Root Canal Configurations and Morphological Variations in Maxillary and Mandibular Second Molars in a Pakistani Population

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ABSTRACT

Objective: To determine the dental morphology and root canal anatomy of maxillary and mandibular second molars in Pakistani population living in Hyderabad.

Study Design: Retrospective, cross-sectional study.

Place and Duration of the Study: Department of Operative Dentistry and Endodontics, Liaquat University of Medical and Health Sciences (LUMHS), Jamshoro, from April to May 2023.

Methodology: This study analysed the number of roots, root canal configurations, and frequency of C-shaped root canals and their configuration assessment. The data was obtained from Cone Beam Computerised Tomography (CBCT) records sourced from the Department of Radiology at Advanced Dental Care Centre of LUMHS.

Results: Two-rooted maxillary second molar was present in 10.6% of teeth, while 5.3% were single-rooted. Among mandibular second molars, 6.8% had one root, while 2.3% had three. The maxillary second molar mesiobuccal roots were Type I in 47.7% cases. The maxillary second molars had C1-shaped canals in 3.8% of cases. The study revealed that 10.6% of mandibular second molars had C-shaped canals, 3.0% were C1, 6.8% C3a, and 0.8% C4. A minority of patients had palatal morphology with two roots (MP and DP) and Type 1 canal structure, while a subset had both MP and DP canals.

Conclusion: The prevalence of radix in mandibular second molars was found to be relatively infrequent. The prevalent root canal configurations were Type I in the mesiobuccal and palatal roots and Type IV in the mesial root of mandibular second molars. A noteworthy correlation was detected between the molar type characterised by a single root and the existence of a C-shaped canal in the female population.

Key Words: *CBCT, Dental anatomy, Gender, Root canal, Morphology, Pakistani population*.

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INTRODUCTION

Dental morphology and root canal anatomy play a crucial role in dentistry, supplying valuable insights into the complex and diverse anatomy of teeth. Understanding the intricacies of dental morphology is essential for developing effective treatment plans and improving patient outcomes, particularly with challenging teeth such as maxillary and mandibular second molars. These teeth have unique anatomy, including varying numbers and shapes of roots and canals, which pose challenges during endodontic procedures.

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The intricate morphology of second molars in the maxillary and mandibular regions poses challenges in achieving complete debridement and obturation of root canals. This has been documented in the literature.[1] The presence of C-shaped root canals and diverse canal configurations pose additional challenges during the cleaning and shaping procedure, thereby, elevating the likelihood of inadequate debridement or instrument fracture.[2] Insufficient knowledge of dental morphology can result in imprecise or deficient diagnosis and treatment planning, which may cause treatment failure, root canal reinfection, and ultimately, tooth loss.[3] Hence, it is imperative to employ sophisticated imaging modalities for precise evaluation of dental morphology prior to and during endodontic therapy.

Cone-beam computerised tomography (CBCT) is recognised as a highly valuable tool in the field of dentistry, as it offers a comprehensive three-dimensional perspective of teeth and adjacent anatomical structures. CBCT helps a thorough evaluation of dental morphology, encompassing the quantification and configuration of roots and canals in both maxillary and mandibular second molars. The utilisation of this sophisticated imaging modality not only facilitates the development of thera-

peutic strategies but also enables endodontic practitioners to detect and address potential complications, such as the existence of C-shaped canals or supplementary root morphologies.[4]

Prior research had investigated the morphological characteristics of second molars found in the maxillary and mandibular regions using CBCT. The inquiries brought to light noteworthy disparities in the configurations of roots and canals across diverse populations.[5] As an illustration, certain studies had reported a high prevalence of C-shaped root canals in mandibular second molars, reaching up to 35.5% in Japan.[6] It had been observed that a considerable proportion of cases exhibit a high prevalence of supplementary canals in the mesiobuccal (MB) roots of maxillary first and second molars in the Turkish population.[7] The statistical data highlighted the importance of conducting a comprehensive evaluation of dental morphology in both maxillary and mandibular second molars.[8]

Thus, more research was required concerning morphological characteristics, including the frequency of C-shaped canals, radix entamolaris, and paramolaris, and their influence on endodontic therapy. The requirement is notably conspicuous in distinct demographic cohorts that are subject to limited investigation, such as the Pakistani cohorts. The provision of valuable insights into dental anatomy and bridging the knowledge gap can potentially improve diagnostic accuracy, personalise treatment approaches, and contribute to dental literature on a national and global scale. This, in turn, can lead to enhanced oral healthcare for the population of Pakistan.

