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MORPHOMETRIC ANALYSIS OF FURCATION ANATOMY OF MAXILLARY AND MANDIBULAR FIRST MOLARS IN SOUTH INDIAN POPULATION

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ABSTRACT

This study has been sketched and formatted to measure and analyze the furcation anatomy of maxillary and mandibular first molars in a South Indian population, so as to assess if specific changes in the furcal anatomy, could predispose these teeth for morbidity associated with periodontal disease.   The experimental sample consisted of 90 (maxillary and mandibular molars) that were extracted due to periodontal disease. The root surfaces were viewed through a 2.5X surgical loupe. The buccal, mesial, distal and lingual surfaces of each tooth was evaluated using a Labomed CZM4 4:1 Stereozoom Microscope. Degree of separation at the point of furcation was calculated using a Image – Pro Plus Software version 6. Mean± standard deviation of different root surface measurements for root trunk length were recorded form axillary and mandibular first molars. Similarly, mean± standard deviation of distance of the fluted area from the CEJ (Cemento-enamel Junction), degree of separation at the point of furcation were also recorded. Statistically significant differences were found between all measured parameters for buccal, mesial and distal surfaces ($p < 0.0001$, paired t test) in maxillary first molars and buccal & lingual surfaces ($p < 0.0001$ and < 0.002, paired t test) in mandibular first molars. Correlation of the study results with other studies, revealed significant differences in the furcal anatomy in this study population, on comparison with other published studies. The study also discusses its clinical significance.

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INTRODUCTION

Furcation areas present some of the greatest challenges to the success of periodontal therapy. Higher tooth mortality and compromised prognosis for molars with furcal involvement have been reported in several retrospective studies of tooth loss.[1] Additionally, reduced efficacy of periodontal therapy has been consistently found in multirooted teeth with furcal involvement, regardless of the treatment modality employed. The glossary of periodontal terms given by the AAP[2] in 1992 defines furcation as "the anatomic area of a multirooted tooth where the roots diverge" and furcation invasion refers to the "pathologic resorption of bone within a furcation". Effective instrumentation of furcation defects have always been a challenge for dentists[3,4] due to the limited accessibility through the furcation entrances as well as the complex anatomy and morphology of molar teeth.[5,6] In addition, the morphology of the furcation region provides an environment favorable for bacterial plaque retention, which hampers professional and personal dental plaque control, thereby negatively affecting the prognosis of the diseased tooth.[2,7] The various factors at the region of the furcation that compromise the prognosis of a tooth are the root trunk length, the degree of root separation, the location of the furcal entrance with relation to the cemento-enamel junction (CEJ), the presence of cervical enamel projection and enamel pearls, the presence of radicular concavities and furcation ridges. All these anatomical features can favour plaque and calculus accumulation and hamper their removal thereby compromising their response to periodontal treatment. Therefore the aim of the present study is assess if specific changes in the furcal anatomy, could predispose these teeth for morbidity associated with periodontal disease.

MATERIALS AND METHODS

The purpose of this study is to analyze the furcation anatomy of maxillary and mandibular first molars in a South Indian population. The study was approved by the institutional ethical committee and clearance was obtained from Institutional Review Board, SRM Dental College, Ramapuram (IRB No: SRMU/M&HS/SRMDC/2011-2012/M.D.S-PG Student/501)

Number of Samples
The experimental sample consisted of 90 extracted permanent human first molars (45 maxillary and 45 mandibular molars) affected by periodontal disease. The samples were collected from the Department of Oral and Maxillofacial Surgery, SRM Dental College and Hospital, Ramapuram and also from Tamilnadu Government Dental College, Chennai.

Selection Criteria
First maxillary and mandibular molars that were extracted due to periodontal disease with visible CEJ and intact root structure were considered for the study. Teeth with dental caries, restorations, cervical abrasion, attrition, teeth with fractured crown or root, concrescence, dilaceration, fusion, root perforation and endodontically treated teeth were excluded for the study.

Study Variables
Furcation anatomy elicited were the distance of point of root separation from CEJ, distance of the fluted area from CEJ, radicular concavities, furcal grooves at fornix, cervical enamel projection, enamel pearl, degree of separation at the point of furcation.

