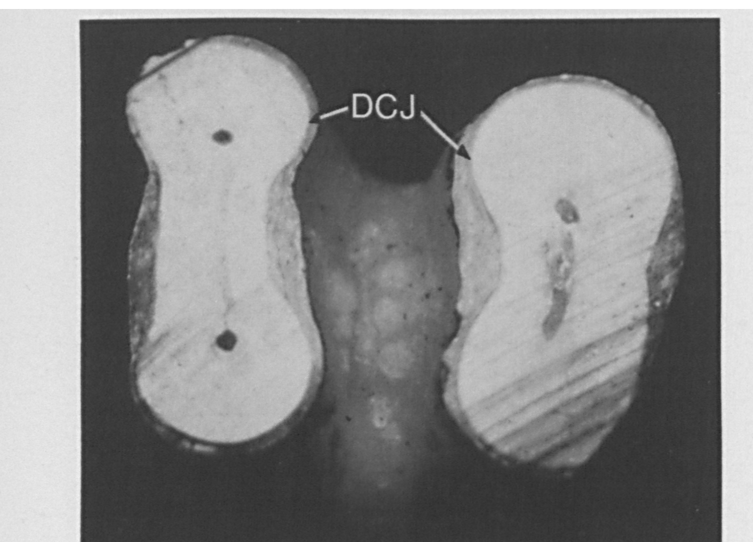

FIGURE 6. *Differences in optical properties of dentine and cementum when viewed with light reflecting directly from the cut surface.* DCJ—*dentinocemental junction.*

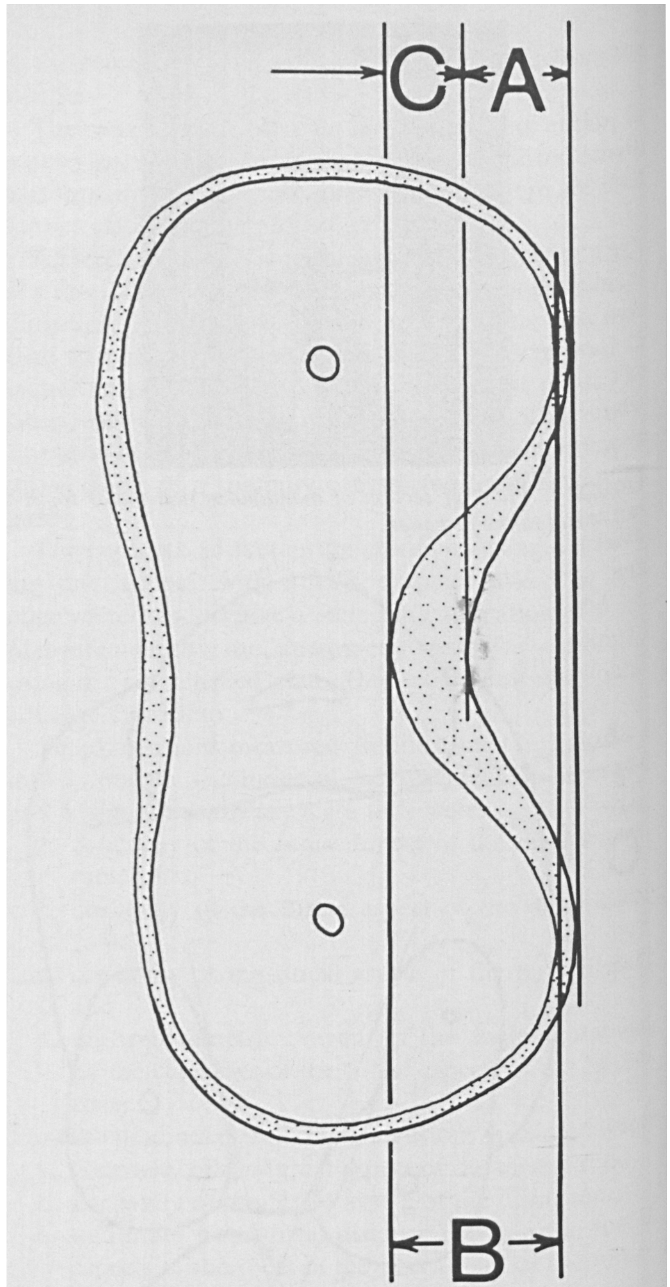

FIGURE 7. *Dimensions measured using directly reflected light from the cut surface of transversely sectioned tooth roots.* A—*depth of concavity of furcal aspect of root,* B—*depth of concavity of dentinocemental junction of furcal aspect of root,* C—*cementum thickness between these two concavities.*

To ensure that the difference in optical properties observed on the root surface was an indication of dentine and cementum surface distribution one tooth was measured using the described technique then decalcified and paraffin embedded. Sections cut in the same plane as the original root section and taken close to the level of the original section were stained, then measured using a normal light microscope and eyepiece reticle. Dimensions were found to be identical using both techniques.

