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The influence of dilacerated impacted maxillary central incisors on the incisive canal and nasal cavity characteristics: a retrospective comparative study

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Abstract

Background Dental anomalies significantly impact oral structures, particularly impacted maxillary central incisors. These anomalies can complicate interactions with nearby anatomical features like the incisive canal and nasal cavity. Accordingly, this study aimed to three-dimensionally and comprehensively assess the effects of dilacerated impacted maxillary central incisors on the characteristics of incisive canal and nasal cavity.

Materials and methods A seventeen cone-beam computed tomography images with an average age of 8.98 ± 0.925 years were classified into a control group and a dilacerated impacted maxillary central incisor group (DIMCI group), each containing 35 patients. A linear, angular, and volume measurements of the incisive canal and nasal cavity were measured using Mimics 21 and Anatomage Invivo Dental 6.0 software. The incisive canal measurements were performed at three levels: H1, the lowest point of the incisive canal buccal wall; H2, midlevel; H3, root apex level.

Results The incisive canal volume was significantly lower in the DIMCI group compared to the control group, measuring 109.39 ± 12.28 versus 93.17 ± 12.72 mm^3, respectively. Furthermore, the incisive canal widths at the palatal opening and levels H2 and H3 were significantly reduced in the DIMCI group compared to the control group ($P < 0.05$). Additionally, the contralateral central incisor's angulation was considerably greater (113.18 ± 2.77 vs. $109.09 \pm 3.74°$), and the anterior nasal floor was significantly narrower (12.27 ± 1.60 vs. 13.61 ± 1.57 mm) in the DIMCI group than in the control group.

Conclusions The impaction of the maxillary central incisor is related to an increased buccal inclination of the contralateral central incisor and decreased anterior nasal floor width in pediatric patients, indicating a potential need for maxillary expansion. Moreover, a precise evaluation of the incisive canal is necessary for safe management during surgical exposure and orthodontic treatment.

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Keywords Dilacerated impacted maxillary central incisor, Incisive Canal, Nasal cavity, Cone-beam computed tomography (CBCT)

Introduction

The influence of dental anomalies on oral structures has been a significant area of interest and concern in dentistry [1]. Among these dental anomalies, impacted maxillary central incisors pose a distinctive challenge due to their potential interactions with nearby anatomical structures, such as the incisive canal and nasal cavity [2, 3].

Dilaceration is a cause of impaction in the maxillary central incisor. This condition, marked by an angle or deviation in the tooth's root, typically results from trauma or developmental anomalies during the tooth's formation [4, 5]. When dilaceration impacts the maxillary central incisor, it often leads to impaction, inhibiting the tooth from correctly erupting into the dental arch. Previous studies have reported that the prevalence of maxillary central incisor impaction ranges from 0.06 to 0.20% [6]. Research indicates that approximately 65.7% of impacted cases exhibit some degree of dilaceration [7].

The intricate relationship between dental anatomy and neighboring structures often complicates the diagnosis and treatment planning [8]. Recent studies on craniofacial anatomy underscore the close relationship between the incisive canal and maxillary central incisors. These are closer to the cortical palate than any other structure [9, 10]. The canal, nestled behind the roots of these incisors, is a significant anatomical feature in the premaxilla, linking the nasal and oral cavities via the incisive and nasal foramina. Encased in dense bone and hosting the incisive bundle, the canal heavily influences the sensory and vascular functions of the anterior maxilla [11, 12]. Variations in incisor angles, alveolar bone thickness, and canal morphology often complicate maxillary incisor adjustments [13–16]. Such transformations, mainly when dealing with a dilacerated impacted maxillary central incisor (DIMCI), can risk interfering mechanically with the incisive canal. This interference potentially leads to sensory and vascular complications, thus adding complexity to surgeries in the anterior maxillary area. Therefore, a thorough preoperative evaluation is vital to mitigate these risks and guarantee effective treatment planning.

The nose and the maxillary central incisors originate from neural crest cells derived from the ectoderm [17]. This indicates a close relationship between the structure of the nose and the maxillary central incisors [17, 18].

Limited research has explored the relationship between the roots of the maxillary central incisors and the floor of the nasal cavity using computed tomography (CT) [19]. Findings from these studies suggest a proximity between the apex of the maxillary central incisors and the nasal floor. In light of this, this study used cone-beam computed tomography (CBCT) to assess three-dimensionally (3D) and comprehensively alterations in the morphology of the incisive canal and the nasal cavity that are associated with the presence and position of DIMCI.