The aim of this study was to determine the dental morphology and root canal anatomy of maxillary and mandibular second molars in a population living in Hyderabad, Pakistan. The primary aim of this study was to determine the quantity of roots, evaluate the canal configurations, and appraise the incidence of morphological deviations in the above teeth.

METHODOLOGY

The present investigation used a cross-sectional, observational method to examine the dental morphology and root canal anatomy of maxillary and mandibular second molars in a population from Hyderabad, Pakistan. This study was conducted from April to May 2023.

It was conducted at the Department of Operative Dentistry and Endodontics, at the Institute of Dentistry, Liaquat University of Medical and Health Sciences (LUMHS), Jamshoro. The research employed a convenience sampling approach, wherein the inclusion criteria consisted of individuals aged ≥18 years from Hyderabad, Pakistan, with CBCT scans of maxillary and mandibular second molars that were of diagnostic quality and had closed apices, scans that displayed clear and identifiable root and canal morphology, and CBCT scans that contained patient demographic information, such as age, gender, and geographic region. The study's exclusion criteria comprised of CBCT scans that exhibited a history of endodontic treatment or periapical surgery in the maxillary or mandibular second molars, scans that displayed teeth with notable dental anomalies, such as fusion, gemination, or dilaceration, which could potentially impact the interpretation of root and canal morphology, and CBCT scans of deciduous or supernumerary teeth.

To find the proper sample size for the study, the researchers considered a finite population size (n) of 1002 individuals as reported in the literature. The prevalence of C-shaped canals within the population (p) was calculated to be 5.28%.[9] The aim was to reach a confidence level of 95%, accompanied by an absolute margin of error (d) of 5%. The OpenEpi Sample Size for Frequency in a Population was used to calculate the sample size, which revealed that an adjusted sample size of approximately 55 CBCT scans was required.

The Department of Radiology at Advanced Dental Care Centre, LUMHS, supplied all CBCT scans from January to December 2022. Teeth were positioned at intervals of 0.2 mm within the reconstructed volume, which was created using the data from slices parallel to the alveolar process's horizontal axis.

The CBCT images were analysed using specialised software by trained and calibrated examiners. The examiners were blinded to patient information to minimise bias during the analysis. Two fourth-year endodontic residents received calibration training using a sample CBCT image. Prior to analysing the study material, these examiners evaluated 10 CBCT images, and their assessments were compared based on their analysis of the CBCT images. For each tooth, the axial, coronal, and sagittal views were scrollable, and if there was any disagreement between the examiners, they discussed the case until a consensus was reached. To assess intra- and inter-examiner reliability, a follow-up session took place after four weeks of the first evaluation.

In this study, SPSS 20.0 was employed to assess the various variables such as the count of roots, root canal arrangement, and the occurrence of C-shaped root canals and their corresponding configurations. The variables were used to describe the distribution of root and canal configurations, along with morphological variations. The study recorded the root canal pattern at the orifice of C-shaped molars and categorised the root canal configuration based on the modified Melton's classification.[10] The study incorporated demographic variables, including age and gender, and evaluated tooth morphology by analysing the count of roots per tooth. The analysis of canal configurations in non-C-shaped roots was conducted utilising Vertucci's classification. Any supplementary configurations were delineated in accordance with the methodology of Sert and Bayirli.[11,12] Molars possessing a solitary root were categorised into two groups, specifically O- or C-shaped, predicated on the configuration of the root's cross-sectional area.[9]

The demographic characteristics of the sample and the frequency of various dental morphological features were summarised using the descriptive statistics. The frequency and percentages of distinct canal configurations and morphological variations were computed. The study employed statistical methods, including Chi-square tests to assess the relationship of variables with gender with significance level of 0.05.

RESULTS

Intra-examiner reliability was proved by having the principal investigator perform measurements on the same set of scans on two separate occasions, with a four-week interval between the sessions. The results showed an intra-class correlation coefficient of 0.8. For inter-examiner reliability, other authors independently evaluated the root canal configuration using CBCT scans from the same dataset. All examiners followed the established protocol and were blinded by each other's measurements. The substantial Cohen's Kappa coefficient was 0.72.

