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ORIGINAL ARTICLE

Epidemiological, clinical, and 3-dimentional CBCT radiographic characterizations of supernumerary teeth in a non-syndromic adult population: a single-institutional study from 60,104 Chinese subjects

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Abstract

Objective This study was aimed to delineate the prevalence, clinical, and 3-dimentional radiographic characteristics of adult supernumerary teeth (ST found) in a Chinese non-syndromic, dental population.

Materials and methods Medical records and cone beam computed tomography (CBCT) images were utilized to identify adult patients with ST in a tertiary referral dental hospital between June 2012 and December 2018. CBCT scan coupled with 3-dimentional reconstruction was used to characterize the detailed location, morphology, orientation of ST, and their relationship with adjacent teeth and neighboring structures. All relevant information regarding age and gender of patients, morphology, and 3-dimentional topography of ST as well as ST-associated complications were recorded and statistically analyzed.

Results A total number of 1149 ST was identified in 921 eligible patients screened from 60,104 subjects with the prevalence of 1.5%. Male patients outnumbered females with a gender ratio of 1.76:1. The majority of ST was single, located in the maxilla, especially the maxillary central incisor region. Most ST were conical shape, inverted orientation, and impacted. ST-associated complications including impaction or root resorption of adjacent teeth, and cystic/tumor-like lesions were totally found in 13% ST and significantly associated with location, orientation, and morphology of ST.

Conclusions Most ST in Chinese adults were conical, inverted, impacted, and located in the maxillary central incisor region, and associated with various complications. Our findings offer valuable information concerning the prevalence, clinical, and radiographic characteristics of ST in non-syndromic Chinese adults.

Clinical relevance These findings are beneficial for clinicians to comprehensively understand the incidence, pathogenesis, and clinical management of ST.

Keywords Supernumerary teeth · Permanent dentition · Cone beam computed tomography (CBCT) · Epidemiology

Introduction

Supernumerary teeth (ST) are defined as teeth or tooth-like structures that have erupted or kept impacted in jaws in addition to the 20 primary teeth or 32 permanent teeth, which are also one of the most common developmental anomalies among humans [1, 2]. Although the accurate etiology of ST remains incompletely known thus far, various hypotheses have been proposed to explain the etiology and pathogenesis of ST, including atavism, the dichotomy of tooth germ, hyperactivity of dental lamina, and environmental factors [1, 3]. Previous reports have also suggested the key roles of genetics and heredity responsible for the occurrence of ST, especially in those syndromic patients or patients with family history [4, 5].

The prevalence of ST ranges from 0.2 to 0.8% in primary dentition and from 1.5 to 3.8% in permanent dentition,

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respectively [6–9]. ST in males are more prevalent than those in females with ratios from 1.18:1 to 4.5:1 [10, 11]. Several studies have documented the prevalence of ST in certain ethnic populations like Turkish, Italian, and Chinese, and also revealed ethnic-specific or geographic characteristics [12–15]. In addition, ST can be single or multiple, unilateral or bilateral in their distribution, and more frequently occur in the maxilla than the mandible [6, 14]. Despite of its rarity in the population and sometimes asymptomatic, ST have possibilities to induce various complications such as failure of eruption, displacement, root resorption, and crowding of adjacent teeth, as well as cyst or tumor formation [10, 16].

Traditionally, ST were occasionally found and diagnosed using panoramic radiographs. However, routine 2-dimensional (2D) radiographic images failed to assess accurate locations of tooth as well as its spatial relationships with neighboring structures and adjacent teeth, which are pivotal for treatment planning. Conventional CT provides highly detailed three-dimensional (3D) information without superposition of bony and dental structures. However, the disadvantages of its relatively high cost and high radiation dose outweigh these advantages during ST diagnosis [17]. With the advent of cone beam computed tomography (CBCT) and its popular utilization in dentistry, CBCT coupled with 3-dimentional reconstruction offers adequate and precise information regarding location and morphology of dental structure of interest. Thus, CBCT has been advocated to determine the accurate location and shape of ST as well as their associated conditions such as root resorption of neighboring teeth [10, 18, 19]. Several pioneering studies have reported the clinical and radiographic characterizations of ST using CBCT scan and supported the values of CBCT to assist the diagnosis, treatment planning, and operative removal of ST [10, 17, 19, 20].

The purpose of this study was to present the epidemiological, clinical, and 3-dimentional CBCT radiographic characteristics of non-syndromic ST in a Chinese adult, dental population. Our findings are beneficial for clinical diagnosis and treatment planning as well as epidemiological studies of ST.

Materials and methods

Patients

This study enrolled adult patients (age over 18 years old) who underwent CBCT radiography at their initial visits to Affiliated Stomatological Hospital, Nanjing Medical University, for their dental or maxillofacial diseases from June 2012 to December 2018. Subjects with prior history of tooth extractions, maxillofacial anomalies such as cleft lip and palate, or diseases associated with systemic conditions and craniofacial syndromes were excluded. To verify the diagnosis of ST, two professional dentists (Drs. Yue Jiang and Xiaowei Ma) evaluated the CBCT images independently and achieved the final consensus after consultation with another examiner (Dr. Dongmiao Wang) when different diagnoses were reported. Among 60,104 adult patients with qualified CBCT and detailed medical records available, one or more ST were found in 921 patients after 3-dimentional CBCT examinations. Thus, these 921 eligible patients with 1149 ST were enrolled and defined as research cohort here. All relevant epidemiological data (age, gender), clinical information, and radiographic details about ST (the number, morphology, location, eruption state, and associated complications) were collected. The methods and protocols were performed in accordance with the tenets of the Declaration of Helsinki for research involving human subjects. The whole study was reviewed and approved by the Ethics and Research Committee, Nanjing Medical University.

