Morphometric Analysis of the Furcation Anatomy of Mandibular Molars

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Abstract: The furcation is an area of complex anatomy and its involvement complicates treatment planning and the performance of therapeutic procedures, and directly affects the ability of both the patient and therapist to successfully maintain the dentition after active treatment. A thorough knowledge of the anatomy of the furcation is as essential to successful treatment as a mastery of the various methods of furcation therapy. This study aims to determine the bucco- lingual measurements of the root at the level of cemento-enamel junction and the mesial and distal roots at the level of root separation. One hundred extracted permanent human mandibular molars which consisted of 50 first mandibular molar and 50 second mandibular molar were used in the study. The width of the teeth is recorded at four points, at the center of cemento enamel junction entrance, the width of the furcation roof at the point of separation of the mesial and distal roots and the maximum width of the mesial and distal roots at the level of furcation entrance. The results showed that the width at the entrance of the furcation has a mean of 6.54 ± 0.60mm in first molars and 5.94 ± 0.71 in second molars. The results of this study suggest that 4.45 to 7.90 mm of horizontal attachment loss in the interradicular periodontium may result in communication between the buccal and lingual furcation entrances.

Introduction:

Loss of attachment in the furcation area has long been considered as an adverse event in the prognosis of multi rooted teeth .The decision for a specific treatment mode for a periodontitis-affected furcation certainly depends on several factors, with both a general and local perspective. The furcation is an area of complex anatomy and its involvement complicates treatment planning and the performance of therapeutic procedures, and directly affects the ability of both the patient and therapist to successfully maintain the dentition after active treatment. A through knowledge of the anatomy of the furcation is as essential to successful treatment as a mastery of the various methods of furcation therapy.[1] The presence of furcation involvement is one clinical finding that can lead to a diagnosis of advanced periodontitis and potentially to a less favourable prognosis for the affected tooth or teeth. Furcation involvement therefore presents both diagnostic and therapeutic dilemmas.[2] The degree of success in managing furcation involvement is inversely related to horizontal probing depth[3]. The depth of the horizontal component of attachment loss can vary depending on the external tooth surface reference points used. However, the anatomical factors affecting horizontal component of attachment loss have not been previously assessed. Therefore this study aims to determine the bucco- lingual measurements of the root at the level of cemento-enamel junction and the mesial and distal roots at the level of root separation.

Materials and Methods:

The experimental sample consisted of 100 extracted permanent human mandibular molars which consisted of 50 first mandibular molar and 50 second mandibular molar. They were procured from the department of oral and maxillofacial surgery. Vinayaka Mission Sankarachariyar Dental College. Ariyanoor, Salem, India.

Inclusion Criteria; Mandibular first and second molars with considerably intact crown and fully developed roots were included in the study.

Exclusion criteria:

1. Mandibular first and second molars that had undergone periodontal therapy.
2. Teeth with developmental anamolies.
3. Teeth with fused roots and
4. Teeth that had caries or restorative treatment that extended to the cemento enamel junction or furcation entrance at the measurement sites were excluded.

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Immediately after extraction the teeth were washed in tap water and remanents of blood and soft tissues were removed. Calculus attached to the areas of interest was carefully removed with ultrasonic instruments (NSK-piezoelectric scaler) carefully to avoid removal of tooth structure. The teeth were then decontaminated in a freshly prepared solution of sodium hypochlorite (NaOCl) solution for 24 hours. They were then washed in tap water, air dried, labelled and stored individually. After this process of decontamination they were measured under direct light, at 3x magnification with a bouleys gauge. Measurements were recorded to the nearest 0.10 mm. duplicate measurement were performed for each tooth by a second examiner and subsequently averaged.

Four horizontal bucco lingual distances were evaluated:

1. **CEJ**; The width of the tooth recorded at the center of cemento enamel junction entrance.
2. **Furcation entrance (FE)**: The width of the furcation roof at the point of separation of the mesial and distal roots.
3. **Mesial root width (MRW)** : The width of the mesial root in a point parallel to the FE and DRW, at the maximum convexity of the root at the lingual and buccal surfaces;
4. **Distal root width (DRW)**: The width of the distal root in a point parallel to the FE and MRW, at the maximum convexity of the root at the lingual and buccal surfaces.

Before the teeth were measured, the points of interest were identified on the root and marked with a 0.5 mm graphite pencil.