Correlations between each of the dimensions, measured or calculated, were computer calculated and since the sample used in the first part of the study is the same as that used in a previously published study[9] values obtained in the latter study were also correlated. The values included were mesio-distal tooth width and furcation entrance diameter.

The samples in the second part of the study were reduced for both maxillary and mandibular first molar teeth. In order to correlate these samples with those previously reported[9] the same teeth were deleted from the original samples for computing correlations.

Results

Part One

a. *Concavity of the Furcal Aspects of Maxillary First Molar Teeth.* The furcal aspects of roots sectioned 2 mm apical to the most apical root division were found to be concave in 94% of mesiobuccal roots, 31% of distobuccal roots, and 17% of palatal roots. The mean depth of concavity of those mesiobuccal roots which demonstrated concavity was 0.3 mm (SD 0.14, range 0.1 mm to 0.7 mm), while in the distobuccal and palatal roots which demonstrated concavity the mean depth was 0.1 mm in each case (SD 0.28, range 0.1 mm to 0.2 mm; and SD 0.03, range 0.1 mm to 0.2 mm respectively). Comparison of depth of concavity between the three roots of the maxillary first molar is illustrated in Figure 8. Concavity of the furcal aspect of the mesiobuccal root was found greater than the concavity of either the distobuccal or palatal roots in 92% of teeth. In 3% the concavity of the distobuccal root was greatest and in the remaining 5% of maxillary first molar teeth there was equal concavity between the mesiobuccal root and the palatal or distobuccal root. These differences were tested by the Wilcoxon Rank Sum Test and found to be significant beyond the 0.001 level of confidence.

b. *Divergence of the Furcal Aspects of the Buccal Roots of Maxillary First Molar Teeth Towards the Palatal.* The trigonometric tangent of the angle subtended by the furcal aspects of the two buccal roots at the level of section was used to calculate the angle of divergence (or convergence) toward the palate. The result is expressed in degrees. The mean divergence toward the palate was found to be 22° (SD 10.4, range −11° to +50°). Divergence toward the palate was found in 96% of teeth, while 3% of root pairs were considered parallel, and in 1% (one tooth) the buccal roots converged toward the palate. The distribution of the degree of divergence is illustrated in Figure 9.

c. *Concavity of the Furcal Aspects of Mandibular First Molar Teeth.* The furcal aspects of roots sectioned 2 mm apical to the most apical root division of mandibular first molar teeth were found to be concave in 100% of mesial roots and 99% of distal roots. The mean root concavity for mesial roots was 0.7 mm (SD 0.19, range 0.3 mm to 1.3 mm) for distal roots 0.5 mm (SD 0.20, range 0 mm to 1.0 mm). The distribution of depth of concavity for both mesial and distal roots is illustrated in Figure 10. Concavity of the furcal aspect of the mesial root of mandibular first molars was found greater than that of the distal root in 84% of teeth. In 10% the concavity in both roots was equal and in 6% the concavity of the distal root was greater than that of the mesial root. The tendency for the mesial root to have the greater concavity