Detailed characterizations of ST in 3-dimentional CBCT radiography

All original CBCT data in DICOM format for each patient were retrieved from our CBCT radiographic data center and then individually introduced into Proplan CMF 1.4 software (Materialise NV, Leuven, Belgium) for further assessments. Detailed characterizations of ST from axial, sagittal, and coronal CBCT views as well as 3-dimentional image reconstruction were performed similarly as previous reports [10, 14, 17] and listed as follows:

1 Type of ST: mesiodens, lateral incisors, canines, premolars, paramolars, and distomolars.
2 Morphology of ST: conical, tuberculate, supplemental, and germ (Fig. 3).
3 Location of ST crown: labial/buccal, median/within arch, and palatal/lingual (Fig. 4).
4 Orientation of ST: normal, inclined, transverse, inverted, and horizontal (Fig. 5).
5 State of eruption of ST: erupted or impacted.
6 Spatial relationship of ST with neighboring structures: nasal floor, nasopalatine canal, maxillary sinus, or mandibular ramus (Fig. 6).
7 Associated complications: impaction of adjacent tooth, root resorption of adjacent tooth and cystic/tumor lesions (Fig. 6).

Statistical analyses

All relevant data including the demographic, clinical, and radiographic data of patients were collected. Associations between categorical covariates were assessed by Chi-square tests or Fisher exact test as indicated. The inter-observer variability and reproducibility of these radiographic measurements were

assessed with Cohen's kappa values. All tests were two-sided, and *P* values less than 0.05 were considered statistically significant. All statistical analysis was performed with GraphPad Prism 8.0 and Stata 14 software.

Results

Demographic characteristics of patients and epidemiological features of supernumerary teeth

Through CBCT screen and medical record review, 912 adult patients with 1149 ST satisfied our inclusion criteria, which were enrolled here. As listed in Table 1, among these patients included, 581 (63.71%) were males and 331 (36.29%) were females, presenting a gender ratio of 1.76:1 and an obvious male preponderance. The ages of patients ranged from 18 to 87 years with a mean age of 35 years. Among these adults, ST was the most commonly found in their 18–30 years (49.56%), and the incidence gradually decreased as the age became larger. Most of the patients had single ST (710, 77.85%), while 202 (22.15%) patients had multiple ST.

As shown in Table 2, ST were more frequently found in the maxilla than mandible (949/200). The most common region for ST is the middle incisor area in the anterior maxilla (701 teeth), followed by the mandibular premolar region (153 teeth) and maxillary lateral incisor region (100 teeth). The total number and detailed distribution of ST in the maxillary and mandibular dental arches were shown in Fig. 1.

Table 1 Descriptive epidemiological data of 912 adult patients with supernumerary teeth, *ST* supernumerary teeth

Variable		Number (%)
Age (years)	Mean 35 (18–87)	
	18–30	452 (49.56%)
	31–40	176 (19.30%)
	41–50	136 (14.91%)
	51–60	73 (8.00%)
	> 60	75 (8.22%)
Gender	Male	581 (63.71%)
	Female	331 (36.29%)
Number of ST	Single	710 (77.85%)
	Multiple (2 3 4 5 6 8)	202 (22.15%)
Arch	Maxilla	768 (84.21%)
	Mandible	126 (13.82%)
	Both	18 (1.97%)
Side	Right side	302 (33.11%)
	Left side	247 (27.08%)
	Midline	189 (20.72%)
	Multiple regions	174 (19.08%)

Representative CBCT images showing diverse numbers of ST in jaws were displayed in Fig. 2.

Interrater agreement regarding 3-dimentional CBCT radiographic evaluations of supernumerary teeth

To testify the reliability and reproducibility of our 3-dimentional CBCT radiographic evaluations of ST, 50 patients were randomly selected from these 912 patients and initially evaluated by two independent examiners (Dr. Yue Jiang and Xiaowei Ma) for ST in their jaws via CBCT radiography. The data regarding location, morphology, and orientation as well as associated pathologies of ST were recorded and compared between these two dentists. The Cohen's kappa values for interrater agreement in terms of these measurements ranged from 0.72 to 0.95, thus supporting the reliability and reproducibility of our 3-dimentional CBCT evaluation about ST.

Morphology and 3-dimentional position of supernumerary teeth

Similar with previous reports [10, 21], morphological classifications of ST include the following 4 types: conical, tuberculate, supplemental, and germ (Fig. 3). Conical was the most common morphology (805 teeth) and most of these conical ST (621 teeth) were situated in the maxillary central incisor region. The second common morphology was supplemental (186 teeth), which were frequently located in the premolar region. In addition, 138 and 20 ST were tuberculate or germ morphology, respectively.

To comprehensively characterize the positions of ST in a 3-dimentional manner, we analyzed these teeth from three aspects including localization of crown, orientation, and eruption status. As shown in Fig. 4, similar with previous studies [10, 14], localization of the crown can be classified into three types as labial/buccal, median/within arch, or oral (palatal/lingual). Among 1149 ST, 917 were identified as palatally/lingually located, 144 median/within the arch, and 88 buccally/labially located. In terms of orientation of ST, five subtypes such as normal, inclined, transverse, inverted, and horizontal orientation were radiographically defined according to CBCT scan (Fig. 5). Inverted orientation was the most common type (554 teeth), followed by normal orientation (264 teeth), inclined orientation (146 teeth), transverse orientation (142 teeth), and horizontal orientation (43). Among the 554 inverted ST, most were situated in the anterior area of the jaws (468 in central incisor region, 38 in lateral incisor region, 26 in canine region). However, normal and inclined orientations of ST in the posterior area of the jaws were more common than others. Moreover, most ST (1029 teeth) were impacted and 120 were erupted. Detailed data regarding location, orientation, and eruption status of ST were listed in Table 2.