A total of 100 CBCT scans were acquired, out of which 66 were evaluated based on their fulfilment of the inclusion criteria. There were 37 (56.1%) males, and 29 (43.9%) females. The mean age was 29.79 years.

The present study examined the root distribution in a sample of 132 teeth from 66 patients. Among these, 109 (82.6%) teeth showed three roots in their maxillary second molars and merely 2 (1.5%) teeth showed the presence of four roots. Among mandibular second molars, 120 (90.9%) had two roots, while 3 (2.3%) teeth exhibited three roots (Table I).

Regarding the arrangement of roots in the maxillary second molars, MB and disto-buccal (DB) roots were fused with each other in 12 (9.1%), MB and palatal (P) in 3 (2.3%), and DB and P in 2 (1.5%). All roots were fused in 7 (5.3%), MB fused to P with separate DB and DP roots in 1 (0.8%), or four separate roots in 1 (0.8%).

The incidence of C-shaped canals in maxillary teeth was infrequent, found in only 5 (3.8%) cases with C-shaped canals of the C1 category. The study found that 14 (10.6%) mandibular teeth displayed C-shaped canals. Among these, 4 (3.0%) showed a C1 configuration, 9 (6.8%) showed a C3a configuration, and 1 (0.8%) showed a C4 configuration.

Regarding maxillary second molars with a single root, 5 (3.8%) showed an O-shaped and 3 (2.3%) showed C-shaped roots, while 2 (1.5%) showed an O-shaped canal, and 4 (2.3%) showed a C-shaped canal in mandibular second molars.

With respect to the occurrence of radix entamolaris or radix paramolaris in mandibular second molars, only 3 (2.3%) showed a radix paramolaris and 1 (0.8%) showed a radix entamolaris. The prevalent radix configuration was Type I, characterised by a solitary canal that extended from the pulp chamber to the apex (Table II).

Regarding the root canal configuration, the prevalent configuration in the MB root of maxillary second molars was Type I, found in 63 (47.7%). The findings of the study indicated that a significant proportion of maxillary second molars exhibited a single canal in both the DB and P roots, with a prevalence of 121 (91.7%) and 129 (97.7%), respectively. The prevalent mesial root configuration in mandibular second molars was identified as Type IV in 46 (34.8%). Type I configuration was predominant in the distal root, accounting for 117 (88.6%) cases (Table III).

There was no significant association between the number of maxillary roots and gender (p=0.985). The results of both Pearson's (r) and Spearman's correlation coefficients showed a negative weak correlation between the number of roots and gender, which was not statistically significant.

Table I: Descriptive statistics of tooth characteristics by gender.

Variable	Gender		Total	p-value
	Male	Female		
Number of Roots of Maxillary 2nd Molar				0.441
1 Root	2 (2.7%)	5 (8.6%)	7 (5.3%)	
2 Roots	7 (9.5%)	7 (12.1%)	14 (10.6%)	
3 Roots	64 (86.5%)	45 (77.6%)	109 (82.6%)	
4 Roots	1 (1.4%)	1 (1.7%)	2 (1.5%)	
Number of Roots of Mandibular 2nd Molar				0.093
1 Root	8 (10.8%)	1 (1.7%)	9 (6.8%)	
2 Roots	65 (87.8%)	55 (94.8%)	120 (90.09%)	
3 Roots	1 (1.4%)	2 (3.4%)	3 (2.3%)	
C-shaped Canal in Maxillary 2nd Molar				0.654
Absence of C- shaped canal	72 (97.3%)	55 (94.8%)	127 (96.2%)	
Presence of C1	2 (2.7%)	3 (5.2%)	5 (3.8%)	
C-shaped Canal in Mandibular 2nd Molar				0.715
Absence of C- shaped Canal	67 (90.5%)	51 (87.9%)	118 (89.4%)	
Presence of C1	2 (2.7%)	2 (3.4%)	4 (3.0%)	
Presence of C3a	4 (5.4%)	5 (8.6%)	9 (6.8%)	
Presence of C4	1 (1.4%)	0 (0.0%)	1 (0.8%)	
Arrangement of Maxillary 2nd Molar Roots				0.245
All roots fused with each other	2 (2.7%)	5 (8.6%)	7 (5.3%)	
MB & DB is fused with each other	7 (9.5%)	5 (8.6%)	12 (9.1%)	
MB & P root is joined	1 (1.4%)	2 (3.4%)	3 (2.3%)	
DB & P root is joined	0 (0.0%)	2 (3.4%)	2 (1.5%)	
3 separate roots	63 (85.1%)	43 (74.1%)	106 (80.3%)	
MB fused to palatal with separate DB and DP roots	0 (0.0%)	1 (1.7%)	1 (0.8%)	
4 separate roots	1 (1.4%)	0 (0.0%)	1 (0.8%)	

DB, Disto-buccal; MB, Medio-buccal; P, Platal.

