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Original Article

Cone-Beam Computed Tomography Assessment of Middle Mesial Canal Prevalence in Mandibular First Molars in an Indian Population

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ABSTRACT

This research sought to determine the occurrence rate and morphological features of middle mesial (MM) canals in mandibular first molars across an Indian cohort, stratified by the nation's various geographical regions, using cone-beam computed tomography (CBCT) imaging. Based on specified inclusion and exclusion benchmarks, 452 CBCT scans were gathered in December 2021. The images were obtained from five distinct regions of the country, with 80–100 scans from each region. An axial plane assessment was conducted to identify the existence of an MM canal (MMC); whenever spotted, confirmation was subsequently carried out in the coronal plane. Of the 452 scans reviewed, 39 showed MMCs, yielding a 8.6% rate. A bilateral manifestation was recorded in 8 scans (1.8%). Accordingly, of the 904 molars assessed, 47 had MMCs. This translates to a tooth-based prevalence of 5.2% for MMC. Among the teeth harboring MMCs, 70% concluded with two apical exits. Male subjects had a higher prevalence than females (10.25% vs. 6.88%, $P < 0.05$). A steady reduction in MMC detection was also noted with advancing age ($P < 0.05$). The prevalence of MMCs in this Indian sub-population is 8.6%. Despite being on the lower end of the spectrum relative to other groups, thorough inspection remains crucial to prevent overlooking the MMC, which could compromise treatment success. Age and sex were also recognized as influential variables affecting MMC presence.

Keywords: Cone-beam computed tomography, Indian sub-population, Mandibular first molar, Middle mesial canal

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Introduction

Endodontic disease emerging after treatment—characterized by pain, edema, or impaired mastication—frequently stems from substandard care. Contributing factors range from deficient chemomechanical instrumentation and overlooked canals to inadequate filling. An untreated or missed canal constitutes a leading cause of endodontic failure [1]. Apical periodontitis was present in 98% of cases with unaddressed canals, a markedly higher frequency than in completely treated teeth [2]. Endodontically treated teeth exhibiting missed canals carried 4.4 times greater odds of correlating with a periapical radiolucency than those without [3]. Anatomically aberrant teeth are particularly prone to failure owing to their intricate configurations. Consequently, exhaustive disinfection and shaping of the root canal space are indispensable for facilitating the resolution of periradicular tissues.

As the first permanent teeth to erupt into the oral environment, mandibular molars are more likely to require endodontic therapy than their counterparts [4]. Their root canal architecture is inherently elaborate—two roots, typically a mesial root containing two canals and a distal root with 1 or 2 canals. Yet the frequency of atypical morphology is substantial, spanning reports of six to seven canals, supernumerary roots, and C-shaped configurations [5-8].

The middle mesial (MM) canal lies between the mesiobuccal (MB) and mesiolingual (ML) canals. First described in the 1970s, it has since attracted considerable scholarly attention [9, 10]. Reported frequencies are understood to fluctuate across ethnic groups [11, 12]. A multitude of investigations worldwide have gauged the prevalence of MM canal (MMC) across disparate populations. Versiani *et al*. [13] reported a rate of 14.8% in a Turkish sample, versus 22.1% in a Brazilian sample. Exceptionally low figures have likewise been observed; for instance, Aldosimani *et al*. [14] reported a mere 0.9% prevalence in a Saudi group. Population-level discrepancies are thus clearly demonstrable.

Three-dimensional radiographic technology supports improved clinical diagnostics. Cone-beam computed tomography (CBCT) is a modern diagnostic adjunct that enables straightforward visualization of MMC [15]. Limited published data exist on MMC prevalence evaluated via CBCT in an Indian population, segmented by geographic zone, and that additionally capture the modifying effects of age and sex on MMC rates. This study quantifies MMC incidence within an Indian cohort distributed across multiple regions using archived CBCT volumes and further records how subject age and gender influence its occurrence.

Materials and Methods

This work was performed collaboratively in the Conservative Dentistry and Endodontics unit alongside the Oral Medicine and Radiology unit. Ethical clearance was obtained from the institutional review board (AMC/IRB/ENDO/PG21/22). A starting collection of 630 CBCT volumes was acquired from multiple geographic regions of the country in December 2021; after applying selection and rejection criteria, 452 scans were ultimately retained.