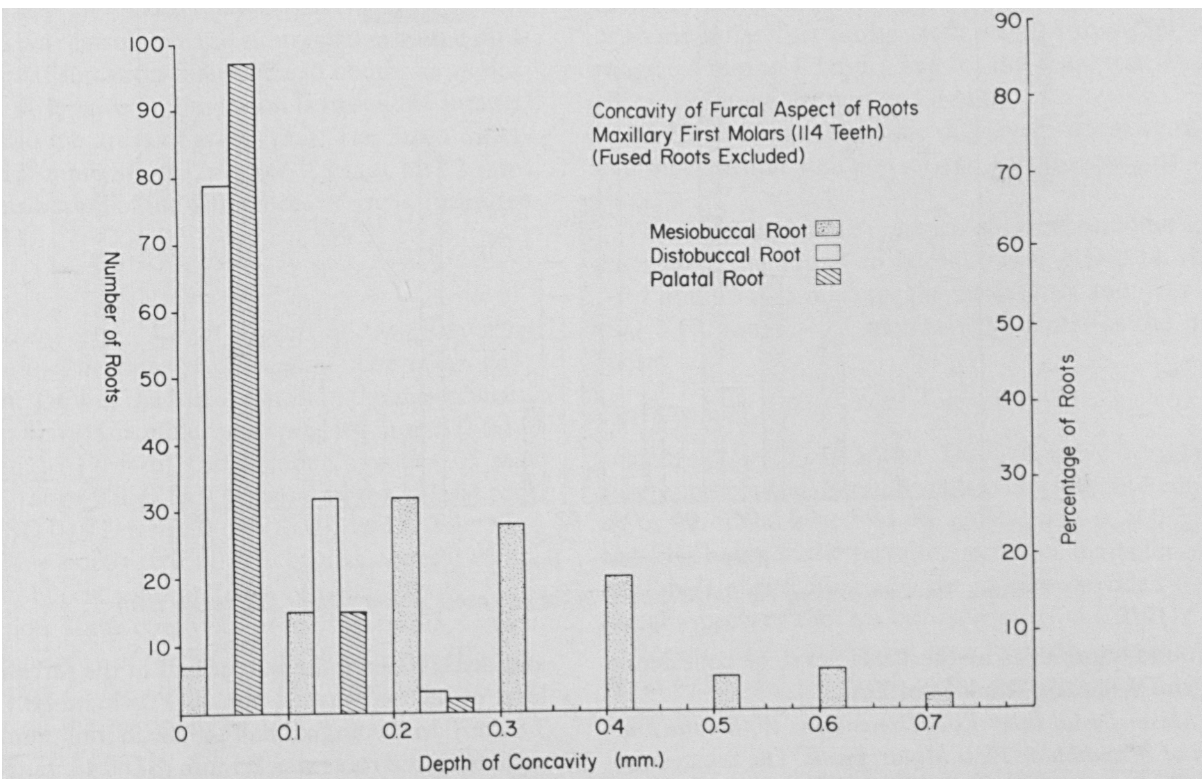

FIGURE 8. *Concavity of the furcal aspects of the three roots of maxillary first molar teeth.*