Sample Preparation
Forty-five maxillary and forty -five mandibular first molars affected by periodontal disease and indicated for extraction were collected. Selected teeth were washed in tap water and remnants of blood and soft tissue were removed. Calculus attached to the teeth were carefully removed with EMS(Electro medical systems) MiniPiezon ultrasonic scaler with extreme care to avoid removal of tooth structure. After calculus removal, all the teeth were once again examined, so that it satisfies all the selection criteria. Maxillary first molar were segregated from mandibular first molars. All the teeth were stored in 250ml labeled clear plastic jar with screw lid. The selected teeth were decontaminated and bleached with 6% hydrogen peroxide solution for a week. It was then finally washed in tap water and dried using a hand towel. Each maxillary molar was allotted a numerical number starting from 1 to 45.Similarly, mandibular molars were also numbered. The numbers were written boldly on the occlusal surface of each tooth using a fine point permanent marker. The purpose of numbering the each tooth was to avoid repetition of the tooth and their measurements. Both maxillary and mandibular molars were sectioned horizontally 2mm from the point of root separation. The exact sectioning site on the root surface was marked by drawing a horizontal guideline using 0.5mm microtip graphite lead pencil. The guideline was to aid in the precise sectioning of the tooth. Sectioning was done using a double sided diamond disc, fitted to the M3 micromotor with straight handpiece. During sectioning, to avoid injury or trauma to the operator, the tooth was held using a straight mosquito artery forceps. The artery forceps provided a firm grip which prevents the probability of tooth slipping from the operator hand and also increased the working efficiency.[5]

Morphometric Analysis of Furcation Anatomy
All root surfaces after the initial preparation were illuminated with a 55 W Halogen light source. The roots were viewed through a 2.5 X surgical loupe.

Distance of Point of Root Separation from Cemento-enamel Junction
A continuous line was drawn tracing the CEJ present on the buccal, mesial, distal and lingual surface of each tooth with a 0.5mm microtip graphite lead pencil. Reference point were marked at the point of root separation on the buccal, mesial and distal surfaces of each tooth. The distance between the line tracing the CEJ and the reference point at the point of root separation gives the distance of point of root separation from CEJ. This distance was measured using an UNC 15 probe. The same procedure was followed for maxillary and mandibular molars.

Distance of the fluted area from cemento-enamel junction

The distance between the line tracing the CEJ and the starting point of the fluted area gives the distance of fluted area from CEJ. This distance was measured using an UNC 15 probe. The same procedure was followed for maxillary and mandibular molars.

Radicular concavities

Radicular concavities (RC) was assessed on the mesial and distal aspect of the mesio-buccal root, mesial and distal aspect of the disto-buccal root, buccal and palatal aspect of the palatal root of maxillary teeth and the mesial and distal aspect of the mesial root and the distal root of mandibular teeth. Most of the RCs can be seen through the naked eye. But in case of doubt, an UNC 15 probe is placed parallel, touching the mesial or distal aspect of the root. If there is a concavity or gap exist between the instrument and the surface of the root, it was taken to indicate the presence of RC. The presence or absence of RCs was indicated accordingly.

Furcal grooves at fornix

Furcal grooves at fornix were assessed between the mesio-buccal and disto-buccal root, mesio-buccal and palatal root and disto-buccal and palatal root of maxillary teeth and between mesial and distal roots of mandibular teeth.

Cervical enamel projection (CEP)

If the CEJ takes a dip or projects towards the apex of the tooth it indicates the presence of CEP. Masters and Hoskins [8] introduced a grading system in 1964.

Enamel pearl (EP)

The illuminated fornix and the inner surfaces of the root, extending to 2mm from the FE were examined with a dental loupe 2.5 X for the presence of EPs. The identification of the EPs was aided by the running of a sharp explorer over the root surface. When EPs were identified their location was marked.

Degree of separation at the point of furcation

The buccal, mesial, distal and lingual surface of each tooth was evaluated using a Labomed CZM4 4:1 stereozoom microscope. The magnified object (tooth) was photographed using a Sony DSC – S930 digital camera. DS at the point of furcation was assessed on the buccal, mesial, distal and lingual surface of each tooth. DS at the point of furcation was calculated using a Image – Pro Plus Software version 6.