Inclusion criteria

1. Mandibular first molars are present on both sides
2. Mandibular first molars displaying fully matured root structures
3. Subjects older than 12 years (this cutoff was chosen to ensure only molars with finalized root development were enrolled).

Exclusion criteria

1. Any missing mandibular first molar
2. Imaging artifacts that obstructed reliable interpretation
3. Mandibular first molars previously subjected to root canal procedures.

Data collection and analysis ran from March through May 2022. The CBCT files were drawn from five national zones, namely North, East, South, West, and Central. A quota of 80–100 scans per zone was set (North, South, and East zones contributed 90 each; West zone supplied 100; Central Zone furnished 82), summing to 452. The datasets consisted of previously captured CBCT examinations stripped of all personal details such as patient names and clinical indications for scanning. Sex and age information were retained, as the research design included incidence calculations by sex. The directors of the respective imaging centers formally granted access rights to the patients' CBCT records. Only scans produced by CBCT devices operating at 70 KVp, 8 mA, 12 seconds, employing an 80 mm × 80 mm field of view and a voxel size of 0.32 mm, were considered.

For the secondary aim of estimating MMC occurrence across different age strata, the sample was partitioned into four cohorts: under 20 years (111 scans), 20–40 years (142 scans), 40–60 years (136 scans), and over 60 years (63 scans).

Image interpretation was carried out by two endodontists working independently. Before commencing the formal assessment, a calibration round was held, during which each examiner reviewed a batch of 25 randomly selected CBCT datasets not linked to this investigation. Consistency was measured using Cohen's kappa statistic. Both intra-rater and inter-rater agreement proved to be very strong (0.91 and 0.93, respectively). Following calibration, the evaluators first filtered the scans against the study's entry and exclusion rules; any disagreements at this stage were resolved by consulting an oral radiologist until consensus was reached. The evaluators then proceeded with image analysis, and wherever their findings diverged, the matter was settled through group dialogue until a unified judgment was reached.

The assessment began by orienting the mandibular first molar in the axial plane; a series of axial cross-sections was produced for the mesial root spanning from the cementoenamel junction to the apical terminus. The canal count was recorded on each successive slice **(Figure 1)**. If an auxiliary orifice appeared between the ML and MB canals, confirmation was sought by re-examining that same axial level in the coronal plane **(Figures 2 and 3)**. This sequence was repeated for the entire set of scans.