Materials and methods

Study sample

A retrospective analysis was conducted on individuals who visited the Orthodontic Department of China Medical University's Stomatology Hospital, China from 2022 to 2024. This study was approved by the Ethical Committee of China Medical University and Stomatology Hospital of China Medical University, China. Informed written consent was obtained from the participant's parents or guardians before the patient entered the study. Moreover, all methods were carried out in accordance with the principles of the declaration of Helsinki. The required sample size, determined via G*Power software (v3.1.3; Franz Faul, Universität Kiel, Germany), aimed towards a significance level of 0.05 and a power of approximately 95%. Power analysis indicated the necessity of 60 cases, though the sample size ultimately reached 70 patients. The subjects were divided into two groups: the control group, without impacted maxillary central incisors, and the dilacerated impacted maxillary central incisor (DIMCI) group.

Patients' inclusion criteria for the DIMCI group were as follows: (1) CBCT scans from subjects aged 8 to 10 years of both genders; (2) the presence of a unilateral intraosseous impacted permanent maxillary central incisor; (3) an impacted central incisor with an apical deviation is equal or greater than 20° relative to the tooth crown axis [20]; and (4) a delayed eruption of the impacted incisor by at least 6 months compared to its contralateral pair.

Inclusion criteria for the control group were patients requiring orthodontic and dentofacial orthopedic treatment where the maxillary central incisors were fully erupted. The exclusion criteria were: (1) patients who had previously undergone orthodontic treatment, (2) cases with impaction of both maxillary central incisors, (3) history of tooth extraction, (4) craniofacial malformations, (5) presence of cleft lip and/or palate, (6) cases of tooth agenesis, (7) presence of odontogenic pathologies, (8) bilateral impacted maxillary central incisors visible on CBCT, and (9) systemic diseases affecting the patients' bone metabolism.

CBCT analysis

Images were captured using a CBCT device (I-CAT®; KaVo Company, Germany), operated by a professional radiographer adhering to established protocols. The parameters for image acquisition were 120 kV and 5 mA, with a field of view measuring 23X 17 cm. Furthermore, the imaging process required an exposure duration of 17.8 s, with the resolution specified at a voxel size of 0.3 mm and a slice thickness of 2 mm.

Incisive canal image acquisition

The Digital Imaging and Communications in Medicine files of CBCT scans were imported into Mimics 21 software (Materialise, Leuven, Belgium) for analysis. Before measurements, all scans were aligned parallel to the Frankfort-horizontal (FH) plane in the sagittal view. The images were standardized to ensure consistent voxel size and grayscale intensity calibration across all scans. A grayscale thresholding technique was applied to distinguish the incisive canal from the surrounding bone. We used a predefined Hounsfield Unit (HU) range based on anatomical structures, ensuring the canal was precisely segmented. This thresholding initially separated the anatomical structures into different masks. These masks could be manually adjusted by adding or removing voxels on each slice. Using mask functions, bone and soft tissue were distinctly separated. Three-dimensional volumetric models of the incisive canal were created (Fig. 1).

The 3D models were then trimmed at the upper boundary by the floor of the nasal cavity and at the lower boundary by the palate's roof. These models enabled the automatic calculation of the incisive canal volume using the 3D measurement tool in Mimics software. We determined and automatically calculated the volume of each patient's incisive canal in cubic millimeters (mm^3). The Invivo dental imaging software (version 6, Anatomage, San Jose, CA, USA) was used to assess additional 3D parameters and linear measurements. A modified methodology described by Cho et al. [21] at three distinct vertical levels on the sagittal plane following the axial cross-sectional images were used to define the linear measurements (CI-IC, Rm-Cat, Rm-Canal, CI-Root, IC width at the level of incisor apices) (Fig. 2A, B). Additionally, some other linear and angular measurements were assessed on the sagittal view of multiple planar reconstruction images, including the incisor/Palatal Plane (PP) angle, palatal alveolar bone width (PABW) at the apical level, IC/PP angle, and IC width at the palatal opening (Fig. 2C). Details about the landmarks are provided in supplementary tables 1, and the measurements are provided in Table 1.

Nasal cavity image acquisition

The skull was realigned in multiplanar reconstruction images in alignment with the FH, as described below (Fig. 3A, B, C). First, for the frontal view, the mid-sagittal plane was adjusted to align with the center of the anterior nasal spine (ANS). Also, an axial plane was established, connecting the right and left orbital points and the right porion point. Second, in the right sagittal view, the axial plane was oriented through the right porion and right orbital landmarks. To ensure standardization, the left sagittal view was omitted to eliminate issues with orientation arising from the asymmetrical positioning of parts. Third, in the axial view, the mid-sagittal plane was created through the Sella Turcica and Basion points [22]. Subsequently, the transverse dimension of the anterior nasal aperture was measured. Measurements of the anterior nasal width (ANW) and anterior nasal floor width (ANFW) were taken in the coronal plane intersecting the cephalometric point N (Fig. 3D; Table 1).