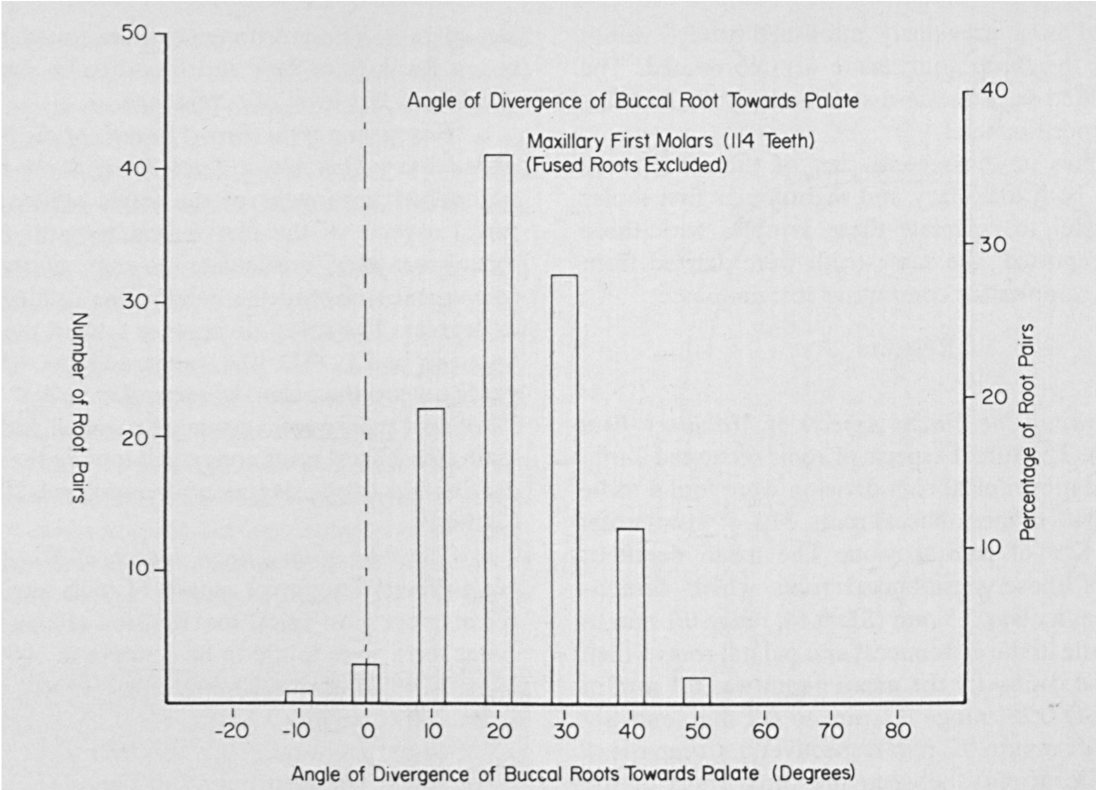

FIGURE 9. *Angle of divergence toward the palate between the furcal aspects of the buccal roots of maxillary first molars. Negative values indicate convergence.*

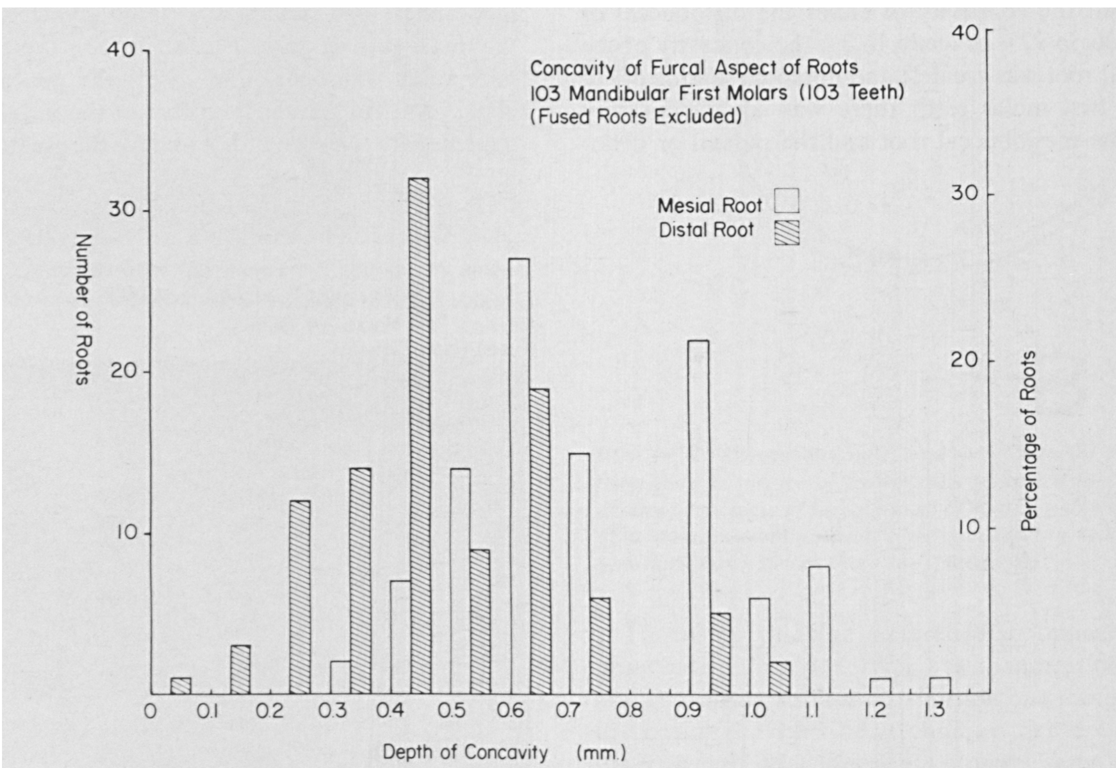

FIGURE 10. *Concavity of the furcal aspects of the two roots of mandibular first molar teeth.*

was found significant at the 0.001 level of confidence using the Wilcoxon Rank Sum Test.

d. *Mesio-Distal Inter-Root Dimensions Within the Furcation of Mandibular First Molar Teeth.* The mean minimum distance between the furcal aspects of the mesial and distal roots in the buccal half of the furcation at the level of section was 2.4 mm (SD 0.49, range 1.2 mm to 3.8 mm). In the lingual half the mean minimum distance separating the roots was 2.5 mm (SD 0.48, range 1.2 mm to 3.8 mm).

