



Dental development in children with supernumerary teeth in the anterior region of maxilla

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Abstract

Objective Development of human dentition has been used as a predictor for evaluating the growth and maturity of an individual. It is fairly identical in a specific population, but the effect of development on subjects with dental anomalies had not been fully explored, particularly on subjects with supernumerary teeth (ST). This study hence aims to evaluate the dental development of children with and without ST.

Materials and methods Sample size calculation was conducted and 320 radiographs of subjects with and without supernumerary teeth (ST) were obtained from the archives of a teaching hospital. The subjects in both groups were age and sex matched. All the subjects belong to southern Chinese ethnicity aged 2 to 14 years. The left-side dentition was scored, and dental age (DA) was estimated by obtaining scores from the southern Chinese dental reference dataset. Paired *t* test was used to calculate the difference between chronological age and dental age (CA-DA) for boys and girls with and without ST and further based on the number and position of ST.

Results The difference between chronological age and dental age (CA-DA) was 0.10 years for boys and 0.19 years for girls with ST whilst 0.01 and 0.05 years for boys and girls without ST ($p > 0.05$). The boys with bilateral ST showed significant delay in dental development of 0.23 years ($p < 0.05$). Position of the ST did not have any influence on dental age.

Conclusions No significant difference was observed in the dental development of children with and without supernumerary teeth.

Clinical relevance Understanding dental development of children with supernumerary teeth may be useful in appropriate treatment planning of such conditions.

Keywords Dental age · Dental maturation · Supernumerary teeth · Southern Chinese · Dental radiograph

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Introduction

Growth and maturity of an individual can be evaluated from the degree of development of the dentition. Analysis of the dental maturation pattern is applied in clinical dentistry for appropriate treatment planning and in forensic dentistry for estimation of age of subjects who do not possess authentic birth records. It is generally accepted that dental development follows a systematic pattern of growth and is influenced by genetic predispositions and other external factors [1]. Correlations between tooth formation, tooth eruption, skeletal maturity, sexual maturity, height, and weight have been already demonstrated [2]. In this context, dental age (DA) refers to the dental maturity of an individual at a given point of time and chronological age (CA) refers to the calendar age. There exists significant variations between DA and CA; it is the dental age which is usually included in the decision-making process in clinical dentistry [3].

A supernumerary tooth (ST) is “any tooth or odontogenic structure that is formed from a tooth germ in excess of the usual number for any given region of the dental arch” [4]. The prevalence rate of supernumerary teeth in Chinese population has been reported at 2.8% in Hong Kong [5] and 7.8% in Taiwan [6]. Moreover, ST has been found to affect males more commonly than females in a ratio of 3:1 [7]. A Mendelian pattern of inheritance has been established for ST. Furthermore, they are commonly reported in Gardner syndrome, cleidocranial dysplasia and Marfan syndrome [8].

Dental development in subjects with medically compromised conditions has been widely reported, and this includes epidermolysis bullosa [9], chronic renal failure [10], cystic fibrosis [11] and post chemotherapies [12]. In addition, dental maturation of subjects with craniofacial anomalies including cleft lip and palate and impacted canines has been reported [13–15]. Supernumerary teeth can cause a wide range of complications that include delayed eruption and impaction of adjacent tooth, malocclusion, dentigerous cyst formation and paraesthesia of the affected region [4].

Dental development is consistent within a specific population group, but the effect of it on subjects with dental anomalies has not been fully explored, particularly in subjects with supernumerary teeth. Evaluation of dental maturity discrepancies in children with ST will provide a better understanding of dental development patterns and enhance our understanding so as to facilitate appropriate diagnosis and treatment planning in these children. It is hypothesised that the dental maturity of children and adolescents with ST is delayed in comparison to those without ST. Hence, this study is aimed to evaluate the dental maturity by analysing variations between the chronological age and dental age of boys and girls with and without ST. The objectives of this study were threefold: firstly, to evaluate dental age of children with and without ST; secondly, to estimate differences between unilateral and bilateral ST and thirdly, to analyse the age of subjects based on the location of ST in the dental arch.

