Furcation Anatomy Revisited: A Two-dimensional Radiographic Evaluation of Healthy Mandibular Molars
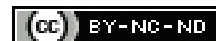
TARONA AZEM SUBBA[1], RAGHAVENDRA VAMSI ANEGUNDI[2], BIJU THOMAS[3],
SUDHIR RAMA VARMA[4], RAHUL BHANDARY[5], AMITHA RAMESH[6]

ABSTRACT

Introduction: Furcation regions present some of the most significant challenges to the successful outcome of periodontal therapy. Due to their anatomical complexities, the areas become inaccessible, and instrumentation is generally tricky and often incomplete. Hence, it is essential to have a thorough knowledge of molar anatomy to assess the case difficulty, appropriate diagnosis, and treatment planning.

Aim: To radiographically evaluate and classify the furcation anatomy of mandibular first and second molars based on root trunk length and root divergence angle.

Materials and Methods: This retrospective observational study was carried out in AB Shetty Memorial Institute of Dental sciences, Mangalore between February and March 2020. Orthopantomograms (OPG) with permanent healthy first (25 right and 25 left) and second mandibular molars (25 right and 25 left) with no alveolar bone loss obtained from systemically healthy individuals were selected for the study. They were screened for root divergence angle and root length to root trunk length ratio. According to the root divergence angle, the total sample was classified as Group I (with angle <30°), Group II (with angle 30° to 60°), Group III (with angle >60°). They were classified into Type A, B, and C based on Hou and Tsai classification. Type A root trunks involving the cervical third or less, Type B involves upto cervical half of the length of the root and Type C involves cervical two-thirds of the root, respectively. The data

were collected and entered in the Microsoft Excel sheet. Mean and standard deviation was calculated for root divergence. Statistical analysis was performed using Statistical Package for Social Sciences (SPSS) version 23.0. Student t-test was used to compare intragroup variations in root divergence in the left and right molars. The p<0.05 was considered to be significant.

Results: Total 100 teeth (50 mandibular first molar (25 left and 25 right) and 50 mandibular second molars (25 left and 25 right)) were included in the study and analysed. In terms of Furcation Angle (FA), mandibular left first molar showed an increased frequency of Group II (48%) and Group III (48%), while mandibular left second molar showed an increased frequency of Group II (68%). Among mandibular right first molar Group III (56%) showed an increased frequency, while Group II (92%) was commonly seen in right second molar. Intergroup comparison revealed a statistically significant difference in divergence between mandibular left first and second molars (36 and 37) p<0.01, mandibular right first and second molars (46 and 47) (p<0.01). Divergence of furcation was more significant in 36 and 46 than 37 and 47, respectively. The current study results showed a higher frequency of Type A in all the four involved teeth, i.e., left first (96%) and second (68%) molars, right first (92%) and second (88%) molars.

Conclusion: The study results showed an increased frequency of Group II FA and Type A root trunks. The divergence of furcation was greater in first molars compared to the second molars.

INTRODUCTION

Periodontal disease is a host-mediated inflammatory condition initiated by dental biofilm. Although biofilm is considered an initiator of the disease, anatomical, genetic, environmental factors have been known to modify the progression of the disease [1,2]. Furcation areas present some of the most significant challenges to the successful outcome of periodontal therapy. A furcation is an anatomical area of a multi-rooted tooth where the roots divide, and furcation involvement refers to the pathological bone resorption within a furcation. Periodontal therapy outcomes are poor in teeth with furcation involvement, regardless of the therapy applied [3]. Compromised results in furcation areas can be attributed to improper instrumentation, which can be attributed to complex furcation anatomy and thereby persistence of aetiologic factors. Developmental anomalies such as cervical enamel projection, bifunctional ridges, enamel pearls, root fusion, and root concavities further complicate the root anatomy and thereby compromising the healing of the involved furcation [4]. Nonetheless, evidence documenting the typical morphology of the furcation is scarce [2,5-7].

The furcation region has three parts: the roof, the region immediately above the root bifurcation, and the region of root separation. The

FA (Furcation Angle) or degree of separation, furcation entrance root trunk, root surface area, and root length are fundamental components of the root, complicating the furcation anatomy [8].

Most popularly employed classification systems are based on soft and hard components, such as Hou GL and Tsai CC, Glickman I et al., Goldman HM, Hamp SE et al., Ramfjord SP and Ash MM, Tarnow D and Fletcher P, Pilloni A and Rojas MA despite the prominent role of the furcation's topographical characteristics in diagnosis and treatment outcomes [5,9-14]. Hou GL and Tsai CC recommended a classification based on the variations in root trunk length and inferred that molar with short root trunks have a higher predisposition to advanced furcation involvement [5].