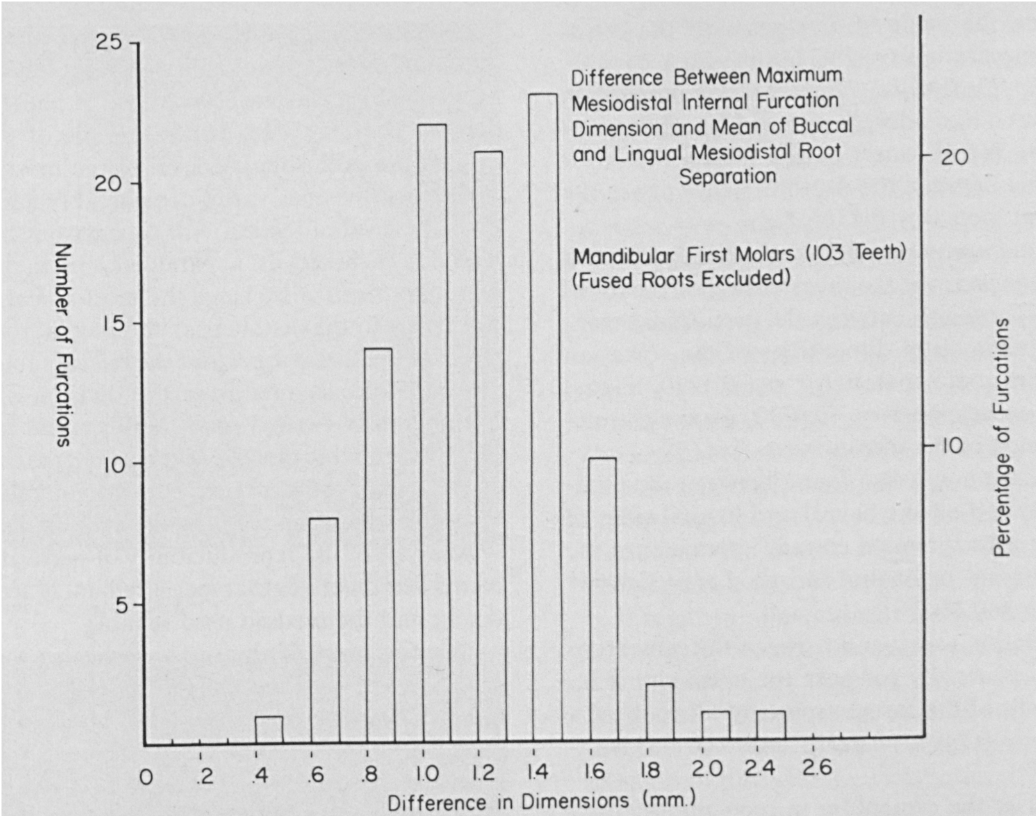

FIGURE 11. *Difference in mesiodistal dimension, between maximum internal furcation dimension and the mean of buccal and lingual root separation for mandibular first molar teeth.*

The mean maximum mesiodistal distance separating the roots in the central region of the furcation at the level of section was 3.6 mm (SD 0.54, range 2.1 mm to 4.9 mm).

The average of buccal and lingual minimum root separations was calculated and subtracted from the maximum internal furcation dimension to obtain an indication of the difference in dimension between the internal furcation and the areas of access to it. The mean difference was 1.2 mm (SD 0.32, range 0.5 mm to 2.2 mm) and the distribution of the differences in size is illustrated in Figure 11.

Part Two

a. *Concavity of the Furcal Aspects of Maxillary First Molar Teeth—The Role of Cementum.* The mean concavity of the DCJ of the furcal aspect of the mesiobuccal root of maxillary first molar teeth was 0.4 mm (SD 0.16, range 0 mm to 1.0 mm), the distobuccal root 0.05 mm (SD 0.091, range 0 mm to 0.4 mm) and the palatal root 0.02 mm (SD 0.071, range 0 mm to 0.4 mm).

The DCJ was concave in 99% of mesiobuccal roots, 34% of distobuccal roots and 10% of palatal roots.

Subtraction of the concavity of the cementum surface from the concavity of the DCJ indicates the net effect of the cementum on the concavity. The mean net effect of cementum on the mesiobuccal root was +0.2 mm (SD 0.14, range −0.1 mm to +0.5 mm), on the distobuccal root + 0.03 mm (SD 0.09, range −0.02 mm to +0.3 mm), and on the palatal root + 0.008 mm (SD 0.07, range −0.1 mm to +0.4 mm).

b. *Concavity of the Furcal Aspect of Mandibular First Molar Teeth—The Role of Cementum.* The mean concavity of the DCJ of the furcal aspect of the mesial root of mandibular first molar teeth was 0.8 mm (SD 0.17, range 0.4 mm to 1.3 mm), and for the distal root 0.6 mm (SD 0.19, range 0.1 mm to 1.3 mm).