Table II. Descriptive statistics of tooth characteristics by gender.

Variable	Gender		Total	p-value
	Male	Female		
Single Rooted Maxillary 2nd Molar				0.103
O-shaped	2 (2.7%)	3 (5.2%)	5 (3.8%)	
C-shaped	0 (0.0%)	3 (5.2%)	3 (2.3%)	
Single Rooted Mandibular 2nd Molar				0.036
O-shaped	2 (2.7%)	0 (0.0%)	2 (1.5%)	
C-shaped	6 (8.1%)	0 (0.0%)	6 (2.3%)	
Presence of Radix in Mandibular 2nd Molar				0.097
Radix Paramolaris	0 (0.0%)	3 (5.2%)	3 (2.3%)	
Radix Entamolaris	1 (1.4%)	0 (0.0%)	1 (0.8%)	

Table III. Canal configuration based on gender.

Vertucci Canal Configuration	Gender		Total	p-value
	Male	Female		
MB Root of Maxillary 2nd Molar				0.015
Atypical Configuration	6 (8.1%)	5 (8.6%)	11 (8.3%)	
Type I	33 (44.6%)	30 (51.7%)	63 (47.7%)	
Type II	16 (21.6%)	20 (34.5%)	36 (27.3%)	
Type IV	19 (25.7%)	3 (5.2%)	22 (16.7%)	
DB Root of Maxillary 2nd Molar				1.000
Atypical Configuration	6 (8.1%)	5 (8.6%)	11 (8.3%)	
Type I	68 (91.9%)	53 (91.4%)	121 (91.7%)	
Palatal Root of Maxillary 2nd Molar				0.582
Atypical Configuration	1 (1.4%)	2 (3.4%)	3 (2.3%)	
Type I	73 (98.6%)	56 (96.6%)	129 (97.7%)	
Mesial Root of Mandibular 2nd Molar				0.024
Atypical Configuration	8 (10.8%)	6 (10.3%)	14 (10.6%)	
Type I	5 (6.8%)	7 (12.1%)	12 (9.1%)	
Type II	23 (31.1%)	19 (32.8%)	42 (31.8%)	
Type III	4 (5.4%)	10 (17.2%)	14 (10.6%)	
Type IV	33 (44.6%)	13 (22.4%)	46 (34.8%)	
Type V	0 (0.0%)	3 (5.2%)	3 (2.3%)	
Type VI	1 (1.4%)	0 (0.0%)	1 (0.8%)	
Distal Root of Mandibular 2nd Molar				0.525
Atypical Configuration	8 (10.8%)	6 (10.3%)	14 (10.6%)	
Type I	66 (89.2%)	51 (87.9%)	117 (88.6%)	
Type V	0 (0.0%)	1 (1.7%)	1 (0.8%)	

Similarly, there was no significant difference in the distribution of roots in mandibular second molars between genders ($p > 0.05$). The tests also examined the distribution of roots in relation to the side. The correlation coefficients (Pearson's r) showed a weak negative correlation for males and a weak positive correlation for females. The correlations were not statistically significant ($p > 0.05$).

There was no statistically significant correlation between single-rooted molar type and the presence of a C-shaped canal in males ($p = 0.103$). A statistically significant correlation was seen between the presence of a C-shaped canal and single-rooted molar type among females and the overall sample ($p = 0.036$, $r = 0.064$).

The present study involved an examination of tooth characteristics with respect to gender, using a sample size of 132 teeth, consisting of 74 male and 58 female specimens. Most individuals showed a tricuspid morphology in their maxillary second molars (n = 109, 82.6%), while a bicuspid morphology was seen in their mandibular second molars (n = 120, 90.9%). The incidence of C-shaped canals was noted in only five (3.8%) subjects' maxillary teeth and 14 (10.6%) subjects' mandibular teeth.