The existing systems have given the least importance to the tooth's anatomy and were not included in most of the classifications [9-13]. Therefore, thorough knowledge regarding molar root anatomy is vital for treatment planning and execution. The studies that evaluated the furcation anatomy were on extracted teeth or using Computer-Aided-Design and Computer-Aided-Manufacturing (CAD-CAM), which involved teeth lost due to periodontitis or previously accessed teeth for root instrumentation [6,7]. Evidence regarding the anatomy of furcation in healthy teeth is scanty.

Hence, the aim of the current study was to radiologically evaluate the type of the root divergence, ratio of the length of the root trunk to the average length of the root of healthy mandibular first and second molars.

MATERIALS AND METHODS

The present retrospective observational study was conducted on Orthopantomographs (OPGs) radiograph of 100 teeth, 50 mandibular first molar (25 left and 25 right) and 50 mandibular second molars (25 left and 25 right). The study was conducted between February and March 2020. The two-dimensional (2D) radiographs taken from 2017 to 2020 for third molar extraction, orthodontic purposes, Temporomandibular Joint (TMJ) evaluation, etc. were taken from the digital records from 2017-2020.

Inclusion criteria: The OPGs of permanent healthy bilateral first and second molars with no alveolar bone loss from systemically healthy individuals were selected for the study.

Exclusion criteria: Teeth with fused, curved roots, evidence of caries or periodontitis (or furcation involvement), resorption or restorations extending apically to Cementoenamel Junction (CEJ) were excluded from the study.

A single-blinded expert periodontist assessed all the radiologic parameters. The anatomy of furcation is described in [Table/Fig-1].
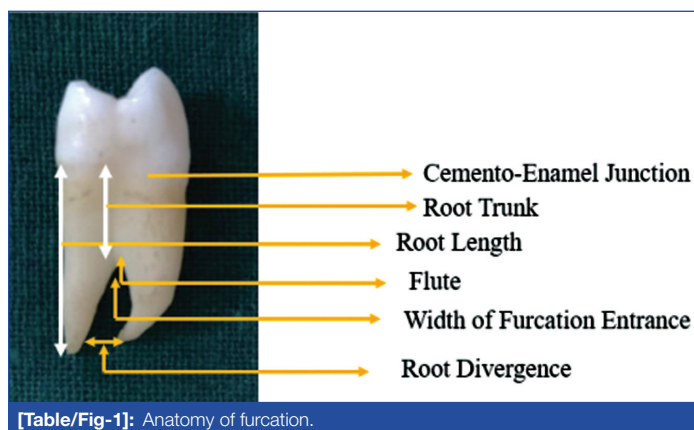
[Table/Fig-1]: Anatomy of furcation.

Radiographic Assessment

The following parameters were analysed radiographically

1. Root divergence

2. Root length: Root trunk length ratio [Table/Fig-1]

Digitalised radiographs were taken, and root divergence was measured using imaging software (Planmeca Romexis®). From a point (pink) made at the fornix, two lines (red) were drawn along each root to the alveolar crest level inside the furcation and the root divergence angle was measured.

The yellow line indicating the CEJ was drawn, and a white line was drawn along the long axis of the tooth from the fornix to CEJ, indicating root trunk length. Root length is measured from the midpoint on the apex of each root to the CEJ along the axis of the tooth (black line), following which root length: root trunk ratio was calculated [7]. The resulting value is grouped into either of the groups, according to Hou GL et al., [15]. Representative images of the OPGs showing measurements taken are given in [Table/Fig-2].

The FA collected from the current study utilising radiographic analysis were grouped into following categories [16]:

Group I: <30°

Group II: 30-60°

Group III: >60°

Based on the ratio of the length of the root trunk to the average length of the root, the teeth could be classified as given in [Table/Fig-3] [15]:

Type A: Root trunks involving cervical one-third of root length
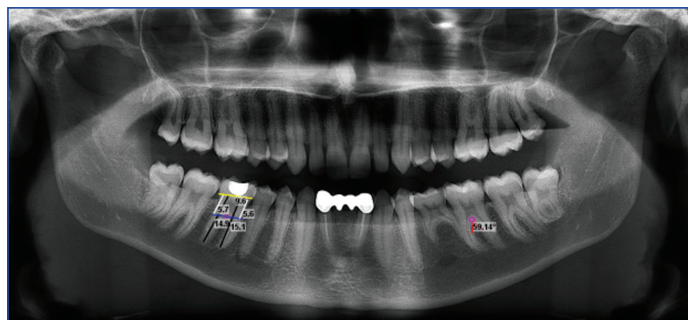
[Table/Fig-2]: Radiographic measurements.
Pink Point- Fornix, Yellow line- CEJ; White Line- CEJ to the Fornix (Root Trunk); Red line- Line of divergence on two roots (to measure angle between them); Black line- CEJ to the apex (Root length); CEJ: Cementoenamel junction
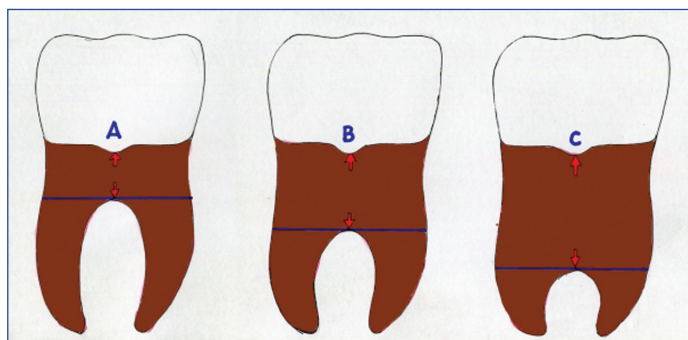
[Table/Fig-3]: Representation of Hou GL et al.,[15] classification, Type A, Type B and Type C. Source: Image hand drawn by authors.

Type B: Root trunks involving cervical half of the root length

Type C: Root trunks involving cervical two-thirds of root length

STATISTICAL ANALYSIS

The data were collected and entered in the Microsoft Excel sheet. The data was analysed for frequency and percentage for both type of FA and root trunk. Mean and standard deviation was calculated for root divergence. Statistical analysis is performed using International Business Management (IBM) SPSS version 23.0. Student t-test was used to compare intragroup variations in root divergence in the left and right molars. The $p < 0.05$ was considered to be significant.

RESULTS

Out of total 100 teeth included and analysed for FA, mandibular left first molars showed an equal distribution of group II and III. Among mandibular left second molars, frequency of distribution was highest for group II, while none of the examined teeth had group III [Table/Fig-4]. Among mandibular right first molars, group III had an increased frequency (56%) followed by group II. No incidence of group I was observed [Table/Fig-4]. Among mandibular right second molars, there was no incidence of group III [Table/Fig-4].

Teeth	Group I		Group II		Group III	
	Frequency (n)	Percentage (%)	Frequency (n)	Percentage (%)	Frequency (n)	Percentage (%)
Mandibular left first molar (n=25)	1	4	12	48	12	48
Mandibular left second molar (n=25)	8	32	17	68	-	-
Mandibular right first molar (n=25)	-	-	11	44	14	56
Mandibular right second molar (n=25)	2	8	23	92	-	-
Cumulative	11	11	63	63	26	26

[Table/Fig-4]: Frequency distribution of different groups among mandibular left and right molars (n=100).

Mandibular First Molars (left and right): Group I: 2% group II: 46% group III: 52%. Mandibular Second Molars (left and right): Group I: 20% group II: 80%. The current study results showed a higher frequency of Type A root trunk in all the four involved teeth, i.e., 36, 37, 46, and 47, with the highest among left mandibular molars [Table/Fig-5].

Teeth	Type A		Type B		Type C	
	Fre-quency	Percent-age (%)	Fre-quency	Percent-age (%)	Fre-quency	Percent-age (%)
Mandibular left first molar (n=25)	24	96	-	-	1	4
Mandibular left second molar (n=25)	17	68	7	28	1	4
Mandibular right first molar (n=25)	23	92	1	4	1	4
Mandibular right second molar (n=25)	22	88	3	12	-	-
Cumulative	86	86	11	11	3	3

[Table/Fig-5]: Frequency of distribution of different types of root trunks among mandibular left and right molars (n=100).

Intergroup comparison revealed a statistically significant difference in the divergence between left mandibular first and second molars (p<0.01) and right mandibular first and second molars (p<0.01). The results showed an increased divergence in mandibular first molars than the second molars [Table/Fig-6].