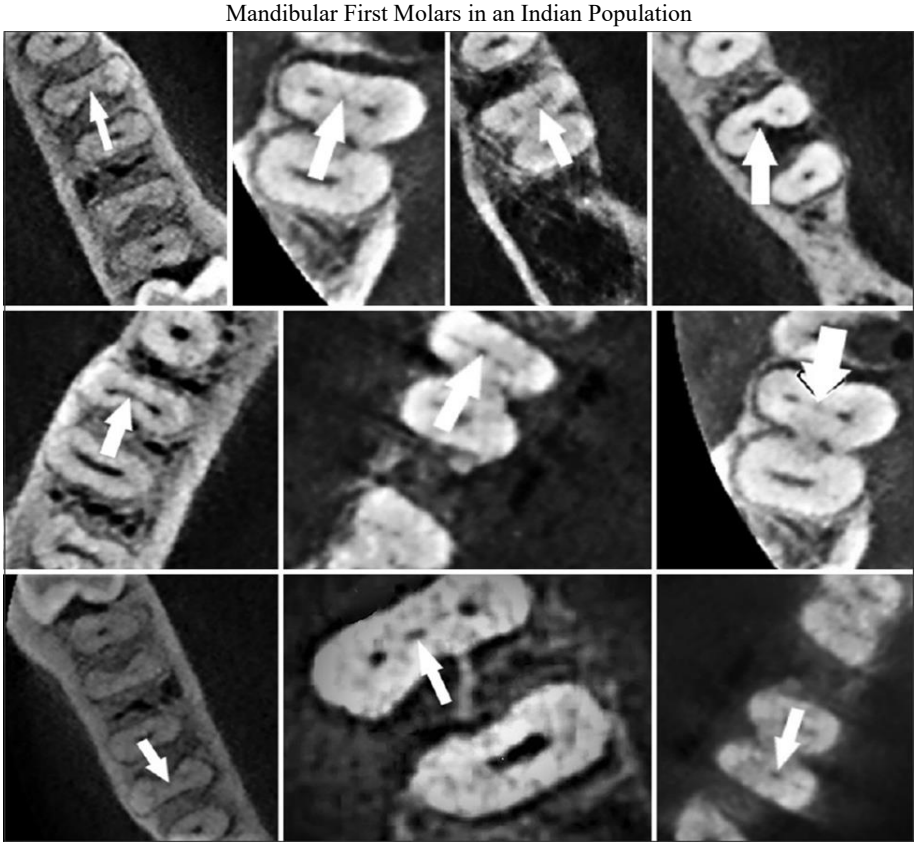


Figure 1. Selected axial slices illustrating a middle mesial canal. Arrows pinpoint the middle mesial canal.

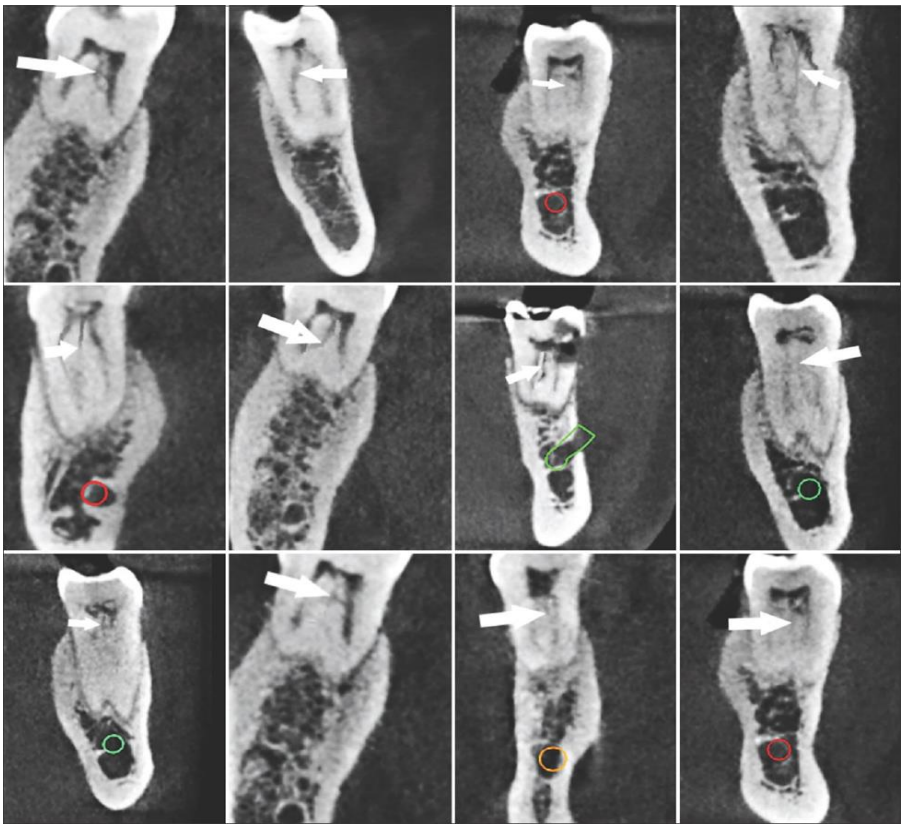


Figure 2. Selected coronal slices illustrating a middle mesial canal terminating in two apical exits. Arrows pinpoint the middle mesial canal.