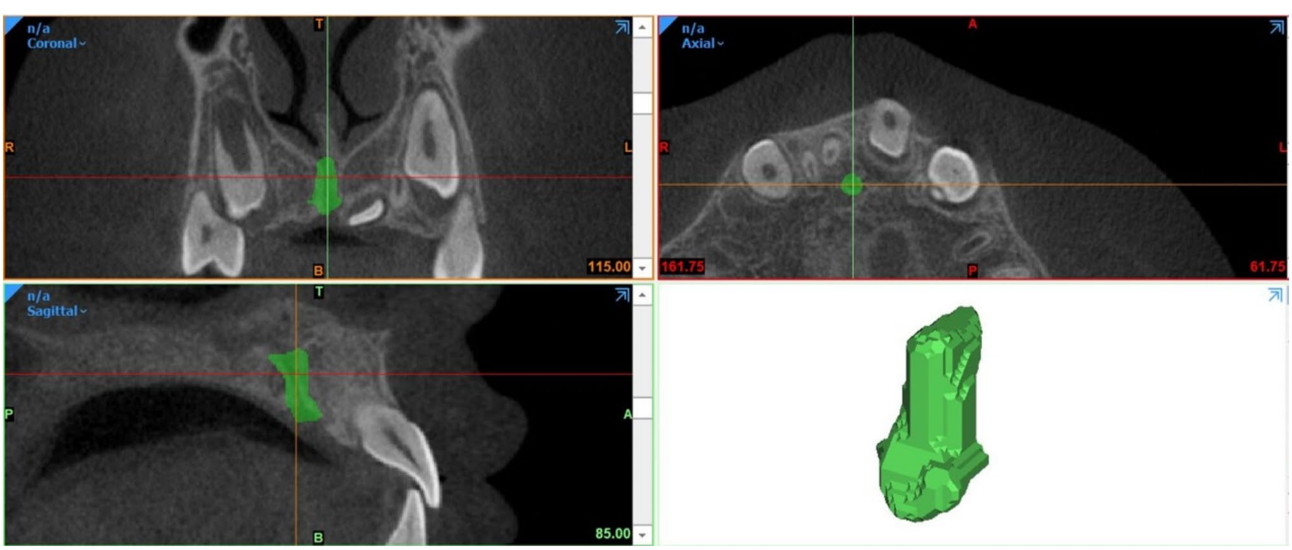

Fig. 1 Incisive canal volume measurement shows the segmentation of the internal portion of the incisive canal with the resulting 3D model