STATISTICAL ANALYSIS

The statistical software SPSS was used for the analysis of the data and Microsoft word and excel have been used to generate graphs and tables. Mean and Standard deviation was estimated from the sample for each study group. Mean values were compared among different study groups by using Paired sample 't' test.In the present study, $p < 0.05$ was considered as the level of statistical significance.

RESULTS

The paired sample t test was used to analyse the distance of point of root separation from CEJ and the distance of the most fluted area from CEJ and the degree of separation at the point of furcation in maxillary and mandibular first molars.

Distance of point of root separation from CEJ in maxillary first molars

On evaluation of the buccal surfaces, for the distance of point of root separation from the CEJ, they had a distribution from 2 – 5mm and the frequency was greatest at the 4mm mark (51.1 %) and least at the 5mm mark (6.7 %). On evaluation of the mesial surfaces, for the distance of point of root separation from the CEJ, they had a distribution from 3 – 6mm and the frequency was greatest at the 4mm mark (46.7%) and least at the 5mm and 6mm marks (13.3%). On evaluation of the distal surfaces, for the distance of point of root separation from the CEJ, they had a distribution from 2 – 6mm and the frequency was greatest at the 4mm mark (40.0%) and least at the 2mm mark (2.2%).(Figure 1)
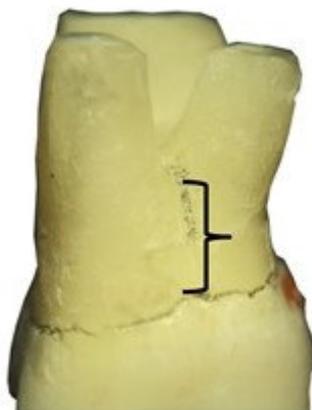
Figure1
Distance of point of root separation from cementoenamel junction

Figure 2
Degree of divergence at the point of furcation.

Table 1
*Paired sample t test for distance of point
of root separation from CEJ*

PAIRS	ROOT SURFACES	MEAN	STANDARD DEVIATION	P VALUE
1	BUCCAL	3.51	± 0.815	< 0.0001
	MESIAL	4.13	± 0.968	
2	BUCCAL	3.51	± 0.815	< 0.0001
	DISTAL	4.16	± 0.928	
3	MESIAL	4.13	± 0.968	< 0.881
	DISTAL	4.16	± 0.928	

The mean values for the distance of point of root separation from the CEJ from buccal, mesial and distal root surfaces when evaluated by paired t test was found to be statistically highly significant between buccal& mesial root surfaces and buccal & distal root surfaces. (Ta ble1)Distance of point of root separation from CEJ in mandibular first molars. On evaluation of the buccal surfaces, for the distance of point of root separation from the CEJ, they had a distribution from 3 – 7mm and the frequency was greatest at the 4mm mark (42.2 %) and least at the 7mm mark (2.2%). Evaluation of the lingual surfaces for the distance of point of root separation from the CEJ, revealed that they had a distribution from 2 – 6mm and the frequency was greatest at the 3mm mark (55.6 %) and least at the 6mm mark (4.4%). The mean values for the distance of point of root separation from the CEJ, on buccal and lingual surfaces when evaluated by the paired t test was found to be statistically highly significant (p value = <0.0001).

Distance of the fluted area from the CEJ in maxillary first molars

On evaluation of the buccal surface for the distance of the fluted area from the CEJ, revealed a distribution from 1-3mm and the frequency was greatest at the 1mm mark (51.1%) and least at the 3mm mark (8.9%). On evaluation of the mesial surface for the distance of the fluted area from the CEJ, a distribution from 1-4mm was noted and the frequency was greatest at the 2mm mark (55.6%) and least at the 3mm mark (6.7%). On evaluation of the distal surface for the distance of the fluted area from the CEJ, a distribution 1–5mm was observed and the frequency was greatest at the 2mm mark (48.9%) and least at the 1mm mark (2.2%). The mean values for the distance of the fluted area from the CEJ for buccal, mesial and distal root surfaces when analyzed by the paired t test was found to be statistically highly significant between buccal& mesial root surfaces (p values = <0.0001) as well as between buccal& distal root surfaces (p values = <0.0001). There was no statistically significant differences between mesial & distal root surfaces (p values = < 0.390). (Table 2).