Analysis of root divergence	Paired differences (In degrees)		Significance
	Mean±SD	Std. Error of mean	
Divergence for left first and second molars (n=50)	22.99±19.04	3.808	<0.01*
Divergence for right first and second molars (n=50)	20.50±12.75	2.55084	<0.01*

[Table/Fig-6]: Comparison of root divergence between left and right first and second mandibular molars.
*Statistically significant; Student t-test

DISCUSSION

The critical step in periodontal regeneration therapy is to modify the periodontitis-affected cemental surface to make it a suitable substrate to support and encourage migration, proliferation, attachment and proper phenotypic expression of undifferentiated mesenchymal stem cells from periodontal ligament [17]. Furcation areas favour plaque accumulation as they are anatomically complex structures inaccessible for instrumentation, thereby contributing to the progression of periodontal disease [18].

The results of the study revealed that the FA in the mandibular first molars (left and right) tend to be in Group III (52%) followed by Group II (46%). This uniform distribution may clinically elucidate itself to a greater ease of root instrumentation as the furcation is wider and hence more accessible [19]. The significance and the challenge involved with mechanical debridement of the furcation area have been equally well documented, and the presence of morphologically complex regions would further complicate the process by making the region inaccessible such as narrow FA. It was also found that mandibular first molars have shown good predictability to both resective and regenerative therapy [20]. The second mandibular molars showed a significantly greater frequency of group II (80 %). Intergroup analysis revealed that divergence in mandibular first molars was significantly more than in second molars.

In a previous study, FA was evaluated on extracted teeth and the FA was evaluated using CAD-CAM. The study results showed an increased incidence of Group II in first molar and Group III in second molar, which is in contrast to the current study [6]. This might be due to lack of standardisation of teeth (periodontitis and healthy) for evaluation in the previous study and radiographic artifacts (distortion or magnification) in the current study.

Generally, the access to instrumentation may be limited when the dimension of the furcation entrance is small or narrow (such as Group I FA) [8,19,21]. The long-term data suggest that the first molar responds better to treatment than the second molar due to the narrow furcation (Group I) angles in second molars [6]. However, in the current study a greater prevalence of Group III and Group II FA (compared to group I) were observed in both the first and second mandibular molars.

As the furcation entrance dimension depends on the FA, Group I would result in a furcation dimension that would be too narrow to permit instruments, thereby influencing surgical periodontal procedures [8]. Extreme root divergence as seen in group III, which would allow adequate access for instrumentation but limit the amount of attachment gain achieved due to significant bone defects [22]. Therefore, Group II can be expected to respond favourably to periodontal therapy compared with the other two groups. Since, group I exhibited the least prevalence (11%), this study strengthens the reason why mandibular molars are favourable to treatment in terms of anatomy, which is in line with regenerative and resective therapies mentioned in the literature.

The maxillary and mandibular molar's average root trunk surface area is around one-third of the complete root surface area. Consequently, horizontal bone loss leading to the involvement of furcation jeopardises the root trunk, destroying 33% of the total periodontal support of the tooth [23]. The importance of the length of the root trunk of a multi-rooted tooth correlates with both treatment complexity and the outcome [24]. The classification used in the study takes account of this anatomical complexity i.e., the length of root trunk. Evidence suggests that teeth with Type C or longer root trunks have poorer prognosis than the teeth with shorter root trunks. Therefore, it is also important for clinicians to have knowledge regarding the type of root trunk before assigning prognosis and consequently treatment planning [25].

Traditionally, clinical assessment and radiographic examination have been the principal diagnostic methods for recognising and identifying furcation involvement in multi-rooted teeth. If radiographs are appropriately taken and processed, they can be used as a priceless adjunct in periodontal disease diagnosis to reveal the morphologic aspects of alveolar bone [26]. Conventional radiography viz., Intra-Oral Periapical (IOPA), bitewing radiographs and OPG, are a 2-Dimensional interpretation of a 3-Dimensional object and is a mainstay in periodontal diagnosis because of its user-friendly image acquisition, cost-effectiveness, and ready accessibility. Since, 3D dimensional imaging cannot be the first radiographic image to be taken, an initial 2D radiograph is necessary in assessing the extent of periodontal destruction. In cases of severe periodontal destruction diagnosed using clinical measurements and 2D radiographs, 3D imaging can be used for pre-operative treatment planning. Furthermore, furcation involvement can be correctly identified with an accuracy of 40.4% with panoramic radiographs, 43.7% in intra-oral dental radiographs, and 54% with clinical probing alone [27]. However, the accuracy of conventional radiographs decreases as the severity of the furcation involvement increases [26]. Besides, the shortcomings in traditional radiographs include an inability to detect initial alveolar bone changes, leading to variability in the perception of furcation involvement, distortions and variability in image quality due to processing errors, and overlapping structures' 2-Dimensional nature, further limiting the reliability in diagnosis [28,29]. Hence, a combination of clinical measurements and radiographs (based on As Low As Reasonably Achievable (ALARA) principle) should be used in establishing diagnosis. [28]. Normal anatomical variations should also be incorporated in classification systems for

furcations to estimate case complexity, which will eventually affect treatment outcomes.