Table 2 Descriptive data regarding location, morphology, orientation, eruption status, and associated complications of 1149 supernumerary teeth

		Mesiodens	Lateral	Canine	Premolar	Paramolar	Distomolar	*P* value
Number	1149	703	101	74	191	55	25	
Arch								< 0.001*
Maxilla	949	701 (73.87%)	100 (10.54%)	58 (6.11%)	38 (4.00%)	28 (2.95%)	24 (2.53%)	
Mandible	200	2 (1.00%)	1 (0.50%)	16 (8.00%)	153 (76.50%)	27 (13.50%)	1 (0.50%)	
Morphology								< 0.001*
Conical	805	621 (77.14%)	78 (9.69%)	57 (7.08%)	24 (2.98%)	10 (1.25%)	15 (1.86%)	
Tuberculate	138	65 (47.10%)	15 (10.87%)	7 (5.07%)	20 (14.49%)	23 (16.67%)	8 (5.80%)	
Supplemental	186	16 (8.60%)	7 (3.76%)	10 (5.38%)	131 (70.43%)	20 (10.75%)	2 (1.08%)	
Germ	20	1 (5.00%)	1 (5.00%)	0 (0.00%)	16 (80.00%)	2 (10.00%)	0 (0.00%)	
Localization of crown								< 0.001*
Labial/buccal	88	44 (50.00%)	3 (3.40%)	8 (9.09%)	4 (4.55%)	20 (22.73%)	9 (10.23%)	
Median	144	78 (54.17%)	13 (9.03%)	9 (6.25%)	20 (13.89%)	11 (7.63%)	13 (9.03%)	
Palatal/lingual	917	581 (63.36%)	85 (9.27%)	57 (6.22%)	167 (18.21%)	24 (2.62%)	3 (0.32%)	
Orientation								< 0.001*
Normal	264	91 (34.47%)	25 (9.47%)	16 (6.06%)	88 (33.33%)	28 (10.61%)	16 (6.06%)	
Inclined	146	23 (15.75%)	10 (6.85%)	15 (10.27%)	70 (47.95%)	21 (14.38%)	7 (4.80%)	
Inverted	554	468 (84.48%)	38 (6.86%)	26 (4.69%)	19 (3.43%)	3 (0.54%)	0 (0.00%)	
Transverse	142	97 (68.31%)	19 (13.38%)	12 (8.45%)	11 (7.75%)	1 (0.70%)	2 (1.41%)	
Horizontal	43	24 (55.81%)	9 (20.93%)	5 (11.63%)	3 (6.98%)	2 (4.65%)	0 (0.00%)	
Eruption status								< 0.001*
Erupted	120	46 (38.33%)	13 (10.83%)	9 (7.50%)	32 (26.67%)	14 (11.67%)	6 (5.00%)	
Impacted	1029	657 (63.85%)	88 (8.55%)	65 (6.32%)	159 (15.45%)	41 (3.98%)	19 (1.85%)	
Cystic lesion								=0.001*
Yes	94	67 (71.28%)	12 (12.77%)	9(9.57%)	4 (4.26%)	2 (2.12%)	0 (0.00%)	
No	1055	636 (60.28%)	89 (8.44%)	65(6.16%)	187 (17.73%)	53 (5.02%)	25 (2.37%)	
Root resorption of adjacent tooth								< 0.001*
Yes	43	11 (25.58%)	3 (6.98%)	0(0.00%)	14 (32.56%)	15 (34.88%)	0 (0.00%)	
No	1106	692 (62.57%)	98 (8.86%)	74(6.69%)	177 (16.00%)	40 (3.62%)	25 (2.26%)	
Impaction of adjacent tooth								=0.003*
Yes	23	7 (30.43%)	2 (8.70%)	5(21.74%)	6 (26.08%)	1 (4.35%)	2 (8.70%)	
No	1126	696 (61.81%)	99 (8.79%)	69(6.13%)	185 (16.43%)	54 (4.80%)	23 (2.04%)	

*Statistically significant ($P < 0.05$). The *P* value is calculated by Chi-square tests or Fisher exact test using Stata 14.0

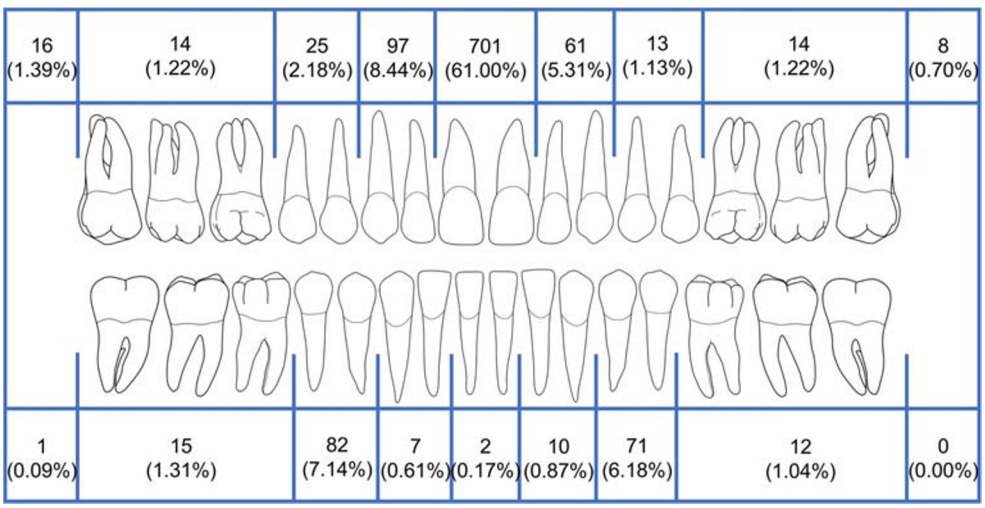

Fig. 1 Detailed distribution of supernumerary teeth in maxillary and mandibular dental arches