All 85 teeth in the sample displayed concavity of the dentinocemental junction of the furcal aspect of both roots.

The net effect of the presence of cementum was again calculated and found to be +0.1 mm (SD 0.14, range −0.1 mm to +0.6 mm) for the mesial root and +0.1 mm (SD 0.17, range −0.3 mm to +0.6 mm) for the distal root.

Correlations

a. *Maxillary First Molar Teeth.* Positive correlation was found between mesiodistal tooth width and concavity of the furcal aspect of the palatal root ($r = 0.2630$)* and also between the furcation entrance diameter of the mesiopalatal furcation and the angle subtended by the furcal aspects of the two buccal roots ($r = 0.2391$).*

Notably low correlation was found between mesiodistal width and the depth of the mesiobuccal concavity

* Significant beyond the 0.01 level of confidence.

($r = 0.1434$) and the angle of divergence of the furcal aspects of the buccal roots ($r = 0.1248$).

b. *Mandibular First Molar Teeth.* Positive correlation was found between mesiodistal tooth width and depth of concavity of the furcal aspect of the mesial root ($r = 0.2902$)* and also between the depth of concavity of the mesial and distal roots ($r = 0.4710$).*

Low correlation was found between mesiodistal tooth width and the concavity of the furcal aspect of the distal root ($r = 0.1917$) and also between the mesiodistal tooth width and the mesiodistal dimensions of the furcation (buccal minimum root separation $r = -0.1290$, lingual minimum root separation $r = -0.0710$, maximum mesiodistal dimension of the furcation $r = 0.0669$).

Positive correlation was also found between the minimum root separation on the buccal and lingual sides of the furcation and the furcation entrance diameter of the corresponding buccal or lingual furcation ($r = 0.4944$* for buccal, and $r = 0.4602$* for lingual).

Positive correlation was found between the cementum thickness in the concavity (or over the convexity if no concavity existed), of the furcal aspects of all roots of a tooth (maxilla $r = 0.7497$,* 0.6735* and 0.6017;* mandible $r = 0.6329$*).

The net effect of the cementum in reducing the concavity at the DCJ is positively correlated to the original depth of the concavity of the dentinocemental junction, (mesiobuccal root $r = 0.4577$,* distobuccal root $r = 0.8308$,* palatal root $r = 0.8870$,* mesial root $r = 0.3762$,* distal root $r = 0.4003$*). The net effect of the cementum is also positively correlated to the thickness of cementum deposited in the concavity of the DCJ (mesiobuccal $r = 0.7822$,* palatal $r = 0.4708$,* and distobuccal $r = 0.2156$,† mesial; $r = 0.8279$,* and distal $r = 0.8422$.*)

Discussion

The importance of adequate root preparation to remove plaque, calculus and cementum contaminated by prolonged exposure to "periodontitis" plaque prior to surgical readaptation of the periodontal soft tissues recently has been reemphasized.[10, 11] *In vitro* evidence also demonstrates that such contaminated root surface is irritant to both epithelial cells[12] and fibroblasts.[13] Thus, if adequate healing is to be expected, all areas of the furcation exposed to periodontal pocketing should be prepared prior to surgical readaptation of the soft tissues. The presented results suggest that the anatomy of the furcation is likely to influence the success of this tooth surface preparation.

Similarly the morphology of the furcation will influence the success of plaque removal procedures if the area is exposed to the oral cavity.

Choice of the level at which to section the roots for this study was influenced by the probable level of loss of periodontal attachment and osseous tissue in clinical situations where periodontal pocketing has involved the furcation to the extent that the furcation is exposed and surgery contemplated. In the sample of maxillary first molars the occlusoapical level of the most apical of the three root divisions varies considerably and so therefore does the level of section. For this reason root separation was not included as a parameter in the study of the maxillary teeth. Also since the most apical root division was between the distobuccal and palatal roots the divergence of the furcal aspects of the buccal roots is measured at a variable distance from the division of these roots. No obviously twisted roots were present in the sample and it is probable that the divergence of the furcal aspects of the buccal roots is consistent throughout the range of levels at which the teeth in the sample were sectioned.

Analysis of the reproducibility of performed measurements demonstrates that measurement is acceptably consistent and the method used reliable.