Table 2
*Paired sample t test for distance of the
fluted area from the CEJ*

PAIRS	ROOT SURFACES	MEAN	STANDARD DEVIATION	P VALUE
1	BUCCAL	1.58	± 0.657	< 0.0001
	MESIAL	2.24	± 0.773	
2	BUCCAL	1.58	± 0.657	< 0.0001
	DISTAL	2.36	± 0.802	
3	MESIAL	2.24	± 0.773	< 0.390
	DISTAL	2.36	± 0.802	

Distance of the fluted area from the CEJ in mandibular first molars

On the buccal surface, the distance of the fluted area from the CEJ, had a distribution from 1–5mm and the frequency was greatest at the 2 mm mark (60.0%) and least at the 5mm mark (2.2%). In the lingual surfaces, the distance of the fluted area from the CEJ, had a distribution from 1–3mm and the frequency was greatest at the 1mm mark (57.8%) and least at the 3mm mark (4.4%). The mean values, for the distance of the fluted area, from the CEJ, on buccal and lingual root surfaces was assessed and was found to be statistically highly significant (p values = < 0.0001).

Radicular concavities

Of the 45 maxillary teeth evaluated 35 presented with RCs on the distal aspect of the mesio-buccal root (77%). However only one root presented with a RC on facial aspect of the palatal root (2%) and there were no RCs on the mesial aspect of the disto-buccal root. Of the forty-five teeth included in the study 40 teeth (89%) presented with RCs on the distal aspect of the mesial root whereas 35 of the 45 teeth evaluated (78%) had RCs on the mesial aspect of the distal roots.

Furcal grooves at fornix

The frequency of the furcal grooves observed at the fornix of the maxillary teeth, was eighteen out of a total of forty-five teeth examined (40%).Of these ten were present between the mesio-buccal and disto-buccal root (22%). Seven of the teeth examined (16%) had furcal groove between the mesio-buccal and palatal root and only 1 tooth (2%) had a furcal groove between the disto-buccal and palatal root. On examining the mandibular teeth, seventeen out a total of forty-five mandibular first molar teeth examined had furcal grooves present (38%).

Cervical enamel projection

The frequency of the CEPs on maxillary and mandibular molar teeth was calculated. Out of the forty-five maxillary molar teeth evaluated thirty-three had CEPs (73%). Among the mandibular molar teeth evaluated an equal 73% (33 teeth) presented with CEP. Among the maxillary first molar teeth evaluated 19 teeth presented with CEP along one surface of the tooth (42%), eleven teeth along two surfaces (24%) and three teeth along three surfaces (7%).Of the CEPs in the evaluated maxillary teeth 47 surfaces had grade I CEPs (94%) whereas only 3 surfaces had grade II CEPs (6%). None of the surfaces presented with grade III CEP. Among mandibular teeth evaluated 18 teeth had one surface with CEPs (40%), whereas 15 of the teeth had CEPs on both the facial and lingual surfaces (33%). Forty-two out of forty-eight CEPs on mandibular teeth were grade I and the rest were grade II CEPs.

Enamel pearl

Out of all the 45 maxillary teeth evaluated for the presence of EPs only 2(4%), had EPs in the furcal region. From among the 45 mandibular teeth assessed only 5 teeth had EPs in the furcal region (11%).

Degree of separation at the point of furcation in maxillary first molars

The mean values for the DS at the point of furcation for buccal, mesial and distal root surfaces was assessed. The buccal root surface had a mean frequency value of 42^0, while the mesial root surface had a mean frequency value of 58^0 and the distal root surface had a mean differences on evaluation frequency value of 65^0. These differences were found to be statistically highly significant between buccal & mesial root surfaces (p value = < 0.0001) and buccal& distal root surfaces (p value = <0.0001). There was statistically insignificant difference between mesial and distal roots surfaces (p value = < 0.026). For the mandibular first molars, the buccal root surface had a mean frequency value of 51^0 and the lingual root surface had a mean frequency value of 58^0. This difference on evaluation by the paired t test was found to be statistically highly significant (p value = < 0.002).(Figure 2)