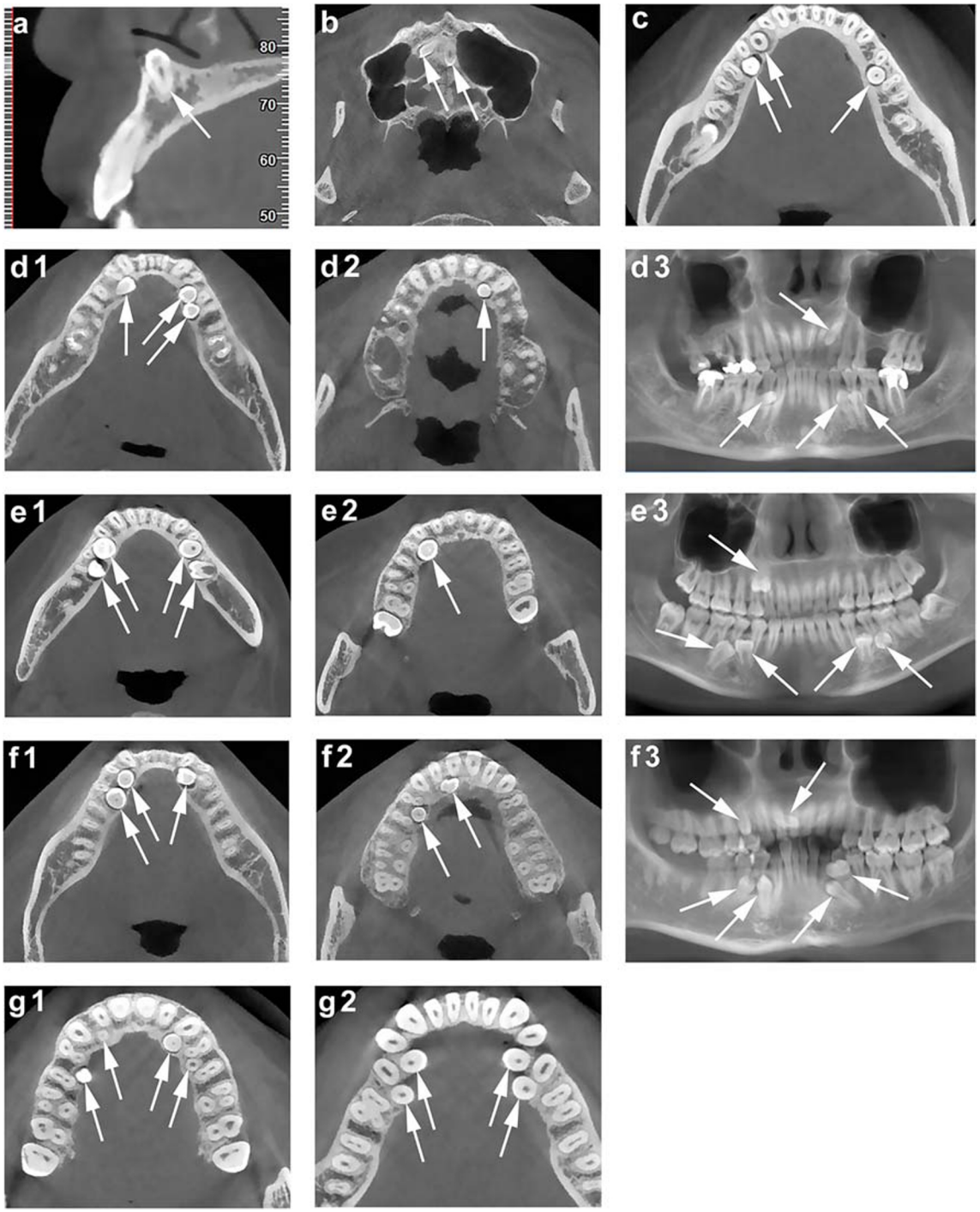

Fig. 2 Representative CBCT images exhibiting diverse numbers of ST. (a) Single ST; (b) Two ST; (c) Three ST; (d1–d3) Four ST; (e1–e3) Five ST; (f1–f3) Six ST; (g1–g2) Eight ST. The white arrows point to the ST in the CBCT images

ST-associated complications

As shown in Fig. 6, ST sometimes can be found in local neighboring structures including the nasopalatine canal, nasal floor, maxillary sinus, or mandibular ramus, which usually cause aberrations or complications. Noticeably, these ST-associated complications included cystic lesions, root resorption of adjacent tooth, and impaction of adjacent tooth, as well as combinations of these complications. However, these situations did not always induce prominent discomfort or symptoms in the clinic. In our cohort, 94 ST-associated cystic lesions were found, which were further diagnosed as common cyst, dentigerous cyst, and ameloblastoma following post-surgical pathology (Fig. 6e). ST-associated root resorption or impaction of adjacent teeth