Materials and methods

Considering the population size, desired confidence interval of 80% margin of error of 5%, expected frequency of 50% and the assumed effect size of 0.8, sample size for subjects with ST was calculated as 160. Taking this into account, a total of 160 DPT (dental panoramic tomographs) of children with unilateral and bilateral ST were obtained from the archives of Paediatric Dentistry and Orthodontics, Prince Philip Dental Hospital, Hong Kong. To compare the dental development, a total of 160 radiographs of children without supernumerary teeth (non-ST) were obtained from the same archives and age and sex matched with the ST group. The chronological age (CA) of subjects in the ST group was calculated in decimal

years, from the date of birth (DOB) and the date of exposure of radiograph (DOR) using the formula: $CA = (DOR - DOB) / 365.25$. This age, in decimal years, was matched closely to the CA in decimal years of subjects in the non-ST group. In total, 320 subjects were included in the analysis; see Table 1. The age of subjects included in the study ranged between 2 and 14 years, and all the subjects were of southern Chinese ethnicity identified from the name and ancestral details as provided in the hospital records. All of the DPTs used in this study had been taken previously for diagnostic purposes and re-used in the current study. Children with craniofacial disorders, dental anomalies other than supernumerary teeth, those undergoing orthodontic treatment were excluded in both ST and non-ST groups. Ethics approval for this study was obtained from the Institutional Review Board of the University of Hong Kong (Reference Number: UW 12–280).

The Dental Panoramic Tomographs (DPTs) was used to evaluate the development of the teeth of the subjects involved in the study. Each DPT was assigned a unique number so as to mask the identity and other details of the subjects. Hard copies of the DPTs were scanned at a resolution of 300 dpi in greyscale format (Canon, Canon Inc., Japan) and evaluated on a widescreen monitor (27IE, Philips, Philips Corp, USA) at a magnification of 120 to 160%. Two trained and calibrated examiners (JJ and MSK) scored all the permanent teeth in the left side of maxillary and mandibular arches. Both examiners are specialists in Paediatric Dentistry with considerable experience in scoring and evaluating radiographs. The ST in the panoramic radiograph were identified based on the size, morphology, stage of development, and orientation in the anterior region of the maxilla. By this way, the ST were excluded in the staging and scoring process. Each permanent tooth was assigned a score based on the Demirjian's classification of stage of dental development (A-H) [16]. The stages were recorded on a score card specifically designed for a dental age estimation study [17].

The scores were later transferred to individual Microsoft Excel spreadsheets for each subject. Dental age was calculated by obtaining the mean age of attainment (AoA) for each tooth development stage (TDS) corresponding to individual tooth morphology type (TMT). The scores were obtained from the southern Chinese Reference Dataset (RDS) constructed from the dental development of 2306 southern Chinese subjects aged between 2 and 24 years [18]. The mean AoA score for each tooth was averaged to derive at a dental age (DA). The chronological age was calculated from the date of birth and the date of exposure of radiograph. Using SPSS statistical package (version 21.0, IBM Inc., Armonk, NY), the difference between the chronological age and dental Chronological Age and Dental Age (CA-DA) was analysed using paired *t* test. Statistical significance was set at $p < 0.05$, and the test was independently carried out for boys and girls with unilateral and bilateral ST. In addition to this, Bland and Altman

Table 1 Distribution of subjects with and without supernumerary teeth

Gender	Without ST	Unilateral	With ST Bilateral	Total ^a
Boys	120	76	44	120
Girls	40	32	8	40
Total ^b	–	108	52	160

ST supernumerary teeth

^a Total number of subjects with ST

^b Total number of ST

plots were constructed to analyse the difference between the chronological age and dental age (CA-DA) in boys and girls. Kappa statistics were used to evaluate inter-examiner and intra-examiner reliability at statistical significance of $p < 0.001$.