Limitation(s)

In addition to the small sample size, the study only looked at the left and right mandibular molars. The study was confined to mandibular molars since the morphology of maxillary molars is more complex than that of mandibular molars, and OPG does not allow for the comprehensive examination of the maxillary molars (furcation). However, the current study involved only healthy natural teeth hence 2D imaging was deemed sufficient.

CONCLUSION(S)

The results of the study suggest an increased frequency of Group II FA and Type A root trunk. The divergence of right mandibular molar is lesser than left mandibular molars. These factors as discussed before have an impact during root instrumentation. Hence, clinicians must carefully assess the FA and the existence of furcation in relation to the length of the root trunk before root instrumentation. So far, however, no comprehensive classification has been proposed that aids clinicians in accurate presurgical planning, assessing treatment complexity, or predicting outcomes. As a result, prospective classifications should include the anatomy of furcation in addition to current categories that may provide helpful information on treatment complexities, prognosis, and therapeutic outcomes, particularly in teeth with furcation. Future research is recommended to examine the furcation anatomy of all multi-rooted teeth, including maxillary molars and premolars, using 3D imaging to strengthen the current evidence.

REFERENCES

[1] Page RC, Kornman KS. The pathogenesis of human periodontitis: An introduction. Periodontology 2000. 1997;14(1):09-11.
[2] Hou GL, Chen SF, Wu YM, Tsai CC. The topography of the furcation entrance in Chinese molars: Furcation entrance dimensions. Journal of Clinical Periodontology. 1994;21(7):451-56.
[3] Drisko CH. Nonsurgical periodontal therapy. Periodontology 2000. 2001;25:77-88. Doi: 10.1034/j.1600-0757.2001.22250106.x.
[4] Novaes Jr AB, Palioto DB, Andrade PFd, Marchesan JT. Regeneration of class II furcation defects: Determinants of increased success. Brazilian Dental Journal. 2005;16(2):87-97.
[5] Hou GL, Tsai CC. Types and dimensions of root trunk correlating with diagnosis of molar furcation involvements. Journal of Clinical Periodontology. 1997;24(2):129-35.
[6] James JR, Arun K, Talwar A, Kumar T. Mathematical analysis of furcation angle in extracted mandibular molars. Journal of Indian Society of Periodontology. 2013;17(1):68-71.
[7] Hou GL, Hung CC, Tsai CC, Weisgold AS. Topographic study of root trunk type on Chinese molars with Class III furcation involvements: Molar type and furcation site. International Journal of Periodontics & Restorative Dentistry. 2005;25(2):173-79.
[8] Marcaccini AM, Pavanelo Â, Nogueira AVB, Souza JACd, Porciúncula HF, Cirelli JA. Morphometric study of the root anatomy in furcation area of mandibular first molars. Journal of Applied Oral Science. 2012;20(1):76-81.
[9] Glickman I, Carranza FA. Glickman's clinical periodontology: Prevention, diagnosis, and treatment of periodontal disease in the practice of general dentistry: WB Saunders Company; 1979.
[10] Goldman HM. Therapy of the incipient bifurcation involvement. The Journal of Periodontology. 1958;29(2):112-16.
[11] Hamp SE, Nyman S, Lindhe J. Periodontal treatment of multirooted teeth Results after 5 years;1975;2(3):126-35.
[12] Ramfjord SP, Ash MM. Periodontology and periodontics: WB Saunders Company; 1979.
[13] Tarnow D, Fletcher P. Classification of the vertical component of furcation involvement. Journal of Periodontology. 1984;55(5):283-84.
[14] Pilloni A, Rojas MA. Furcation involvement classification: A comprehensive review and a new system proposal. Dentistry Journal. 2018;6(1):34.
[15] Hou GL, Chen YM, Tsai CC, Weisgold AS. A new classification of molar furcation involvement based on the root trunk and horizontal and vertical bone loss. International Journal of Periodontics & Restorative Dentistry. 1998;18(3):257-65.