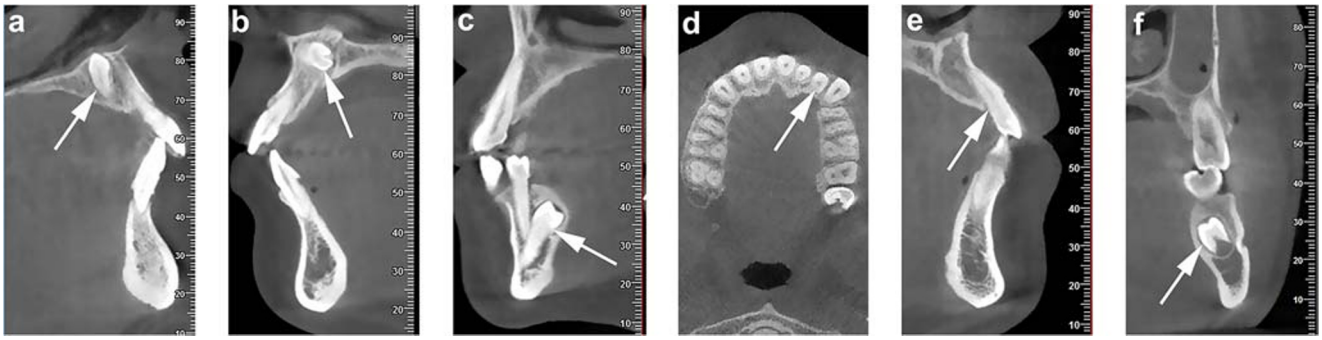

Fig. 3 Representative CBCT images exhibiting morphology of ST. **a** conical morphology; **b** tuberculate morphology; **c** supplemental morphology of premolar; **d** supplemental morphology of lateral incisor (axial image); **e** supplemental morphology of lateral incisor (sagittal image); **f** germ morphology. The white arrows point to the ST in the CBCT images

was detected with 43 and 23 patients, respectively (Fig. 6f, g). Interestingly, ST-associated cystic lesions combined with root resorption or impaction of adjacent tooth were identified in 12 patients (Fig. 6h).

To further explore the potential associations between these complications and location, morphology, and orientation of ST, we performed statistical analysis and listed the detailed data in Table 3. Our data revealed that the occurrence of complications was significantly associated with position and morphology of ST. For example, cystic lesions were significantly associated with the morphology, orientation, and maxilla/mandible distribution of ST. Among 94 cystic lesions, most occurred in the maxilla and these associated ST frequently presented as conical morphology and inverted orientation. Moreover, root resorption of adjacent teeth was also significantly associated with the morphology, orientation, and

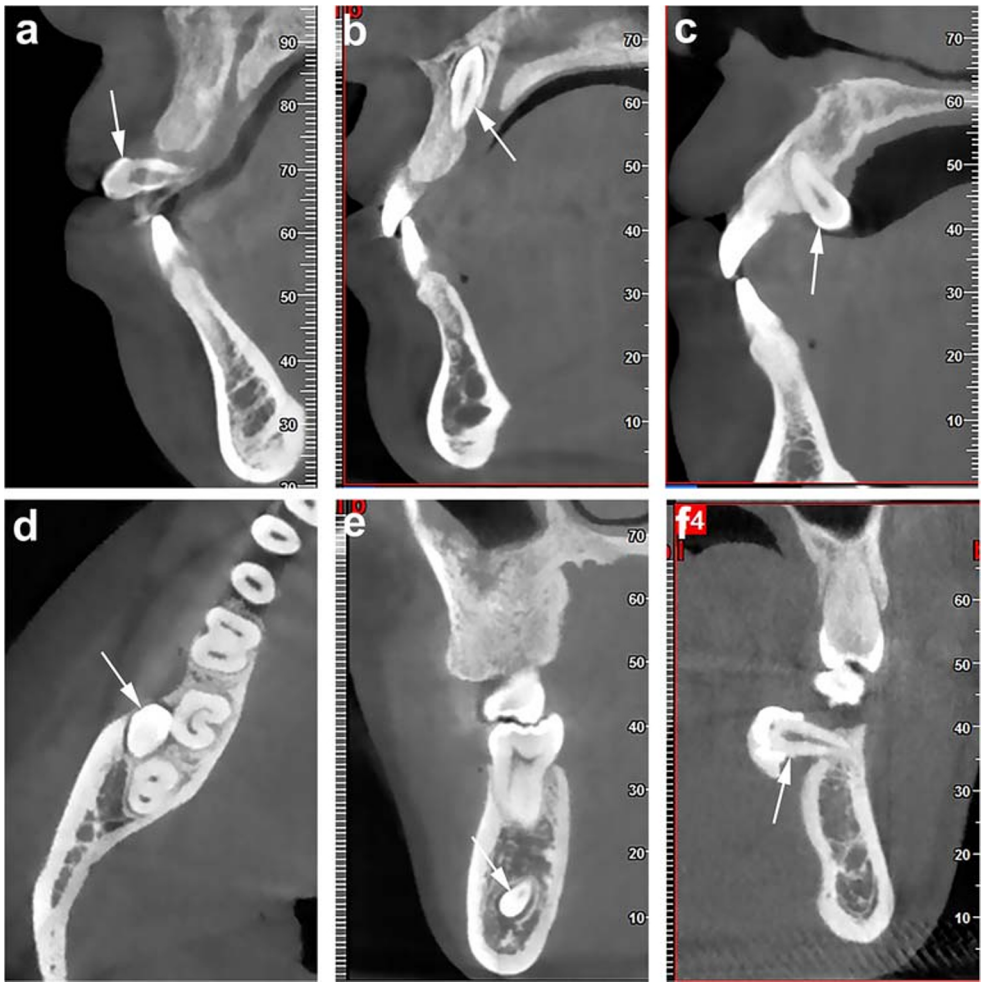

Fig. 4 Representative CBCT images exhibiting locations of ST crown. **a-c** Locations of ST crown in maxilla (**a** labial location of the crown; **b** median location of the crown; **c** palatal location of the crown), **d-f** locations of ST crown in mandible (**d** buccal location of the crown; **e** median location of the crown; **f** lingual location of the crown). The white arrows point to the ST in the CBCT images