DISCUSSION

The involvement of furcation areas by periodontal disease, presents one of the greatest challenges to periodontal therapy. Various studies have recognized that Furcation Involvement significantly increases the risk of tooth loss. The reason for the increased risk for periodontal breakdown and tooth morbidity associated with these sites, is primarily the complex radicular anatomy, that makes the furcal region inaccessible for periodontal therapy as well as plaque control. In harmony with these studies are others that have shown a good long term prognosis, for teeth with Class II furcations – that are accessible for periodontal therapy. [9,10,11,12] Since accessibility is a crucial factor, that determines a favorable prognosis, the tooth related factors that govern furcal accessibility, gain immense clinical importance. It is also significant, that tooth dimensions are determined by genetic factors, therefore implying that geographical variation to FA could have a significant bearing to prognosis of the tooth, during long term maintenance care. This study has focused on tooth related factors that can alter the prognosis of a multi-rooted tooth, either due to fact prognosis of a multi-rooted tooth, either due to factors that promote plaque accumulation or by compromising access to the furcal region.This study was undertaken on ninety, maxillary and mandibular first molar teeth that were extracted due to periodontal disease. Factors evaluated were, Root Trunk Length, distance of Furcal Entrance from the CEJ, the presence of Cervical Enamel Projections, the Degree of Root Separation between two roots, the presence of Enamel Pearls, the presence of Bifurcation Ridges and also the presence of Radicular Concavities. All of the above factors are proven risk determinants in the progression of periodontal disease in multi-rooted teeth, and also play a significant role in prognosticating their response to periodontal therapy. The distance of the point of root separation from the CEJ, indicates the amount of attachment loss that is required to occur before a simple pocket turns into a complex pocket. This study reveals that in the maxillary teeth evaluated, the point of root separation was maxillary teeth evaluated, the point of root separation was significantly closer to the CEJ on the buccal root surfaces than the mesial or distal surfaces. The mean value for the buccal surfaces was 3.51mm, while on the mesial surface it was 4.13mm

and 4.16mm on the distal surfaces. On the mandibular teeth evaluated, the buccal surface had a distribution ranging from 3 to 7mm and the highest frequency was at the 4mm mark (42%). The lingual surface had a distribution ranging from 2 to 6mm.However the frequency was the highest at the 3mm mark (56%). There was a significant difference between the mean values for the buccal and lingual surfaces (Buccal - 3.2mm; lingual -4.16mm).This result is significantly different from studies that have been done earlier in maxillary teeth by Bower[4] which found the mesial point of root separation at 5mm and the distal point of root separation at 5.5mm. In mandibular teeth, the studies by Bower[4] as well as by Gher and Dunlap[13], found the buccal point of root separation at 3mm and and 4.0mm at the lingual surface, which correlates with the mean value in this study (3.2mm in the buccal surface and 4.16mm in the lingual surface).

Furcation entrance
The maxillary teeth revealed that on the buccal surface, the mean distance of the FE from the CEJ was at 1.58mm, while on the mesial FE the mean distance from the CEJ was 2.24mm and on the distal FE, the mean distance was 2.36mm. The mandibular teeth examined in this study had FEs at a mean distance from the CEJ, on the buccal surface of 2.27mm. On the lingual surface, they showed a mean distance from the CEJ of 1.47mm. The study by Gher and Dunlap,[13] showed that the mandibular teeth had a mean FE at 2.4mm from the CEJ, which is comparable to the 2.27mm, in this study. However, their study had found a mean distance on the lingual surface of 2.5mm, which is significantly different from the 1.47mm, which was the mean distance of the FE on the lingual surface, which was recorded in this study. The current study, has found that the FE in maxillary teeth to be significantly closer to the CEJ, which implies that these teeth are more at risk to develop Furcation Involvement by periodontal disease, when compared with the Gher and Dunlap[13] study. When comparing mandibular teeth, this study reveals that the lingual FEs are closer to the CEJ, than the earlier quoted studies, making these areas more prone to breakdown by periodontal disease. The current study has also found that the mean distance of the buccal FE on maxillary teeth to be closer to the CEJ, on comparison with the buccal surface of mandibular teeth. This is also different from the earlier quoted studies.

Radicular concavities
This study had a lesser percentage of roots77% of maxillary teeth with RCs, when compared to the earlier studies by Bower[4] and also by Gher and Dunlap.[13] The mandibular teeth examined in this study had 88.8% of the roots presenting with RCs on the distal aspect of the mesial root, which is lesser than the 100% which was reported by Bower.[4]

Furcal grooves
The present study found that 37.7% of teeth had furcal grooves among the mandibular teeth examined. This is a significantly lower percentage than in the earlier studies by Burch[14] et al (76.8%), as well as in the studies by Tamsailom[15] et al (62%). A significant 40% of teeth had furcal grooves in the maxillary teeth investigated. The current study has confirmed that a high percentage of furcal grooves are present on the fornix of the Maxillary molars.