[16] Hou GL, Hung CC, Tsai CC, Chen PH, Yang YH, Shieh TY. Topographic study of extracted molars with advanced furcation involvement: Furcation entrance dimension and molar type. The Kaohsiung Journal Of Medical Sciences. 2003;19(2):68-73.
[17] Polson AM. Periodontal regeneration: current status and directions: Quintessence Publishing Company; 1994.
[18] Kinane D, editor The role of interdental cleaning in effective plaque control: Need for interdental cleaning in primary and secondary prevention. Proceedings of the European Workshop on mechanical plaque control; 1998: Berlin, Quintessence.
[19] Bower RC. Furcation morphology relative to periodontal treatment: Furcation entrance architecture. Journal of Periodontology. 1979;50(1):23-27.
[20] Sanz M, Giovannoli JL. Focus on furcation defects: Guided tissue regeneration. Periodontology 2000. 2000;22(1):169-89.
[21] Joseph I, Varma B, Bhat KM. Clinical significance of furcation anatomy of the maxillary first premolar: A biometric study on extracted teeth. Journal of Periodontology. 1996;67(4):386-89.
[22] Horwitz J, Machtei EE, Reitmeir P, Holle R, Kim TS, Eickholz P. Radiographic parameters as prognostic indicators for healing of class II furcation defects. Journal of Clinical Periodontology. 2004;31(2):105-11.
[23] Dunlap RM, Gher ME. Root surface measurements of the mandibular first molar. Journal of Periodontology. 1985;56(4):234-38.
[24] Kalkwarf K, Reinhardt R. The furcation problem. Current controversies and future directions. Dental Clinics of North America. 1988;32(2):243-66.
[25] Al-Shammari KF, Kazor CE, Wang HL. Molar root anatomy and management of furcation defects. Journal of Clinical Periodontology. 2001;28(8):730-40.
[26] Gusmão ES, Picarte ACLC, Barbosa MBCB, Rösing CK, Cimoes R. Correlation between clinical and radiographic findings on the occurrence of furcation involvement in patients with periodontitis. Indian Journal of Dental Research. 2014;25(5):572-75.
[27] Topoll H, Lange D. Measurement of sulcus fluid as a diagnostic measure in periodontal diseases.(II). Presence, composition and measurement methods of sulcus fluid. Die Quintessenz. 1980;31(6):99-103.
[28] Jeffcoat MK. Radiographic methods for the detection of progressive alveolar bone loss. Journal of Periodontology. 1992;63:367-72.
[29] Karthikeyan BV, Sujatha V, Prabhuji M. Furcation measurements: Realities and limitations. J Int Acad Periodontol. 2015;17(4):103-15.

PARTICULARS OF CONTRIBUTORS:
1. Postgraduate, Department of Periodontics, AB Shetty Memorial Institute of Dental Sciences, NITTE (Deemed To Be University), Mangalore, Karnataka, India.
2. Postgraduate, Department of Periodontics, AB Shetty Memorial Institute of Dental Sciences, NITTE (Deemed To Be University), Mangalore, Karnataka, India.
3. Professor, Department of Periodontics, AB Shetty Memorial Institute of Dental Sciences, (NITTE Deemed To Be University), Mangalore, Karnataka, India.
4. Clinical Assistant Professor, Department of Clinical Sciences, Ajman University, United Arab Emirates.
5. Professor, Department of Periodontics, AB Shetty Memorial Institute of Dental Sciences, NITTE (Deemed To Be University), Mangalore, Karnataka, India.
6. Professor and Head, Department of Periodontics, AB Shetty Memorial Institute of Dental Sciences, NITTE (Deemed To Be University), Mangalore, Karnataka, India.

NAME, ADDRESS, E-MAIL ID OF THE CORRESPONDING AUTHOR:
Dr. Biju Thomas,
Professor, Department of Periodontics, AB Shetty Memorial Institute of Dental Sciences, NITTE (Deemed To Be University), Derlakatte, Mangaluru-575018, Karnataka, India.
E-mail: bijunicy@yahoo.co.uk

AUTHOR DECLARATION:
• Financial or Other Competing Interests: None
• Was Ethics Committee Approval obtained for this study?   NA
• Was informed consent obtained from the subjects involved in the study?   NA
• For any images presented appropriate consent has been obtained from the subjects.   NA