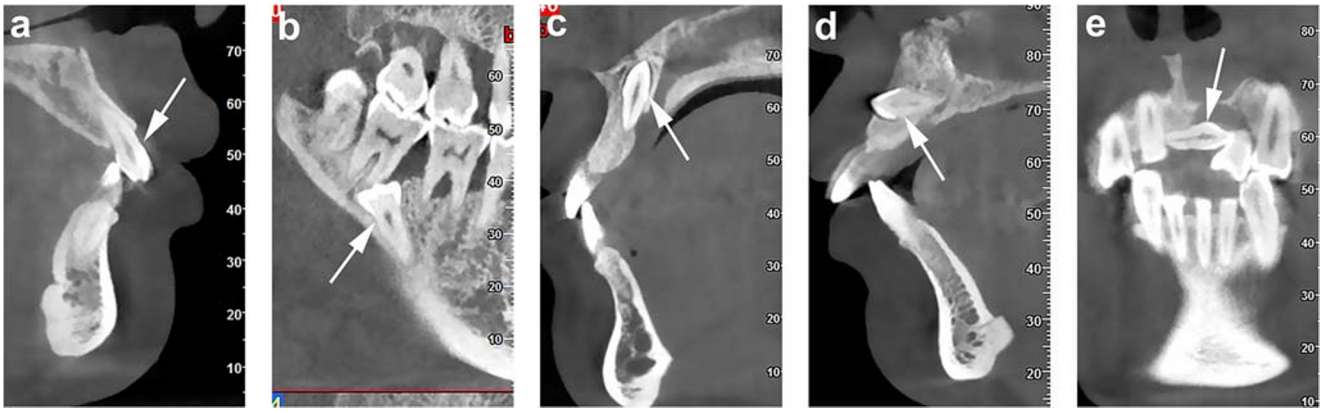

Fig. 5 Representative CBCT images exhibiting orientation of ST. **a** Normal orientation; **b** inclined orientation; **c** inverted orientation; **d** transverse orientation; **e** horizontal orientation. The white arrows point to the ST in the CBCT images

maxilla/mandible distribution of ST. Among 200 ST in mandible, 12.5% were associated with root resorption of adjacent teeth and they usually appeared as supplemental morphology and inclined orientation. However, it seemed that quite fewer (1.9%) root resorption of adjacent tooth was found to be associated with ST in the maxilla. Additionally, impaction of adjacent tooth significantly associated with localization of crown and more frequently occurred with ST which were located palatal/lingual, although its incidence was relatively low in both jaws.

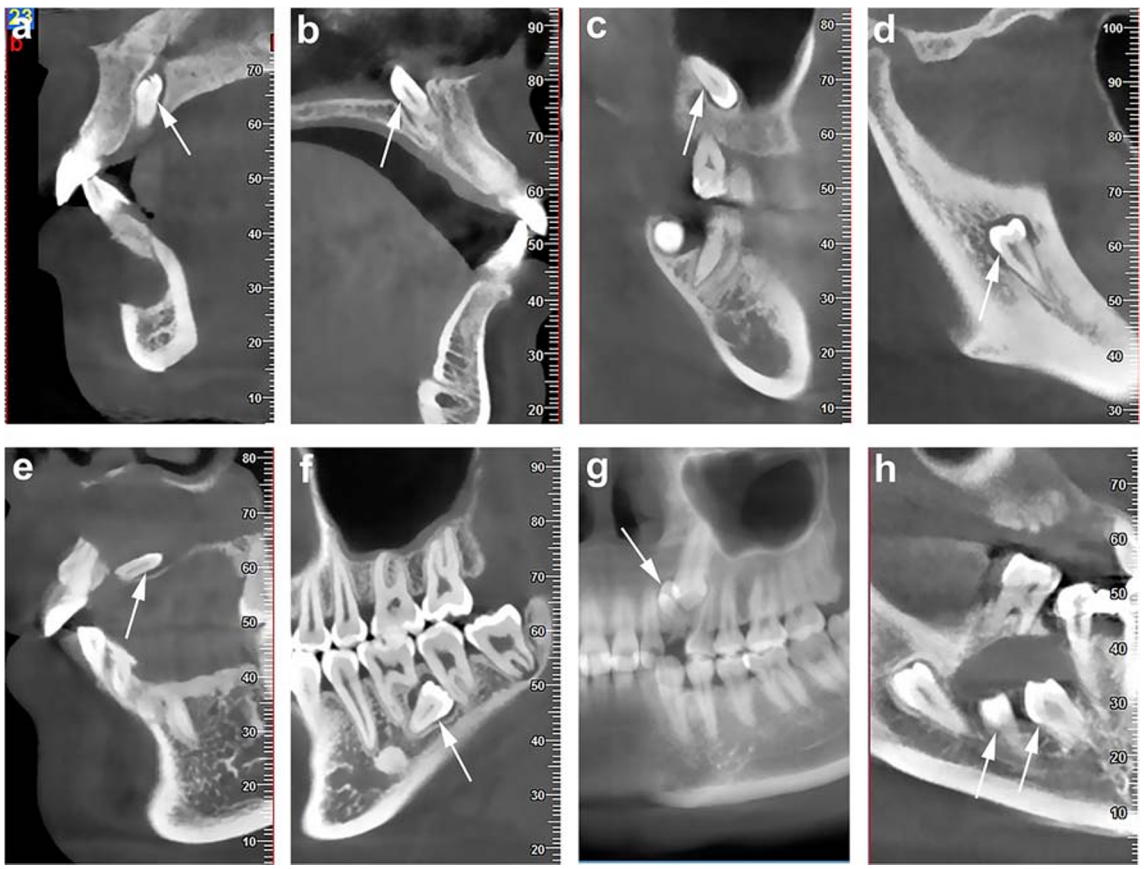

Fig. 6 Representative CBCT images exhibiting relationship of ST with neighboring structures and their associated complications. **a** ST located in nasopalatine canal; **b** ST penetrated into nasal floor; **c** ST located in maxillary sinus; **d** ST located within mandibular ramus; **e** ST-associated cystic lesions in maxilla; **f** ST-associated root resorption of adjacent tooth and concomitant cystic lesion in mandible; **g** ST-associated impaction of adjacent tooth; **h** ST-associated cystic lesion and concomitant impaction of adjacent tooth in mandible. The white arrows point to the ST in CBCT images