Cervical enamel projections
Seventy three percent of both maxillary and mandibular first molar teeth examined revealed CEPs. This is in variance to the study done by Swan[16] et al which found a 13.6% incidence of CEPs in maxillary first molar teeth but in concordance with the study done by Zee[17] et al (67%). As with all previous studies the highest incidence of CEPs was on the buccal surface. Mandibular teeth evaluated in this study had a higher frequency of CEPs present on the lingual surface (51%).This study correlates with the study done by Leite[18] et al that the buccal and lingual surfaces of maxillary and mandibular teeth respectively, had the highest incidence of CEPs. This study has further found that both in maxillary and mandibular teeth evaluated, Grade I CEPs, were the overwhelmingly predominant type of Cervical Enamel Projection.

Enamel pearls
This study found that Enamel Pearls were found in 4.4% of the maxillary first molar teeth evaluated, in the furcal region. This is in conflict with the study done by Chrcanovic[19] et al which found that 10.72% of the maxillary first molar teeth included in their study had EPs. The current study also found 11.1% of mandibular first molar teeth had EPs in the furcation region, which is variance to the study done by Chrcanovic[19] et al, which found only 1.16% of the roots of mandibular first molars presenting with EPs.

DEGREE OF ROOT SEPARATION
The Degree of Root Separation between two roots indicates the angle at which two roots, diverge from the root trunk. The smaller the angle, the more difficult it is, to instrument the furcal region. Among the maxillary first molar teeth evaluated, the buccal roots had the narrowest DS (41.69%). The disto-palatal furcation had the highest DS between two root cones (64.8%). Among the mandibular teeth evaluated, the highest DS was at the lingual furcation (57.8%). This indicated that among maxillary teeth sampled, the point of root separation was less accessible to manual curettes at the buccal furcal region of maxillary teeth. This study was performed to assess, the differences to the FA that may be present in a sample of teeth, extracted due to periodontal disease and collected from a South Indian population. The study has highlighted several salient aspects that will have a bearing on the progression of periodontal disease. Foremost among them are the following All the FEs and points of Root Separation in maxillary first molars, as well as on the lingual aspect of the lower first molar, are present more cervically in the population evaluated, making them more prone for periodontal breakdown and also potentially refractory to periodontal therapy. periodontal therapy. This study found that a significant 40% of maxillary first molars evaluated had furcal grooves. Grade I CEPs were found at a slightly higher incidence on the buccal aspect of maxillary first molar teeth and the lingual aspect of mandibular first molars.All the abovementioned features of maxillary and mandibular first molar teeth, makes them more prone to

develop periodontal disease. This study has found a significantly lesser percentage of mandibular first molar teeth, presenting with Bifurcation Ridges as well as with Radicular Concavities, when compared with previous studies. A significantly lesser number of the mesial surfaces of the disto-buccal roots of the maxillary first molar teeth had Radicular Concavities, making these root surfaces less difficult to instrument, for periodontal therapy.This study has highlighted that geographical variations could play a major role in the could play a major role in the clinical presentation of periodontal disease because of the presence of various risk determinants on the root surfaces, which could initiate periodontal disease or play a role in disease progression and response to periodontal therapy. The furcal region with its various confounders for periodontal disease progression, is more prone to be affected by such geographical variations. It is therefore pertinent for periodontists to be aware of such confounders and take them into consideration while initiating periodontal therapy.

CONCLUSION

It can be concluded that this study population has a significant percentage (40%) of Furcal Ridges in maxillary first molar teeth. The study also found significantly lesser number of mandibular first molar teeth presenting with Radicular Concavities on comparison with previous published studies.Other differences with previous published studies, were on the incidence of Cervical Enamel Projections and Enamel Pearls. Periodontists need to understand about geographical variation to Furcal Anatomy which could have a significant bearing on the development of periodontal disease, its progression, as well as its response to periodontal therapy.

CONFLICT OF INTEREST

Conflict of interest declared none.

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