The first part of this study indicates that the furcal aspect of the mesiobuccal root of maxillary molar teeth has the deepest concavity of the three roots and is the most commonly concave. It also diverges from the furcal aspect of the distobuccal root in most cases making it a difficult area to instrument or clean. In the mandibular first molar tooth the furcal aspects of both roots are concave in virtually all cases with greater concavity present in the mesial root.

These root concavities and root divergences make it unlikely that adequate root preparation by root planing can consistently be achieved using existing techniques. They also must be taken into consideration in plaque removal procedures when the furcation is exposed to the oral environment and mean that straight and rigid cleaning devices (floss and woodpoints) are unlikely to remove all plaque (Figs. 12 and 13). This may explain the reported[3, 4] high incidence of dental caries in exposed furcations.

When root amputation or hemisection is undertaken the established contour of the remaining tooth and restoration should take root concavity into account. The depth of concavity of the furcal aspect is therefore one of the factors to be considered in determining which root should be sacrificed.

Positive correlation between furcation entrance diameter and root separation 2 mm apical to the furcation of the mesial and distal roots of mandibular first molars means that the furcation entrance may be easier to instrument in teeth with widely divergent roots. However, according to previous results[9] it seems doubtful that existing curettes will instrument any but the largest furcation entrances.

No statistically significant correlation exists between mesiodistal tooth width and concavity of the furcal aspect of the mesiobuccal root of the maxillary first molar, or with the concavity of the distal root of the mandibular first molar. No correlation was found between mesio-

* Significant beyond the 0.1 level of confidence.

† Significant beyond the 0.05 level of confidence.

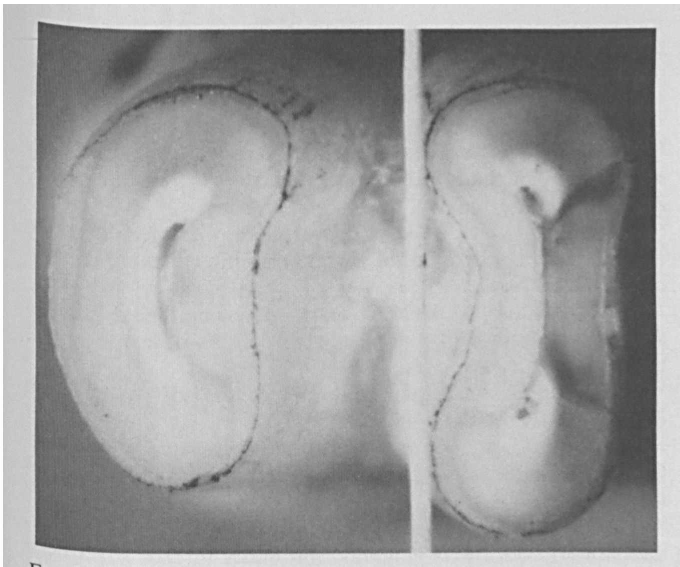

FIGURE 12. *Inability of dental floss to remove plaque from the furcal root aspect due to concavity.*

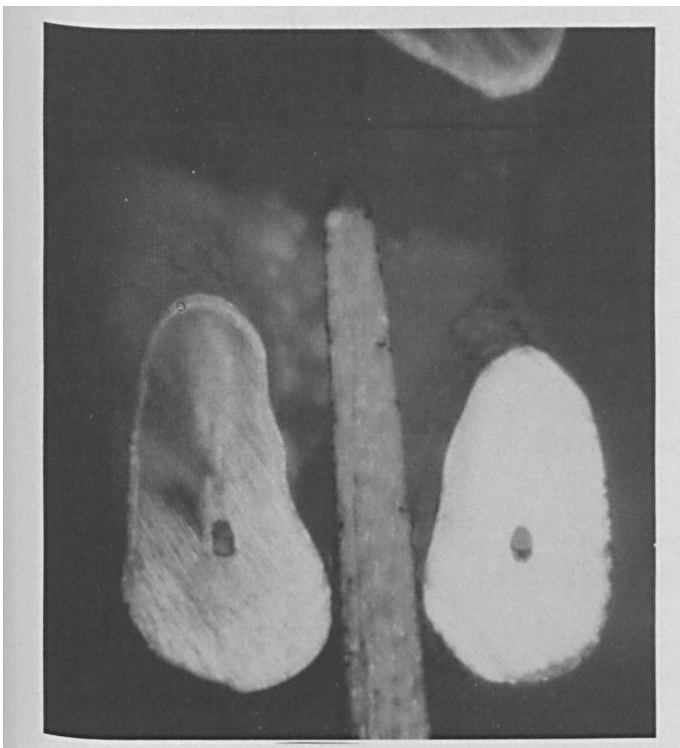

FIGURE 13. *Inability of woodpoints to remove plaque from the furcal root aspect due to root divergence and concavity.*

distal tooth width and divergence of the furcal aspects of the buccal roots of maxillary first molars or with the mesiodistal dimensions of the mandibular molar furcation. Tooth size therefore gives very little indication of furcation morphology.