Table 3 Relationship between complications and location, morphology, and orientation of 1149 supernumerary teeth

	Cystic lesion		*P* value	Root resorption of adjacent tooth		*P* value	Impaction of adjacent tooth		*P* value
	Yes	No		Yes	No		Yes	No	
	94	1055		43	1106		23	1126	
Arch			< 0.001*			< 0.001*			=0.580
Maxilla	91 (9.59%)	858 (90.41%)		18 (1.9%)	931 (98.1%)		18 (1.9%)	931 (98.1%)	
Mandible	3 (1.50%)	197 (98.50%)		25 (12.5%)	175 (87.5%)		5 (2.5%)	195 (97.5%)	
Morphology			< 0.001*			< 0.001*			=0.053
Conical	68 (8.45%)	737 (91.55%)		14 (1.74%)	791 (98.26%)		16 (1.99%)	789 (98.01%)	
Tuberculate	21 (15.22%)	117 (84.78%)		7 (5.07%)	131 (94.93%)		1 (0.72%)	137 (99.28%)	
Supplemental	5 (2.69%)	181 (97.31%)		20 (10.75%)	166 (89.25%)		4 (2.15%)	182 (97.85%)	
Germ	0 (0.00%)	20 (100.00%)		2 (10.00%)	18 (90.00%)		2 (10.00%)	18 (90.00%)	
Localization of crown			=0.863			=0.388			=0.004*
Labial/buccal	8 (9.09%)	80 (90.91%)		2 (2.27%)	86 (97.73%)		2 (2.27%)	86 (97.73%)	
Median	13 (9.03%)	131 (90.97%)		8 (5.56%)	136 (94.44%)		8 (5.56%)	136 (94.44%)	
Palatal/lingual	73 (7.96%)	844 (92.04%)		33 (3.60%)	884 (96.40%)		13 (1.42%)	904 (98.58%)	
Orientation			< 0.001*			< 0.001*			=0.597
Normal	5 (1.89%)	259 (98.11%)		14 (5.30%)	250 (94.70%)		6 (2.27%)	258 (97.73%)	
Inclined	7 (4.79%)	139 (95.21%)		17 (11.64%)	129 (88.36%)		5 (3.42%)	141 (96.58%)	
Inverted	56 (10.11%)	498 (89.89%)		5 (0.90%)	549 (99.10%)		9 (1.62%)	545 (98.38%)	
Transverse	18 (12.68%)	124 (87.32%)		5 (3.52%)	137 (96.48%)		3 (2.11%)	139 (97.89%)	
Horizontal	8 (18.60%)	35 (81.40%)		2 (4.65%)	41 (95.35%)		0 (0.00%)	43 (100.00%)	

*Statistically significant ($P < 0.05$). The *P* value is calculated by Chi-square tests or Fisher exact test using Stata 14.0

Discussion

Supernumerary teeth (ST) are defined as teeth or tooth-like structures in jaws in excess of the usual number and regarded as common developmental anomalies [1, 2]. Several studies have documented the different prevalence of ST in certain ethnic populations and revealed some ethnic-specific characteristics of ST among diverse population [12, 13, 15]. Here, we screened non-syndromic ST in adults from a dental population of 60,104 patients by CBCT radiographic examinations and presented a comprehensive view of epidemiological and clinical as well as radiographic features of ST found in 1149 teeth from 912 Chinese adults. To the best of our knowledge, this might be a single study concerning ST in adults with the largest number of patients from single ethnic population, which offers valuable data for future studies.

Previous studies have established that ST more frequently occurred in permanent dentition than deciduous dentition [9, 11, 14]. The reported incidence of ST in permanent dentition of Caucasians is between 0.15 and 3.9% and might be highest among the Mongoloid [11, 22]. In the primary dentition, the prevalence is less than 1% for Caucasians, while 2.8% and 7.8% are reported in Hong Kong and Taiwan populations, respectively [14, 23]. Consistent with these prior studies, the prevalence of ST in our adult cohort was 1.5% (912/60104), which fell into the reported range [11]. In addition, among patients with ST, males outnumbered females with an obvious male predilection. This notion generally corroborated the gender predilection in ST as previously reported [24]. Higher prevalence in males may be due to the association of ST with autosomal recessive genes which has a greater penetration in males [25]. Of course, the accurate mechanisms underlying the ethnic and gender differences regarding ST remain incompletely known, which deserves further clarification.

Indeed, single or multiple ST can be identified in any regions of the jaws. However, single ST was much more common than multiple ST in patients as evidenced by previous reports which had documented single ST in 76–86% patients as well as multiple ST in 14–31% patients [11, 25, 26]. In line with this, the majority of patients had single ST (77.85%) and 22.15% patients had multiple ST in our cohort. Regarding the distribution of ST, the maxilla has been well established as the most frequent site compared with the mandible [6, 11, 27]. Bereket et al. found that most of ST were located in the maxilla (78%) with the remaining in the mandible in their total number of 1100 ST in a non-syndromic Turkish population based on panoramic radiographs [12]. In accordance with these results, the majority of ST in our cohort was found in the maxilla (84.21%) and quite a few in the mandible (13.82%). In particular, extremely rare ST was found in the mandibular incisor region, which was in agreement with previous studies where ST were rarely located in the mandibular incisor and canine regions [12, 28]. Intriguingly, multiple ST were simultaneously identified in both the maxilla and mandible in 18 (1.97%) patients. In addition, mesiodens have been reported as

the most common ST, followed by supernumerary premolars and distomolars, which is also confirmed by our data [28].