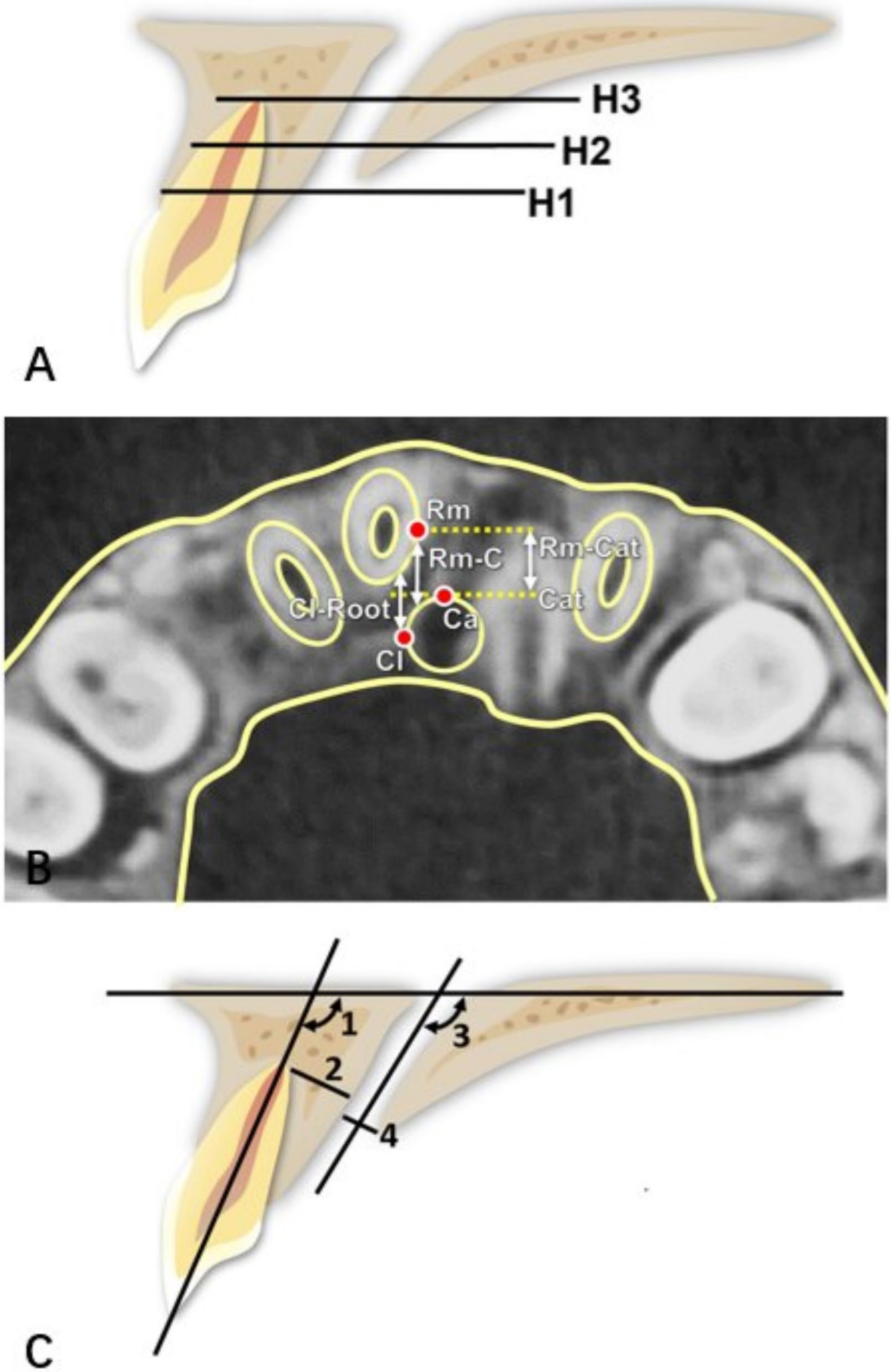

Fig. 2 (See legend on next page.)

(See figure on previous page.)

Fig. 2 Landmarks and linear measurements; **A**, Levels of measurements: H1, the lowest point of the incisive canal buccal wall; H2, midlevel; H3, root apex level. **B**, Landmarks for transverse measurements: Cl, the most lateral point of the incisive canal; Cl-Cl, canal width, and landmarks for sagittal measurements: Rm, the most medial point of the upper central incisor root; Ca, the most anterior point of the IC; Cat, the tangent line through Ca; Rm-Cat, the anteroposterior distance from Rm to Cat; Rm-Canal, the anteroposterior distance from Rm to the anterior border of the IC; Cl-Root, the anteroposterior distance from Cl to the posterior border of the upper central incisor root. **C**, Linear and angular measurements on the sagittal reconstruction: 1 Incisor/Palatal plane angle. 2 Palatal alveolar bone width (PABW) at apex level. 3 IC/ palatal plane angle. 4 Incisive canal width at the palatal opening

Statistical analysis

All analyses were conducted using the Statistical Package for the Social Sciences (SPSS) version 26.0 software (IBM Corp., Armonk, NY, USA). The normality of the data was assessed using the Shapiro-Wilk test. The intraclass correlation coefficient (ICC), Cronbach's Alpha, and a 95% confidence interval were utilized to evaluate intra-observer and inter-observer reliability. Mean values and standard deviations were calculated for all parameters. The difference between various groups was assessed by either the independent sample t-test or the Mann-Whitney U test, with the significance threshold set at $P \leq 0.05$. Two trained examiners performed all the measurements. The Spearman Rank Correlation test was utilized to determine the correlation between the direction of impacted teeth and root axis curvature with the incisive canal and nasal cavity dimensions.

Results

Seventy CBCT scans from patients were selected for this study, with an average age of 8.98 ± 0.925 years. Of the cases, 48.57% ($n = 34$) were males and 51.43% ($n = 36$) were females. These cases were then divided based on the presence or absence of impaction of the maxillary central incisor into two groups: the control group (with no impaction of the maxillary central incisor) and the DIMCI group. There were 35 (50%) cases in each group. The exclusion rate was 55.22% based on the predetermined criteria.

To quantify intra-examiner agreement, ten subjects randomly chosen from each group were reassessed after a fortnight. The ICC disclosed immensely high consistency ($P < 0.001$). As demonstrated in supplementary table 2, the ICC values were extraordinarily high, each surpassing the suggested threshold of 0.95, implying negligible measurement error. Furthermore, all values fell within the tolerated error margin of 5%, affirming the study methodology's high reliability.

The mean direction of the long axis of the impacted tooth was 78.59 ± 27.80°, while the mean root axis curvature was 35.17 ± 22.01°.

Incisive canal volume and width

The volumetric of the incisive canal was significantly reduced in the DIMCI group compared to the control group (93.17 ± 12.72 vs.109.39 ± 12.28 mm^3). The width of the incisive canal at the palatal opening was also significantly narrower in the DIMCI group compared to the control group ($P = 0.002$). At H2 and H3, the incisive canal (CI-CI) width was considerably narrower in the DIMCI group compared to the control group ($P = 0.000$, $P = 0.004$), respectively. The mean incisor/PP was significantly larger in the DIMCI group compared to the control group ($P = 0.000$) (see Table 2).