The second part of this study was concerned with cementum and the influence its thickness has on concavity of the furcal aspects of the teeth. Previous studies[15, 16] have suggested that cementum deposition is continuous and that cementum thickness increases with age. No study examining the presence of cementum in root concavities is known, however several authors have emphasized the large deposits of cementum in the furcation.[8, 17] As the patient's age at the time of extraction of teeth is unknown in this study no conclusions can be reached regarding its importance.

A positive net effect of the cementum in reducing concavity of the DCJ indicates that more cementum is present over concavity of the furcal aspect of the root than over the adjacent convexities. In concavities of the DCJ of both maxillary and mandibular first molar teeth deeper concavity is associated with a greater net reduction in concavity due to the presence of cementum. From the present study, it is not possible to say whether this phenomenon is cause or effect. Deeper concavity may encourage increased deposition of cementum or possibly an increased bulk of ectodermally derived mesenchymal tissue may lead to an indentation of Hertwig's root sheath on the furcal aspect of the root during root development, then subsequently form more cementum.

If removal of all cementum is required to produce a biologically acceptable tooth surface after prolonged contamination by "periodontitis" plaque, as has been suggested,[18] the presence of thick cementum in an area difficult to root plane (concavities) may necessitate changes in root planing techniques.

SUMMARY

Internal furcation root surface morphology was studied in a sample of 114 maxillary and 103 mandibular first molar teeth sectioned transversely at a level 2 mm apical to the most apical root division. The morphology was found to be complex.

The most significant findings were:

1. *Maxillary first molar teeth.*
   a. The furcal aspect of the root was concave in 94% of mesiobuccal roots, 31% of distobuccal roots, and 17% of palatal roots.
   b. The deepest concavity was in the furcal aspect of the mesiobuccal root—mean concavity 0.3 mm.
   c. The furcal aspects of the buccal roots diverge toward the palate in 97% of teeth—mean divergence 22°.
2. *Mandibular first molar teeth.*
   a. Concavity of the furcal aspect was found in 100% of mesial roots and 99% of distal roots.
   b. Deeper concavity was found in the mesial root (mean concavity 0.7 mm) than the distal root (mean concavity 0.5 mm).
   c. The maximum internal mesiodistal dimension of the furcation was larger than the mean mesiodistal root separation at the buccal and lingual (mean difference 1.2 mm).
   d. Wider root separation is associated with larger furcation entrance diameter.

Little indication of internal furcation morphology can be gained from mesiodistal tooth size.

The distribution of cementum over the furcal aspects of the roots was studied in a sample of 92 maxillary and 85 mandibular first molar teeth which are also part of the former sample. The most significant findings were:

1. Cementum distribution was not uniform.
2. Teeth with concavity of the DCJ toward the furcation have more cementum over the concavity than over the adjacent convexities.
3. Greater concavity of the DCJ is associated with increased net reduction of concavity due to the presence of cementum.

The likely significance of such complex morphology on instrumentation and plaque control in the furcation has been discussed.

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Letter to the Editors:

In number 2 of volume 49, pages 77–80, of the Journal of Periodontology an article is published by Voigt, Goran and Fleischer in which they state: "However, no studies have been published which deal with the presence of attached gingiva on the lingual mandibular gingival surfaces". In their list of references they name a publication by Lang and Löe in the same journal (**43:** 623, 1972) in which lingual mandibular measurements of the attached gingiva are described and which my previous work on measurements of the same area were cited (thesis, University of Amsterdam, May 1972).

In number 12 of volume 49, pages 646–648, an article is published by Langer and Calagna in which they discuss the use of free gingival graft to increase the zone of attached gingiva. They state: "However, little mention is given to the lingual gingiva . . . ".

Goldman and Cohen reported in Periodontal therapy 5th ed. pp. 739–741 of a graft on the lingual aspect of the mandible. Schokking reported in the Journal of Clinical Periodontology (1976, **3:** 251–255) two cases of grafts on the lingual aspect of the mandible. It seems that referees are not always very alert.

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