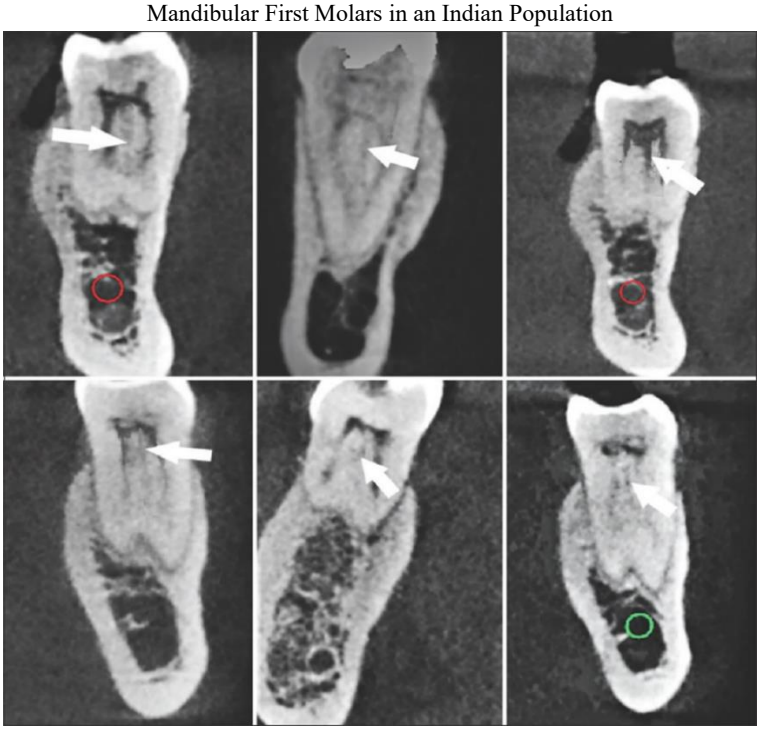


Figure 3. Selected coronal slices illustrating a middle mesial canal with one apical exit and three independent exits. Arrows pinpoint the middle mesial canal.

Whenever an MMC was detected, its morphologic category was assigned according to the updated classification by Ahmed *et al*. [16]. The terminal exit pattern and the total count of apical foramina were likewise documented.

Statistical analysis

All computations were performed on IBM SPSS Advanced Statistics (Statistical Package for the Social Sciences), version 20 (SPSS Inc., Chicago, IL, USA). Quantitative variables were examined via one-way ANOVA. Descriptive summaries were generated, and the Chi-square test was used to examine the relationship between patient sex and age, and canal anatomy. For all inferential tests, P values below 0.05 were taken as evidence of statistical significance.

Results and Discussion

From the pool of 452 scans analyzed, 39 revealed the existence of an MMC. **Table 1** outlines the MMC detection rate according to geographic zone, its breakdown by sex, the tally of bilateral findings, and the apical termination patterns recorded. Within the 47 teeth confirmed to contain an MMC, 70% terminated in merely two apical portals, implying fusion of the MMC with either the MB or ML canal. In contrast, 19% presented an independent orifice for each of the three canals.

Table 1. Detection rate of middle mesial canals stratified by national zone and the count of apical portals observed when detected.

	Number of scans	MM present, n (%)	MM bilateral	Gender division		3 apical foramina	2 apical foramina	1 apical foramen
				Male	Female			
N	90	8 (8.9)	2	4	4	2	8	0
E	90	6 (6.6)	1	4	2	1	5	1
S	90	9 (10)	1	5	4	2	6	2
W	100	11 (11)	3	8	3	3	9	2
C	82	5 (6)	1	3	2	1	5	0

MM: Middle mesial canals, N: North zone, E: East zone, S: South zone, W: West zone, C: Central zone

Mesial root canal configurations for teeth harboring an MMC, codified using the updated Ahmed *et al*. [16] scheme, are summarized in **Table 2**. The digits in the zone column correspond to the unique identifier assigned to each CBCT scan within its respective regional batch.

Table 2. Mesial root canal configurations of mandibular first molars possessing a middle mesial canal, as per the Ahmed *et al*. [16] classification framework.

Zone	Configuration
N16	3-2
N33	3
N42	3-2-1
N56	3-2
N67	3
N67 (bilateral)	3-2
N73	2-3-2
N81	3-2
N84	3-2
N84 (bilateral)	3-2
E9	3
E14	2-3-2
E23	3-2-1
E23 (bilateral)	3-2
E40	3-2
E67	3-2
E81	3-2
S2	3-2
S22	3-2
S38	2-3
S38 (bilateral)	3-2
S51	2-3-2
S67	3-2-1
S74	3-2
S80	3-2
S83	3
S89	3-2
W6	2-3-2
W6 (bilateral)	3-2
W14	3-2
W20	3
W20 (bilateral)	3-2
W30	3-2-1
W34	3-2
W34 (bilateral)	3-2
W40	2-3
W50	3-2
W62	2-3-2
W71	3-2
W80	3
W96	3-2
C16	3-2
C29	2-3-2
C61	3-2
C61 (bilateral)	3
C68	3-2
C82	3-2-1

N: North zone, E: East zone, S: South zone, W: West zone, C: Central zone

The aggregate number of scans, sex-based distribution, and split between right- and left-side scans are consolidated in **Table 3**.