Results:

Statistical Analysis:

All the results were expressed as the mean ± standard deviation inter measurement differences were analyzed with a paired test. An alpha value of ≤ 0.05 was used to indicate statistically significant difference between measurements. In analyzing the reproducibility of the method, duplicate intra examiner measurements revealed agreement within 0.5 mm 98% of the time for CEJ, 97.9% for FE, 95.7% for MRW and 98.9% for DRW. For the second molar the result was 97.7% for CEJ, 99%for FE, 87.6% for MRW and 99% for DRW. Thus, we consider our overall measurement error to be ≤ 0.5 mm, which represents a 6.8% to 8.2% range over our Highest-to-lowest mean values, respectively.

Table 1: Average score and correlation of two variables of CEJ and their significance

	CEJ					
	FIRST MOLAR			SECOND MOLAR		
	Variable 1	*Variable 2*	Diff	*Variable 1*	*Variable 2*	Diff
Mean	8.660	8.592	0.068	8.188	8.106	0.082
Variance	0.376	0.364		0.307	0.305	
Pearson Correlation	0.981			0.978		
t Stat	3.998			4.945		
P(T<=t)	0.000			0.000		

Table 2: Average Score and correlation Of Two Variables Of FE And their Significance

	FE					
	FIRST MOLAR			SECOND MOLAR		
	Variable 1	*Variable 2*	Diff	*Variable 1*	*Variable 2*	Diff
Mean	6.556	6.524	0.032	5.962	5.916	0.046
Variance	0.356	0.371		0.486	0.518	
Pearson Correlation	0.979			0.991		
t Stat	1.830			3.272		
P(T<=t)	0.073			0.002		

Table 3: Average score and correlation of two variables of MRW and their significance

	MRW					
	FIRST MOLAR			SECOND MOLAR		
	Variable 1	*Variable 2*	Diff	*Variable 1*	*Variable 2*	Diff
Mean	8.640	8.606	0.034	7.932	7.866	0.066
Variance	0.363	0.389		0.622	0.708	
Pearson Correlation	0.958			0.876		
t Stat	1.342			1.140		
P(T<=t)	0.186			0.260		

Table 4: Average score and correlation of two variables of DRW and their significance

	DRW					
	FIRST MOLAR			SECOND MOLAR		
	Variable 1	*Variable 2*	Diff	*Variable 1*	*Variable 2*	Diff
Mean	7.928	7.860	0.068	7.202	7.140	0.062
Variance	0.571	0.570		0.597	0.563	
Pearson Correlation	0.989			0.990		
t Stat	4.245			3.904		
P(T<=t)	0.000			0.000		

Multiple Regression Analysis

Discrepancies between FE measurements and MRW, DRW and CEJ were determined in each tooth by subtracting the FE measurements from, respectively, MRW, DRW and CEJ. Correlations between the measurements were calculated and regression analysis was used to develop prediction E from CEJ, MRW and DRW for both first molars and second molars.

Table 5: Correlation coefficient and its squared value between variables of first and second molars:

Molar	R	R Square	F	P VALUE
First Molar	.731	.535	17.607	.000
Second Molar	.788	.621	25.153	.000

Table 6: Regression coefficient for first molar and second molar

	Molar-1				Molar-2			
	B	Std. Error	t	P VALUE	B	Std. Error	t	P VALUE
(Constant)	-.677	1.054	0..642	.524	-.501	.966	.518	.607
CEJ	.160	.113	1.410	.165	.061	.152	.404	.688
MRW	.425	.110	3.862	.000	.268	.103	2.600	.012
DRW	.276	.091	3.035	.004	.533	.101	5.303	.000

Predictors: (Constant), DRW, MRW, CEJ. Dependent Variable: FE

The multiple regression equation for First Molar and Second Molar is as follows:

First Molar: Furcation entrance =0.677+0.160(CEJ) +0.425(MRW) +0.276(DRW).

Second Molar: Furcation entrance =0.501 +0.061 (CEJ) +0.268(MRW) +0.533(DRW)

Mandibular First Molar:s

Measurements, including mean ± SD, range and 99% confidence interval (CI) are shown in Table 7. Analysis of variance revealed (Table 8) that the FE measurement was significantly ($p<0.0001$) smaller than the CEJ, MRW and DRW measurements.