Proximity of contralateral central incisor (U1) and IC

At the three vertical levels, almost all the Rm-Cat, Rm-Canal, and Cl-Root sagittal (anteroposterior) distances (definitions provided in Fig. 2) showed no significant changes compared to the control group (Table 2).

Nasal cavity width

In the DIMCI group, ANW exhibited a non-significant reduction (19.54 ± 1.98 mm) compared to the control group's ANW (20.30 ± 1.66 mm). Conversely, ANFW was significantly reduced (12.27 ± 1.60 mm) compared to the control group's ANFW (13.61 ± 1.57 mm) (Table 3).

Relationship between the impacted teeth direction and root axis curvature with incisive canal and nasal cavity dimensions

Table 4 used the Spearman Rank Correlation test to assess the correlation between the direction of impacted teeth and root axis curvature with the incisive canal and nasal cavity dimensions. A $P > 0.001$ indicated no correlation between these variables.

Discussion

The demographic data from the current study, involving 70 CBCT scans of patients with a mean age of 8.98 ± 0.925 years, shows a nearly equal gender distribution. These cases were divided into a control group and a group with DIMCI, each with equal representation, offering a solid basis for comparative analysis. The intra-examiner reliability, attested by a high ICC of 0.977, emphasizes the accuracy and repeatability of the measurements. This is essential in studies where minor measurement discrepancies can significantly influence the results.

The present study evaluated the relationship between dilacerated impacted maxillary central incisors and surrounding structures, such as the incisive canal and nasal cavity, using CBCT images. This aspect is clinically relevant from both orthodontist and surgeon perspectives. According to available literature, the current prevalence

Table 1 Measurements used in this study

Measurement	Definition
Measurements of Incisive Canal	
Measurement	**Definition**
Incisive canal volume (ICV) (mm^3)	The internal volume of the incisive canal.
Incisive Canal / Palatal plane (PP) angle (°)	The angle between the long axis of the Incisive Canal and the palatal plane.
Incisor/Palatal plane (PP) angle (°)	The angle between the long axis of each central incisor and the palatal plane.
Palatal alveolar bone width at the apical level (PABW) (mm)	The palatal bone width at the level of the central incisor apices.
Incisive canal width at palatal opening (mm)	The width of the incisive canal at the palatal opening.
CI-CI (mm)	The canal width is the distance from CI to CI.
Rm-Cat (mm)	The distance from Rm to Cat.
Rm-Canal (mm)	The distance from Rm to the anterior border of the incisive canal.
CI-Root (mm)	The distance from CI to the posterior border of the maxillary central incisor root.
Measurements of Nasal Cavity	
Measurement	**Definition**
Anterior Nasal Width (ANW) (mm)	Distance between the most lateral points along the inner surface of nasal lateral walls, taken at the coronal plane passing through nasion point.
Anterior Nasal Floor Width (ANFW) (mm)	Distance between the most lateral points along the inner surface of nasal lateral walls at the nasal floor level, taken at the coronal plane passing through nasion point.

of impacted maxillary central incisors ranges from 0.06 to 0.20%; only a few studies have reported slightly larger samples [23, 24].

Though numerous studies have investigated this dental anomaly, they have primarily analyzed how the impaction of the central tooth impacts adjacent teeth. Maxillary central incisors typically erupt between ages 8 and 10 years [25]. Because of their location, impacted maxillary central incisors pose a significant aesthetic concern for the affected child's. Monitoring the growth of the dentition closely and diagnosing any deviations in eruption patterns early is vital. It enables prompt intervention and correction [26, 27].

The present study included impacted maxillary central incisors with dilaceration located at levels 2 and 3 as classified by Vermette et al. [28], who categorized the levels of impaction based on the distance from the most apical point on the incisal edge of the impacted tooth. This distance is measured perpendicularly to a line connecting the incisal edges of the adjacent non-impacted teeth. Impactions less than 12 mm are classified as simple (level 1), 12–15 mm as medium (level 2), and more than 15 mm as complex (level 3). Level 1 impactions were excluded from this study due to their lower frequency and less significant expected impact on the incisive canal and nasal cavity.