Table 3. Detection rate of middle mesial canals according to patient sex and arch side.

	Whole sample	**Sub group with MM canals detected**	**P**
Number of patients	n=452	39 (8.6)	
Gender			
Male	234	24 (10.25)	<0.05
Female	218	15 (6.88)	

Location	Left side scans=452	Left=25	>0.05
	Right side scans=452	Right=22	
		Bilateral=8	

MM: Middle mesial

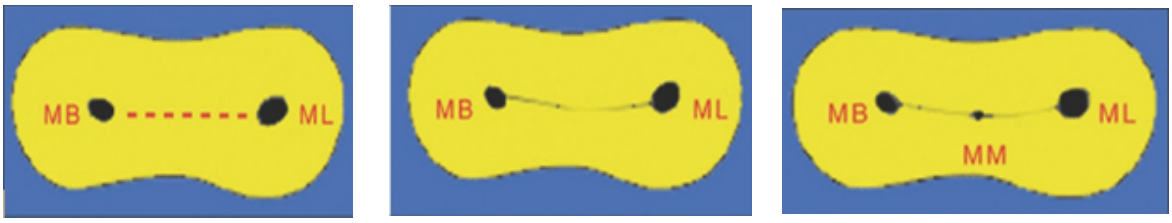
Table 4 presents the MMC occurrence data partitioned by age cohort. A statistically meaningful downward trend accompanied rising age. The detection percentage started at 16.2% among individuals younger than 20, then dropped sequentially to 9.9% for the 20–40 bracket, 4.4% for the 40–60 bracket, and 1.6% among those aged 60 or older.

Table 4. Detection rate of middle mesial canals across successive age cohorts.

Age group	<20 years	20–40 years	40–60 years	>60 years	P
Sample size (n)	111	142	136	63	<0.05
Incidence of middle mesial canals, n (%)	18 (16.2)	14 (9.9)	6 (4.4)	1 (1.6)	

The MMC, sometimes called the accessory mesial canal, occupies the sub-pulpal groove of the mesial root and maintains continuity with the principal mesial canals [17]. The adoption of magnification devices for locating accessory canals has boosted the discovery rate of mesial root anomalies [18]. One contemporary report indicated that detection of such supplementary canals has climbed markedly, hitting 46.2% for the MB2 canal [19].

Martins *et al*. [20] advanced the view that the third mesial canal is not an accessory structure but rather a consequence tied to the isthmus. Directed troughing along the mesial pulpal floor in a mesio-apical direction is recognized as beneficial for exposing accessory canals. A recent study found that 39.6% of canals were confirmed only after deepening the trough to approximately 2 mm **(Figure 4)**. Even so, the procedure is technique-sensitive, necessitating a dedicated armamentarium and vigilance to prevent lateral perforation [19].



a) b) c)

Figure 4. Image underscoring the role of troughing in the search for middle mesial canals. Abbreviations: MM = Middle mesial, ML = Mesiolingual, MB = Mesiobuccal.

Several variables, including racial origin and ethnic heritage, govern the frequency of morphological diversity among tooth types [20]. This largely explains the heterogeneous MMC prevalence figures documented across distinct human groups. Variation in MMC prevalence also depends on the diagnostic precision of the investigative technique employed [21-23]. The identification of supernumerary root canals depends on rigorous and comprehensive radiographic assessment of the tooth in question, achievable through multiple diagnostic modalities. CBCT units are now routinely applied for endodontic diagnostics because comparative studies confirm that CBCT-derived images match the performance of conventional multidetector computed tomography (CT) scans, offering comparable three-dimensional views at both lower radiation exposure and reduced expense [15]. Guided by this evidence, the present work employed cone-beam imaging, a technology with established superiority in disclosing extra canals.

Through cone-beam evaluation, Tahmasbi *et al*. [24] concluded that 20% of extracted mandibular molars possessed genuine MMCs. Their sample skewed toward female subjects. In a separate study, Kuzekanani *et al*. [25] documented an overall prevalence of 8.1%. Those authors noted that demographic variances in age and sex could modulate the findings. In our series, the representation of male and female patients was nearly equal, and the overall prevalence was 8.6%.