Table 7: Root widths (mm) of mandibular first and second molars measured bucco-lingually at various horizontal levels

					99% Confidence Interval for Mean		Range	
		N	Mean	Std. Deviation	Lower Bound	Upper Bound	Min.	Max.
First Molar	**FE**	50	6.54	0.60	6.31	6.77	5.05	7.90
	CEJ	50	8.63	0.61	8.40	8.86	7.00	9.75
	MRW	50	8.62	0.61	8.39	8.85	6.75	9.70
	DRW	50	7.89	0.75	7.61	8.18	5.95	9.45
Second Molar	**FE**	50	5.94	0.71	5.65	6.19	4.45	7.40
	CEJ	50	8.15	0.55	7.94	8.36	6.70	9.10
	MRW	50	7.90	0.79	7.58	8.17	5.35	9.80
	DRW	50	7.17	0.76	6.86	7.45	5.55	9.20

Table-8: ANOVA Analysis of variance**.**

		Sum of Squares	df	Mean Square	F	Sig.
MOLAR 1	**Between Groups**	144.89	3	48.30	116.29	0.00
	Within Groups	81.40	196	0.42		
	Total	226.28	199			
MOLAR 2	**Between Groups**	147.23	3	49.08	98.08	0.00
	Within Groups	98.07	196	0.50		
	Total	245.31	199			

The analysis of variance table shows that the F calculated value is 116.29 for first molar and 98.08 for second molar, and P value is 0.00 for both first and second molar. Since the P value is less than 0.05 and 0.01 there is a significant difference in the mean scores of FE, CEJ, MRW and DRW for first and second molar. Since there is highly significant difference between FE, CEJ, MRW and DRW we move on to the post hoc test.

Table 9: Post Hoc Test

Tukey B	N	Subset		
Molar-1				1
FE	50	6.54		
DRW	50		7.89	
MRW	50			8.62
CEJ	50			8.63
Molar-2				
FE	50	5.94		
DRW	50		7.17	
MRW	50			7.90
CEJ	50			8.15

Table 9 shows that the DRW measurement was significantly smaller than the CEJ and MRW measurements (P<0.000). The differences between the MRW and the CEJ measurements, however, were not significantly different.

Table 10: Root widths (mm) of mandibular first and second molars measured bucco lingually at various horizontal levels

Anatomical Component	Mean ± SD	Range	99% CI
Mandibular first Molar (N=50)			
CEJ	8.63 ± 0.61	7.00-9.75	8.40-8.86
FE	6.54 ± 0.60	5.05-7.90	6.31-6.77
MRW	8.62 ± 0.61	6.75-9.70	8.39-8.85
DRW	7.89 ± 0.75	5.95-9.45	7.61-8.18
Mandibular second Molar (N=50)			
CEJ	8.15 ± 0.55	6.70-9.10	7.94-8.36
FE	5.92 ± 0.70	4.45-7.40	5.65-6.19
MRW	7.87 ± 0.78	5.35-9.80	7.58-8.17
DRW	7.16 ± 0.76	5.55-9.20	6.86-7.45

A mean discrepancy of 2.09 ± 0.01mm (range: 1.85 to 1.95; 99% CI: 2.08 to 2.09) between CEJ and FE occurred in the teeth evaluated. The mean difference between MRW and FE measurements was 2.08 ± 0.01mm, (range: 1.70 to 1.80; 99% CI: 2.08 to 2.09). The mean difference between DRW and FE measurements was 1.35 ± 0.15mm, (range: 0.90 to 1.55; 99% CI: 1.30 to 1.41).

Mandibular Second Molars;

Measurements, including mean ± SD, range and 99% confidence interval (CI) are shown in Table 7. The statistical analysis revealed that the FE measurement was significantly ($p<0.0001$) smaller than the CEJ, MRW and DRW measurements. The DRW measurement was significantly smaller than the CEJ and MRW measurements ($P<0.000$). The differences between the MRW and the CEJ measurements, however, were not significantly different. A mean discrepancy of 2.23 ± 0.15 mm (range: 1.70 to 2.25; 99% CI: 2.17 to 2.29) between CEJ and FE occurred in the teeth evaluated. The mean difference between MRW and FE measurements was 1.95 ± 0.07 mm, (range: 0.90 to 2.40; 99% CI: 1.92 to 1.98). The mean difference between DRW and FE measurements was 1.24 ± 0.06 mm, (range: 1.10 to 1.80; 99% CI: 1.21 to 1.26). Correlation between all measurements is shown in Table 11. All measurements were moderate as well as highly correlated ($P< 0.001$).