Our study revealed a noticeable difference in the volume of the incisive canal between the two studied groups. The DIMCI group displayed a significant reduction compared to the control group. This suggests that the incursion of a central tooth significantly influences the incisive canal's volume, a previously unexplored point. Previous research investigating the interrelation between the incisive canal and maxillary central incisors did not address this correlation in instances of central tooth impaction [21, 29, 30]. Furthermore, prior studies have demonstrated that cases with a larger pre-treatment volume of the incisive canal incurred an incisive canal invasion following the retraction of the upper incisors [31]. Combining the findings of the mentioned previous study with our finding, the main clinical implication of both findings is that in cases where there is an impacted maxillary central incisor and part of the treatment planning will include incisor retraction, especially maximum incisor retraction, careful assessment of the incisive canal is required to avoid root resorption and incisive canal invading.

With regard to the IC width, the results of this study indicated that the sagittal measurements at the palatal opening are particularly informative, as a significant decrease in the sagittal width was observed in the DIMCI group ($P<0.05$). This reduction could suggest an association between the impaction of maxillary central incisors and alterations in the anatomical structure of the IC, potentially due to developmental anomalies or displacement caused by the impacted incisor. Furthermore, a significant narrowing of the IC width at horizontal levels H2 and H3 ($P<0.05$) further supports the hypothesis that impaction influences surrounding anatomical structures. Some studies have indicated that a narrow IC provides a greater opportunity to retract the incisors without the risk of contacting the cortical plate of the IC and causing root resorption [31–33].

Despite the significant differences observed in the dimensions of the IC, the proximity measurements of maxillary incisors and the IC at various vertical levels did not show significantly notable changes ($P>0.05$). This suggests that while impaction does influence the shape and size of the canal, it may not necessarily affect the relative positioning of the incisor to the canal in a measurable way. Further research could explore these spatial relationships to determine whether they influence or are influenced by the etiology of tooth impaction.

Regarding the inclination of the contralateral central incisor with the PP, this study demonstrated a significant increase in buccal inclination in the DIMCI group compared to the control group. This could emphasize the impact of maxillary central impaction on the spatial