Eight bilateral MMC cases were detected in the current study. Documenting both unilateral and bilateral

presentations aligns with observations by Sherwani *et al*. [17] and Kuzekanani *et al*. [25]. Of the 904 individual molars examined, 47 contained MMCs, equating to a tooth-based prevalence of 5.2%.

Beyond prevalence, the configuration of apical foramina within the mesial root was examined. A total of 33 of 47 MMC-positive teeth (70%) had only two apical exits, indicating that the middle mesial canal coalesced with either the MB or ML canal en route to the apex. Of these 33 teeth, the point of union was located at the middle-to-apical third junction in 23 specimens, within the middle third in eight specimens, and at the apical third in two specimens. Nine teeth (19.1%) exhibited three fully separate apical portals, while five teeth (10.6%) demonstrated a single shared exit, indicating total convergence of all three mesial canals. For anatomic cataloging, the mesial root canal systems were classified according to the updated CBCT-specific system proposed by Ahmed *et al*. [16]. This descriptive framework provides precise information on canal counts at each root level; it was thus selected for our study, given the requirement to log the number of apical exits meticulously [26].

In the current dataset, MMCs were more commonly encountered among males than females; of the 39 positive cases, 24 (63%) originated from male patients, while 15 from female patients. A statistically significant gap in prevalence was also evident, with males at 10.25% (n = 234) and females at 6.88% (n = 218). This pattern echoes findings by Kazemipoor *et al*. [27] and Mashyakhy and Gambarini [28], both of whom described significant sex-linked disparities in root canal anatomy.

This inquiry additionally addressed MMC frequency as a function of chronological age. Patient age emerges as a salient factor modulating MMC detectability. Within our dataset, incidence figures dropped progressively across age tiers: 16.2% in subjects under 20, 9.9% in those 20–40, 4.4% in the 40–60 cohort, and 1.6% in individuals older than 60. These observations are in concordance with earlier work by Nosrat *et al*. [29] and Sherwani *et al*. [17], each of which underscored the effect of age on MMC presence. This pronounced age-related decline is largely attributable to the incremental deposition of secondary dentin and the progressive canal obliteration that accompanies aging.

Furthermore, an additional objective of this investigation was to compare CBCT scans sourced from multiple geographic regions of the country to determine MMC prevalence and assess whether any statistically meaningful differences existed among them. Segmenting the sample into five distinct zones was a deliberate strategy intended to represent the nation's entire populace. Large nations frequently exhibit ethnic diversity, and the present work constitutes one such effort to explore this anatomical variant across different subgroups. Subjects from the Western zone registered the highest rate of occurrence (11%), descending in order through the Southern (10%), Northern (8.9%), Eastern (6.6%), and Central zones (6%); nonetheless, the observed disparity failed to reach statistical significance ($P > 0.05$). Even so, additional investigations employing substantially larger cohorts within each regional subgroup remain necessary, and this comparatively modest per-zone sample size may be considered a limitation of the present work.

Looking ahead, the authors advocate that future inquiries be undertaken independently for each zonal population, using considerably larger sample sizes, and further propose that Micro-CT examinations be conducted to verify MMC presence within an Indian demographic.

As a society ages, an increasing number of molar teeth are preserved throughout life. Safeguarding these teeth is critical for maintaining oral health, as it helps prevent the onset of disease. Mandibular molars are susceptible to a range of insults, including dental caries and periodontal breakdown, both of which can jeopardize pulpal vitality—overlooking an MMC results in lingering periapical pathosis and endodontic treatment failure. Consequently, possessing a sound appreciation of MMC occurrence can heighten clinicians' awareness regarding the significance of this entity when treating mandibular molars, as it is imperative to ensure that no persistent foci of infection or inflammation remain.

Conclusion

The aggregate prevalence of MMCs within an Indian sub-population approximates 8.6%. Even though this figure falls toward the lower end of the spectrum compared with other Asian groups, meticulous exploration of the zone between the MB and ML canals is warranted to avoid overlooking the MMC, which could culminate in treatment failure and unfavorable sequelae. Age and sex were also identified as noteworthy determinants of MMC presence.

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Ethics Statement: None

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