Regarding atypical canal configurations, a C-shaped canal was seen between MB and DB in a small number of individuals. Single canals were found in various contexts, including the buccal root, buccal canal, and buccal root with a single canal in the second molar. Additionally, a few individuals had a palatal aspect having two roots (MP and DP) with a Type 1 canal configuration, and some individuals had the presence of MP and DP canals. Lastly, a small number of individuals had two canals extending from the pulp chamber without a C-shaped configuration.

DISCUSSION

In dentistry, it is crucial to thoroughly assess dental morphology and root canal anatomy to ensure effective treatment planning and improve patient outcomes. Specifically, for maxillary and mandibular second molars, accurately assessing dental morphology is of utmost importance as it

significantly impacts the success of root canal treatments.[13] One valuable tool for a comprehensive assessment is CBCT, which allows dentists to find potential complications, improve diagnostic accuracy, and offer personalised treatment approaches. However, it is essential to highlight the need for thorough training and calibration of endodontic professionals in analysing CBCT images to ensure consistent and accurate assessments.[14]

The results of this study uncovered significant insights that hold clinical implications for the planning and outcomes of endodontic treatment. A significant discovery of the research pertained to the allocation of root quantity among maxillary and mandibular second molars. The majority of maxillary second molars (82.6%) were found to have three roots, while a minority (10.6%) displayed a bifurcated root anatomy. The aforementioned discovery was consistent with the frequently documented anatomical diversity in maxillary molars,[8] underscoring the significance of meticulous assessment and comprehension of the root canal morphology in the context of endodontic therapy. By way of comparison, a considerable proportion of mandibular second molars (90.9%) were found to have two roots, while a mere 2.3% showed the presence of three roots. The observation suggested that a considerable percentage of mandibular second molars may show supplementary intricacy in their root canal morphology, needing comprehensive evaluation and potentially revised therapeutic approaches. While comparing this study's findings with the neighbouring countries, the literature showed that the frequency of roots in maxillary and mandibular second molars varies across Chinese, Indian, and Pakistani populations, with low prevalence of 4-rooted molars in China, high variability in India, and no specific data for Pakistan and Iran.[15,16]

The Vertucci classification system was used in this study to evaluate the canal configurations, which was considered a noteworthy aspect. The prevalent canal configuration in maxillary second molars was Type I (47.7%), succeeded by Type II (27.3%) and Type IV (16.7%) in the MB Canal. Type IV configuration was found to be the most prevalent (34.8%) in mandibular second molars, with Type II (31.8%) being the second most common configuration in the mesial root. The aforementioned results underscored the heterogeneous nature of root canal morphology and the necessity of possessing a thorough comprehension of canal configurations, including the existence of an accessory MB canal, in order to achieve favourable endodontic treatment results.[17] The Type IV configuration's high prevalence indicated the existence of fin-like isthmuses and interconnections among root canals, which may present difficulties in achieving sufficient cleaning and shaping of the canals.[18]

The investigation additionally recognised specific morphological discrepancies in the second molars of both the maxilla and mandible. The study revealed that C-shaped canals were present in 3.8% of the maxillary second molars and 10.6% of the mandibular second molars. The existence of C-shaped canals can have a substantial influence on the course of treatment due to their intricate anatomy, which frequently includes irregularities and fins that can heighten the likelihood of inadequate cleaning and shaping.[19] Furthermore, the presence of radix entamolaris was seen in 3% of the mandibular second molars, suggesting the existence of an extra root either on the buccal or lingual aspect. It is imperative for clinicians to have knowledge of these variations to aptly diagnose and treat such dental anomalies. Studies from other countries revealed significant variations in the prevalence and configuration of C-shaped root canal systems in mandibular second molars across different populations. In the native Chinese population, a high incidence was seen with 34.64% found through radiography and 39.18% through a clinical examination. Combining both methods proved to be the most effective approach.[20] Conversely, the Turkish population exhibited a lower prevalence of C-shaped canals, as determined by CBCT.[7] In the Indian population, mandibular second molars demonstrated considerable variability, including rare instances of three roots, a sexual predisposition, and fused roots with C-shaped canals showing notable variations from the coronal to apical third.[16] Notably, C-shaped canals were found in 19.1% of the mandibular second molars examined in the Lebanese population, which may be attributed to the country's geographical location.[21] A study from Manchester on Pakistanis concluded that the occurrence of four root canals in mandibular and maxillary first permanent molar teeth is common among the South Asian especially in Pakistanis.[22]

The absence of noteworthy correlations between gender and the quantity of roots or canal configurations in maxillary and mandibular second molars showed that gender does not exert any influence on these anatomical variations. This is also manifested in the literature.[23] This finding implied that dental practitioners should consider these variations in all patients, regardless of their gender, during the treatment planning and execution.