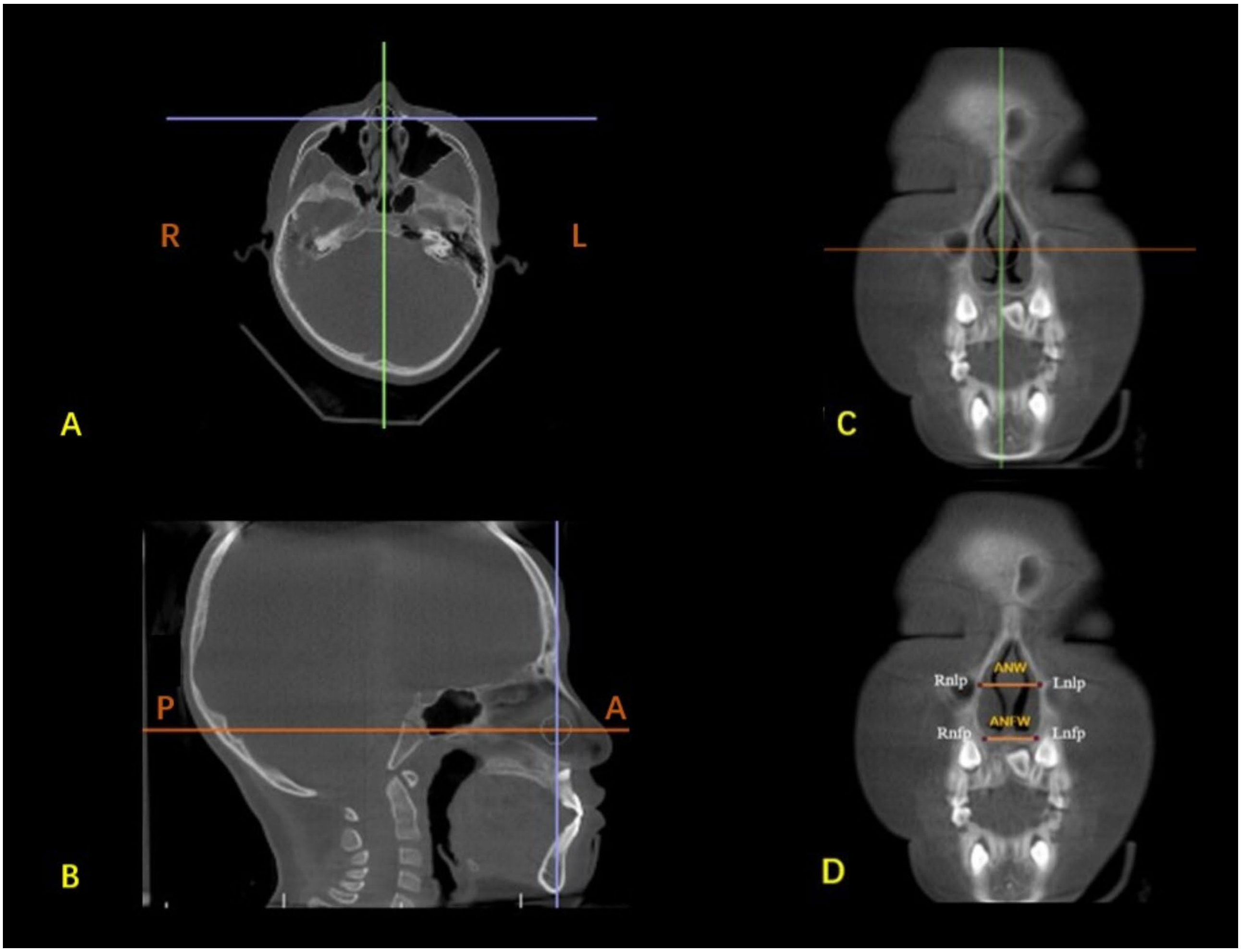

Fig. 3 Head re-orientation on the orthogonal planes of CBCT scans; **A**, axial plane, **B**, sagittal plane, and **C**, coronal plane. **D**, Linear measurements of anterior nasal width (ANW) and anterior nasal floor width (ANFW) in the coronal plane

orientation and potentially the functional alignment of neighboring incisors. This finding is consistent with the results of a previous study [34].

The maxillary central incisors are found directly beneath the nasal bones and adjacent to the nasal cavity. This proximity signifies an essential relationship between these teeth and the nasal cavity [19]. Interestingly, in the current study, the ANW displayed a non-significant reduction in the DIMCI group compared to the control group. This suggests that the developmental dynamics leading to impaction do not significantly affect larger maxillofacial structures such as the nasal cavity. However, this study uncovered that the ANFW was notably reduced in the DIMCI group. This significant reduction in ANFW indicates that impactions can affect dental structures and adjacent nasal anatomy, potentially influencing nasal physiology. Prior studies on changes in the nasal cavity following rapid maxillary expansion suggested that a decrease in nasal cavity width might reduce airway space, affecting nasal patency [35–37]. Therefore, additional research in association with the otolaryngological department must examine this spatial relationship and ascertain if pediatric patients with maxillary central impaction demonstrate reduced nasal function and require maxillary expansion.

Overall, the findings from this study provide valuable insights into the anatomical variations associated with dilacerated impacted maxillary central incisors. These insights enhance our understanding of the underlying mechanisms of tooth impaction and have potential implications for clinical practices, particularly in planning orthodontic or surgical interventions in pediatric patients.

Conclusion

Based on our findings, we draw four main conclusions: (1) The impaction of the maxillary central incisor could result in a reduction in the IC's volume and affect its width both sagittally and axially; (2) The impaction of the maxillary central incisor is linked with an increased

Table 2 Results of statistical comparisons of incisive canal measurements between the control and impaction groups

	Control Group		Impacted Group		Control Group- Impacted Group		t	*P*
	Mean	SD	Mean	SD	Mean	SD		
ICV (mm^3)	109.39	12.28	93.17	12.72	16.22	-0.44	6.93	0.000***
Incisive Canal/PP (°)	103.14	4.16	103.30	6.68	-0.16	1.33	-0.12	0.903
Incisor/PP (°)	109.09	3.74	113.18	2.77	-4.09	0.97	-4.22	0.000***
PABW at apex level (mm)	2.20	1.08	2.58	1.15	-0.38	0.27	-1.43	0.158
Incisive Canal width at palatal opening (mm)	3.13	0.82	2.50	0.80	0.63	0.19	3.24	0.002**
CI-CI H1 (mm)	3.51	0.81	3.29	0.65	0.18	-0.13	1.26	0.212
Rm-Cat H1(mm)	4.15	0.74	4.30	1.10	0.22	-0.60	-0.70	0.487
Rm-Canal H1 (mm)	4.47	0.75	4.18	0.94	0.20	-0.11	1.44	0.153
CI-Root H1 (mm)	2.39	0.60	2.62	1.18	0.22	-0.68	-0.11	0.297
CI-CI H2 (mm)	3.26	0.75	2.89	0.76	0.18	0.88	6.89	0.000***
Rm-Cat H2 (mm)	3.72	0.88	3.61	1.10	0.11	0.24	0.46	0.644
Rm-Canal H2 (mm)	4.12	0.89	4.09	1.06	0.03	0.23	0.13	0.90
CI-Root H2 (mm)	2.64	0.77	2.65	1.06	-0.01	0.22	-0.05	0.961
CI-CI H3 (mm)	3.01	0.78	2.54	0.55	0.48	0.16	2.95	0.004**
Rm-Cat H3 (mm)	3.23	1.05	3.28	1.16	-0.05	0.27	-0.18	0.861
Rm-Canal H3 (mm)	NA	NA	NA	NA	NA	NA	NA	NS
CI-Root H3 (mm)	NA	NA	NA	NA	NA	NA	NA	NS