Table 11: Correlation between measurements on first and second molars

	First molar				Second molar			
	CEJ	**FE**	**MRW**	**DRW**	**CEJ**	**FE**	**MRW**	**DRW**
CEJ	1	.461(**)	.362(**)	.416(**)	1	.511(**)	.584(**)	.504(**)
P Value	.	.001	.010	.003	.	.000	.000	.000
FE	.461(**)	1	.613(**)	.568(**)	.511(**)	1	.589(**)	.734(**)
P Value	.001	.	.000	.000	.000	.	.000	.000
MRW	.362(**)	.613(**)	1	.359(*)	.584(**)	.589(**)	1	.458(**)
P Value	.010	.000	.	.010	.000	.000	.	.001
DRW	.416(**)	.568(**)	.359(*)	1	.504(**)	.734(**)	.458(**)	1
P Value	.003	.000	.010	.	.000	.000	.001	.

Buccolingual measurements of each molars have significant correlation between each other

Table 12: Regression between measurements on first and second molars

	R^2	F	A	b	P Value
First molars	N=50				
CEJ	0.212	12.940	0.456	2.603	0.001
MRW	0.375	28.854	0.605	1.320	0.000
DRW	0.323	22.867	0.452	2.971	0.000
Second molars	N=50				
CEJ	0.261	16.960	0.657	0.589	0.000
MRW	0.347	25.559	0.528	1.769	0.000
DRW	0.539	56.110	0.683	1.038	0.000

Y=b + ax, where y = FE and X = either CEJ or MRW or DRW

Finally, the results of the regression of FE (as the dependent variable) on CEJ, MRW and DRW are shown in Table 12. Thus, if the MRW, DRW OR CEJ dimensions are known, the coefficient and intercept in Table 12 allow for the calculation of FE for a given molar.

Differences between first and second molars:

A comparative analysis of measurements obtained for first and second molars revealed that the first molars exhibited significantly larger dimensions than the second molars for most of the variables tested, including: CEJ (t test, P = 0.000), MRW (t test, P=0.000), DRW (t test, P=0.000).

Table 13: T test for average score

	MOLAR	N	Mean	t	df	P value
FE	1	50	6.5400	4.585	98	.000
	2	50	5.9390			
CEJ	1	50	8.6260	4.142	98	.000
	2	50	8.1470			
MRW	1	50	8.6230	5.143	98	.000
	2	50	7.8990			
DRW	1	50	7.8940	4.780	98	.000
	2	50	7.1710			
CEJ- FE	1	50	2.0860	.967	98	.336
	2	50	2.2080			
DRW-FE	1	50	1.3540	1.030	98	.306
	2	50	1.2320			
MRW-FE	1	50	2.0830	1.007	98	.317
	2	50	1.9600			
MRW-DRW	1	50	.7290	.006	98	.995
	2	50	.7280			

A significant difference is found FE, CEJ, MRW and DRW measurements of first molar and second molar. All the FE, CEJ, MRW and DRW first molar are larger than that of the second molar measurements. First molar FE is 10.1%, CEJ is 5.879%, MRW is 9.165% and DRW is 10.082% larger than the second molar FE, CEJ, MRW and DRW measurements respectively. Interestingly, the dimensions of CEJ-FE (t test, P=0.336), MRW-FE (t test, P=0.317), DRW-FE (t test, P=0.306) and MRW-FE (t test, P = 0.995) were not significantly different between first molars and second molars.

Discussion:

Microbial plaque is the primary etiologic agent of inflammatory periodontal disease. The major purpose of periodontal therapy is the thorough elimination of all bacterial deposits on the tooth surface, the institution of adequate home care and professional recalls to maintain the teeth plaque and inflammation free. Molar with furcation involvement present a unique challenging situation to the therapist. The evaluation of the horizontal component of furcation lesion is an important part of the periodontal therapy. Furcation lesions are the consequence of the destruction of the attachment apparatus in the interradicular area caused by apical and horizontal migration of the bacterial plaque.[4] Traditional methods employed to evaluate furcations include vertical and horizontal probing depths and radiographic evaluations. The extent of tissue destruction in the horizontal direction determines the degree of furcation involvement. However, limited information is available on the horizontal width of the furcation area of human mandibular molars.