The outcomes of this investigation held significant clinical implications for the planning and results of endodontic treatment. The elevated occurrence of maxillary second molars with three roots highlighted the necessity of comprehensive preoperative radiographic assessment and meticulous handling of the supplementary root canals. Inadequate identification and treatment of all root canals may result in persistent infection and treatment failure.

The prevalence of Type IV canal configuration in maxillary and mandibular second molars underscored the intricate nature of root canal morphology. Additionally, this finding served as a secondary point of discussion. The discovery implied that dentists performing root canal treatment must be equipped to manage complex canal systems and should contemplate using sophisticated instrumentation and irrigation methods to guarantee thorough cleansing and sterilisation of the root canal system.

The incidence of C-shaped canals was relatively infrequent within the examined population. Most individuals lacked the presence of C-shaped canals within their maxillary and

mandibular dentition. A minority of individuals manifested C-shaped canals, albeit with diverse configurations. The frequency of C-shaped canals exhibited a greater occurrence in Asian populations in contrast to Caucasians.[24] The phenomenon of bilateral occurrence was often seen, and there is currently no established association between age, gender, and laterality in this regard.

The present investigation revealed differences in the root and canal morphology of maxillary and mandibular second molars. The study found the existence of distinct canals exiting the pulp chamber in maxillary second molars, denoting the presence of Type II and Type IV canal configurations. The results presented in this study are in line with the prior research[25] and underscored the significance of identifying supplementary canals, such as the MB2 canal, in order to prevent unsuccessful treatment outcomes.

Gender was found to have no significant effect on the number of roots in maxillary second molars or the occurrence of single--rooted and multi-rooted mandibular second molars. Females with a single-rooted molar type had a higher probability of exhibiting C-shaped canals. Endodontists should consider multiple factors when planning and performing root canal procedures.

By investigating the specific morphological features in a unique Pakistani population, the study contributed valuable insights to dental morphology research. However, there were limitations to the study, such as the limited generalisability of findings to other populations and the use of CBCT scans, which may not be accessible to all dental practices.

Future research should explore the prevalence of specific morphological features and their impact on treatment outcomes in diverse populations. Prospective longitudinal studies can supply more robust evidence on the relationship between dental morphology variations and treatment success rates.

CONCLUSION

The study found that 82.6% of maxillary second teeth had three roots. C-shaped canals were found in 3.8% of maxillary teeth and 10.6% of mandibular teeth. The number of maxillary second molars with radix entamolaris and paramolaris was 2.3% and 0.8%, respectively. The most common root canal shapes were Type I in the MB and P roots and Type IV in the mesial roots of the second mandibular teeth. There was no statistically significant link between the number of roots and the gender. There was a strong link between the type of molar with a single root and the presence of a C-shaped canal.

ETHICAL APPROVAL:

The Research Ethics Committee of Liaquat University of Medical and Health Sciences, Jamshoro approved the project (LUMHS/REC/-74 Letter of 17 May 2023). To protect the privacy of the participants, the free and open-source ARX Data Anonymization Tool was used to encrypt all the data collected from them. The principles from the Declaration of Helsinki and other applicable ethical guidelines were adhered to throughout the investigation.

PATIENTS' CONSENT:

Due to the retrospective nature of the study, explicit consent was not obtained from the patients.

COMPETING INTEREST:

The authors asserted that there are no conflicts of interest about the dissemination of this article.

DISCLOSURE:

The raw data supporting the findings of this study will be made available by the corresponding author upon request.

AUTHORS' CONTRIBUTION:

SS: Drafting the manuscript, acquisition and interpretation of data.
FA: Supervision, review, and editing.
PR: Results analysis.
MM: Critical revision of content.
MA: Data curation, review, writing, and editing.
FR: Formal analysis, investigation and search of resources.
All authors approved the final version of the manuscript to be published.

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