SD; standard deviation, $^{**}P<0.01$; $^{***}P<0.001$

*Note: NA; not applicable

Table 3 Results of statistical comparisons of nasal cavity measurements between the control and impaction groups

	Control Group		Impacted Group		Control Group- Impacted Group		t	*P*
	Mean	SD	Mean	SD	Mean	SD		
Anterior nasal width (ANW) (mm)	20.30	1.66	19.54	1.98	0.76	0.44	1.76	0.084
Anterior nasal floor width (ANFW) (mm)	13.61	1.57	12.27	1.60	1.35	0.38	3.56	0.001***

SD; standard deviation, $^{***}P<0.001$

Table 4 Correlation between the measurements of impacted maxillary central incisors and incisive canal and nasal cavity measurements

	Direction of the long axis of the crown		Root axis curvature	
	r-value	*P*-value	*r*-value	*P*-value
ICV (mm^3)	0.026	0.882	0.083	0.634
Incisive Canal/PP (°)	-0.280	0.103	-0.248	0.151
Incisor/PP (°)	-0.019	0.913	-0.122	0.484
PABW at apex level (mm)	0.059	0.737	0.178	0.307
Incisive Canal width at palatal opening (mm)	0.099	0.572	-0.078	0.658
CI-CI H1 (mm)	-0.022	0.901	-0.134	0.443
Rm-Cat H1 (mm)	0.082	0.641	0.121	0.488
Rm-Canal H1 (mm)	0.099	0.570	0.190	0.274
CI-Root H1 (mm)	0.164	0.346	0.357	0.035
CI-CI H2 (mm)	-0.100	0.567	-0.043	0.804
Rm-Cat H2 (mm)	0.005	0.977	0.062	0.722
Rm-Canal H2 (mm)	-0.062	0.725	0.044	0.801
CI-Root H2 (mm)	0.213	0.220	0.433	0.009
CI-CI H3 (mm)	-0.029	0.870	-0.140	0.423
Rm-Cat H3 (mm)	0.035	0.840	0.122	0.484
Anterior Nasal Width (ANW) (mm)	0.250	0.148	0.227	0.190
Anterior Nasal Floor Width (ANFW) (mm)	0.038	0.827	– 0.027	0.879

buccal inclination of the contralateral central incisor; (3) Pediatric patients suffering from impaction may exhibit decreased anterior nasal floor width, suggesting a potential need for maxillary expansion to mitigate future nasal function issues; and (4) We found no correlation between the direction of impacted teeth and root axis curvature with the dimensions or volume of the IC and nasal cavity.

Limitations

One limitation of this study is the relatively small sample size ($n = 70$) and the fact that the data was collected from a single center. These factors may limit the generalizability of the findings to a larger, more diverse population. While the results provide valuable insights, the sample size and setting may not fully represent the broader population of children with similar dental conditions. To enhance the external validity of these findings, future studies should consider including larger, multi-center studies with more diverse patient populations. This would allow for a more comprehensive analysis of the factors influencing the outcomes and provide more robust conclusions that could be applied to a wider range of patients. The retrospective nature of this study is another limitation that requires good attention to minimize the selection bias by conducting a prospective clinical trial.

Abbreviations

DIMCI	Dilacerated impacted maxillary central incisor
CBCT	Cone Beam Computed Tomography
3D	Three-dimensional
ICC	Intra-class correlation coefficient
MPA	Mandibular plan angle
FH	Frankfort horizontal
U1	Upper incisor
PP	Palatal plane

Supplementary Information

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Supplementary Material 1

Supplementary Material 2

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Not applicable.

Author contributions

AE is the primary author of this manuscript, contributing to the conception, design, protocol execution, data acquisition, interpretation, analysis, drafting, and critical revision of the manuscript. ZBW and ASA contributed to the conception, design, and critical revision of the manuscript. AB and SHM were involved in data acquisition and analysis. YH contributed to analysis, interpretation, and critical revision of the manuscript. AMS contributed to Grammatical, typo and intellectual editing of the manuscript. LY contributed to the conception, design, interpretation, and critical revision of the manuscript. All authors reviewed the results and approved the final version.

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Data availability

The data utilized and/or analyzed in this study can be obtained from the corresponding author upon reasonable request.

Declarations

Ethics approval and consent to participate

This study was approved by the Ethical Committee of China Medical University and Stomatology Hospital of China Medical University, China, Ethics Approval Number: (No. CMUKQ-2024-020). Informed written consent was obtained from the participant's parents or guardians before the patient entered the study. All methods were carried out in accordance with the principles of the declaration of Helsinki.

Consent for publication

Not applicable.

Competing interests

The authors declare no competing interests.

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