Previous studies usually exploited the 2-dimentional panoramic radiography to characterize the ST [14, 28, 29]. However, this radiographic model failed to definitively and comprehensively view the spatial and morphological details about ST. The advent and widespread use of CBCT enable dentists to accurately pinpoint the 3-dimentional location and morphology as well as its relationship with adjacent structures. Consistent with previous studies [10, 21], all four morphological types including conical, tuberculate, supplemental, and germ were observed in our samples and distributed in both jaws. Noticeably, the conical shape was the most common morphology of ST, irrespective of their locations. This predilection is consistent with previous reported studies [14, 30]. In terms of ST orientation, Liu et al. reported that 40% ST were inverted orientation in their patient group comprised 487 subjects with a total of 626 ST based on CBCT scan [17]. In the present study, approximately half of ST were inverted, similar to the previous findings [10, 14]. However, on the contrary, Rajab et al. reported that 83.1% ST were normally oriented in a study population consisted of 152 children [11]. We believe that this discrepancy might result from racial factor and sampling differences.

With regard to the eruption status of ST, 89% of ST were impacted in our cohort, which is higher than previously reported [13, 31]. Some previous studies have documented that 45.9% ST were impacted as assessed by panoramic X-rays in 25,186 patients and 73.8% ST were impacted in a Turkish population [13, 27]. This difference between ours and others can be explained by the following reasons. In the present study, ST in children or adolescents with primary or mixed dentition were excluded and adults with permanent dentition were enrolled. On the other side, erupted ST is easily detected in primary or mixed dentition and might be extracted timely. In addition, impacted ST is usually insidious and asymptomatic, and occasionally detected by radiography. Thus, it is reasonable that the incidence of erupted ST is much less as compared with impacted ST in adults.

Until now, to the best of our knowledge, three studies regarding ST in the Chinese population have been reported from different regions including Taiwan, Beijing, and Hong Kong [14, 17, 23]. The prevalence of ST in a Taiwan population was 2.6% with a male predominance (male:female = 1.69:1), which was generally similar with our data presented here (1.5%, 1.79:1) [23]. In a Beijing population, the majority of patients had single ST (72%) and most ST are located in the anterior maxilla (92%), which was in line with our results [17]. Moreover, all four studies revealed that the majority of the ST were conical shape, inverted orientation, and palatally/lingually located in diverse Chinese populations [14, 17, 23]. Therefore, based on comparisons between our study and other three studies, we found a high consistency of epidemiological and clinical as well as radiographic features of ST between diverse Chinese populations from different regions.

Accumulating evidence has revealed that ST have various adverse effects on adjacent structures and cause local aberrations and complications such as failure of eruption, displacement, root resorption, and impaction of adjacent teeth, as well as cystic lesions, while sometimes they remain asymptomatic [16, 21]. Generally, incidence ratio of 3 primary complications including root resorption and impaction of adjacent teeth, as well as cystic lesions in this study, was 13% in total. In detail, 8% of ST were found to be associated with cystic lesions and two thirds of them occurred in the mesiodens region. Moreover, root resorption of adjacent teeth was detected in 43 ST, which most frequently occurred in the supernumerary premolars and paramolars. However, Bereket et al. found that 7 ST were detected with cystic lesions and 15 ST were associated with root resorption of adjacent teeth among the 1100 ST through panoramic radiography [12]. We believe that application of CBCT in detecting root resorption is more precise and direct than panoramic radiography, which is well supported by other studies [32]. Intriguingly, our data further revealed that the occurrence of complications significantly associated with position and morphology of ST. ST in the maxilla or presented as conical morphology and inverted orientation tended to be associated with cystic lesion, while supplemental morphology and inclined orientation were found to correlate with root resorption of adjacent teeth. Additionally, impaction of adjacent tooth was significantly associated with localization of crown of ST. This is partially supported by some previous studies wherein they found that inverted ST was in direct contact with the cystic cavity and related teeth, which might facilitate cyst formation and root resorption of adjacent teeth [33]. These ST-associated complications highlight the significance of early diagnosis and timely treatment of ST, which might prevent or minimize the occurrence of associated local aberrations and complication.

Conclusion

In conclusion, our results have documented the prevalence, clinical, and radiographic characteristics about non-syndromic ST in a Chinese adult population. Our data found that most ST were single, conical, inverted, impacted, and located in the maxilla, sometimes associated with complications. These findings will be beneficial for clinicians to more comprehensively understand the incidence and pathogenesis as well clinical management of ST.

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Authors' contributions Drs. Yue Jiang, Xiaowei Ma, and Yaping Wu performed the radiographic analyses, data collection and statistical analyses. Drs. Jin Li, Zhongwu Li, and Yanling Wang participated the study design, data collection, and analyses. Drs. Jie Cheng and Dongmiao Wang conceived and supervised the whole project and drafted the manuscript. All authors read and approved the final manuscript.

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Compliance with ethical standards

Conflict of interest The authors declare that they have no conflict of interest.

Ethical approval The study was reviewed and approved by the Ethics and Research Committee, Nanjing Medical University, and conducted in accordance with the tenets of the Declaration of Helsinki for research involving human subjects.

Informed consent Written informed consent was not required for this study because all of the included patients in the present investigation were collected retrospectively.

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