Hence the aim of this study was to determine the bucco-lingual measurements of the cemento – enamel junction and the medial and distal roots and at the level of root separation. The results showed that the width at the entrance of the furcation has a mean of 6.54 ± 0.60 mm. Varying from the range of 5.05 – 7.90 mm in first molars and a mean of 5.94 ± 0.71 mm, Varying from the range of 4.45 to 7.40 mm in second molars. The 99%

confidence interval was 6.31 to 677 for first molar and 5.65 – 6.19 for second molar. Therefore, the data suggest that the bucco-lingual width of the furcation roof is rather small.

The result obtained by Santana et al (2004)[3] on examination & bucco – lingual width of 100 mandibular molars, 50 first mandibular molar and 50 second molars. Showed the width at the entrance of the furcation has a mean of 5.53 ± 0.45 mm, varying from 4.40 to 6.60 mm in first molars and a mean of 5.61 ± 0.65 mm, varying from 4.30 to 6.90 mm in second molars. The 99% CI in first and second molars was respectively, from 5.36 to 5.70 mm and 5.27 to 5.96 mm.Though these results are similar to the results obtained in our study, the minimal difference in the mean of the widths of the furcation entrance could be attributed to the racial difference.
The results of this study suggest that 4.45 to 7.90 mm of horizontal attachment loss in the inter radicular periodontium may result in communication between the buccal and lingual furcation entrances. These results are similar to the results obtained by Santana et al (2004)[3] that showed that 4.30 to 6.90 mm of horizontal attachment loss in the inter radicular periodontium may result in communication between the buccal and lingual furcation entrances.

The results of our study also show that the FE width was significantly smaller than the width of CEJ and the widths of both the medial and distal root surfaces. This is in perfect conciliation with the study done by Santana et al.[3]

In this study the FE width was significantly smaller than the width of CEJ and the widths of both the medial and distal root surfaces in all 100 teeth evaluated.
In a report on the adaptation of barrier membranes to the root surface of multi rooted teeth, Lu showed that there was a gap ranging from 0.33 to 2.25 mm between the membrane and the tooth surface of mandibular first molars.[5] This discrepancy between the mesial and distal root convexities and the actual location of the furcation entrance as an important determinant for the occurrence of these gaps is also acknowledged in our study. Treatment options for furcation lesions and response to therapy are both determined by the degree of furcation involvement present. Hence accurate identification of the horizontal width of the furcation roof is an important requisite in accurately determing diagnosis, classification, Prognosis and response to treatment in the interradicular area.

Our results demonstrated that the differences between the MRW and FE, and between the DRW and FE measurements are not the same. The measurement of the discrepancies between the external root surfaces and the FE may be an important addition to future studies related to the diagnosis and treatment of furcation lesions measurements of the CEJ, MRW, and DRW could be used to predict FE. Thus CEJ and DRW + MRW measurements may be useful in determining the actual dimension of the horizontal furcation width, the real degree of interradicular destruction and the real amount of regeneration necessary to "close" the furcation involvement. This procedure will likely allow a more precise characterization of the clinical outcomes of therapy in the inter radicular area. Further studies are needed to determine the appropriate land marks for measurements and specific acceptable treatment outcomes to declare clinical closure of a furcation lesion.

The CEJ may be taken as a reference point to estimate the horizontal measurements of least accessible structures, such as subgingival FE. The CEJ width may be useful to estimate the actual FE width before a surgical intervention. These associations may be helpful for a clinician willing to predict the actual FE width and to identify the possible influences of other anatomical factors in the open and closed measurement readings of horizontal attachment loss, such as the depth of the DRG at the level of the FE, the thickness of the gingiva, and the depth of the vertical pocket depth.

Furcation involvement still remains a difficult clinical problem. Knowledge of the anatomy of the furcation area and the adjacent root surfaces of the individual teeth should be considered in treatment-planning to insure an accurate clinical assessment of the extent of periodontal destruction, and to develop an appropriate treatment and maintenance program for the optimal long-term prognosis of the teeth.[4]

Summary:
Furcation involvement remains a clinical challenge for therapist that is to be solved. Thorough knowledge of the furcal anatomy is a necessity for the clinician to understand the pathology, amount of the loss of attachment apparatus, diagnose, plan the treatment and predict prognosis.

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