Results

The mean chronological age (CA) of subjects with and without supernumerary teeth included in the study was 7.13 (2.67) and 7.13 (2.66), respectively. Based on the gender, the mean CA of boys with and without supernumerary was 6.99 (2.62) and 7.00 (2.61) years and for girls, the mean CA was 7.53 (2.82) and 7.54 (2.81) years for with and without supernumerary respectively. The difference between chronological age of subjects with and without supernumerary teeth was not statistically significant ($p > 0.05$). Amongst the sample of subjects with supernumerary teeth (ST), 108 (67.5%) were diagnosed with unilateral ST whilst 52 (32.5%) had bilateral ST. The male and female ratio for unilateral ST was 2.3:1 whereas 5.5:1 for bilateral supernumerary teeth showing higher predilection in males. The reproducibility was 100% for the diagnosis and its classification based on unilateral and bilateral

types. Approximately 20% of the radiographs were randomly chosen to evaluate inter- and intra- examiner reliability (JJ and MSK). The inter-examiner reliability score (JJ and MSK) was 0.80 ($p < 0.001$), 95% CI (0.747 to 0.853) showing “substantial” agreement and intra-examiner reliability score (JJ) was 0.86 ($p < 0.001$), 95% CI (0.817 to 0.903) corresponding to ‘almost perfect’ agreement [19].

Subjects with supernumerary teeth exhibited slight delay compared to those without supernumerary teeth. The overall difference (CA-DA) between the chronological age (CA) and dental age (DA) was 0.01 and 0.05 years for boys and girls without supernumerary teeth and 0.10 and 0.19 years for boys and girls with supernumerary teeth; however, the result was statistically insignificant ($p > 0.05$); see Table 2. Levene’s test for equality of variances was conducted, and it was found that the variances of the sample were equal in both ST and non-ST groups ($p > 0.05$). Bland and Altman plots were constructed to show the difference between the chronological age and dental age (CA-DA) in boys (Fig. 1) and girls (Fig. 2) with and without supernumerary teeth. The difference in the age (CA-DA) was plotted in the y-axis; the mean of CA and DA (age) was plotted in the x-axis. The centre line represents mean of the difference (CA-DA) and the dotted lines represents the standard deviation of the mean at $\pm 2SD$. Minimal dispersion of the CA-DA scores was observed in subjects without ST compared to those with ST (see Figs. 1 and 2). Amongst subjects with unilateral and bilateral supernumerary teeth, the CA-DA difference in boys was 0.02 and 0.23 years respectively and 0.07 and 0.56 years for girls respectively. The difference was statistically insignificant for all groups except for boys with double supernumerary teeth ($p < 0.05$); refer to Table 3.

Children with ST were found to exhibit delay in dental development since the dental age was lower compared to the chronological age (Table 2). Both boys (0.02 years) and girls (0.07 years) with unilateral ST showed comparatively lower

Table 2 Difference between chronological age (CA) and dental age (DA) in subjects with and without supernumerary teeth

Subjects	Number	CA	DA	Mean difference	<i>p</i> value ^c	SE difference	95% CI of the difference	
							Lower	Upper
<i>Boys</i>								
Normal ^a	120	7.00	6.98	0.01	0.765	0.03	– 0.06	0.09
Supernumerary ^b	120	6.99	6.89	0.10	0.158	0.07	– 0.04	0.24
<i>Girls</i>								
Normal ^a	40	7.54	7.70	0.05	0.168	0.03	– 0.02	0.12
Supernumerary ^b	40	7.53	7.34	0.19	0.155	0.13	– 0.07	0.45

SE standard error, CI confidence interval

^a Without supernumerary tooth

^b With single or double supernumerary teeth, ^a Paired *t* test

^c Paired *t* test

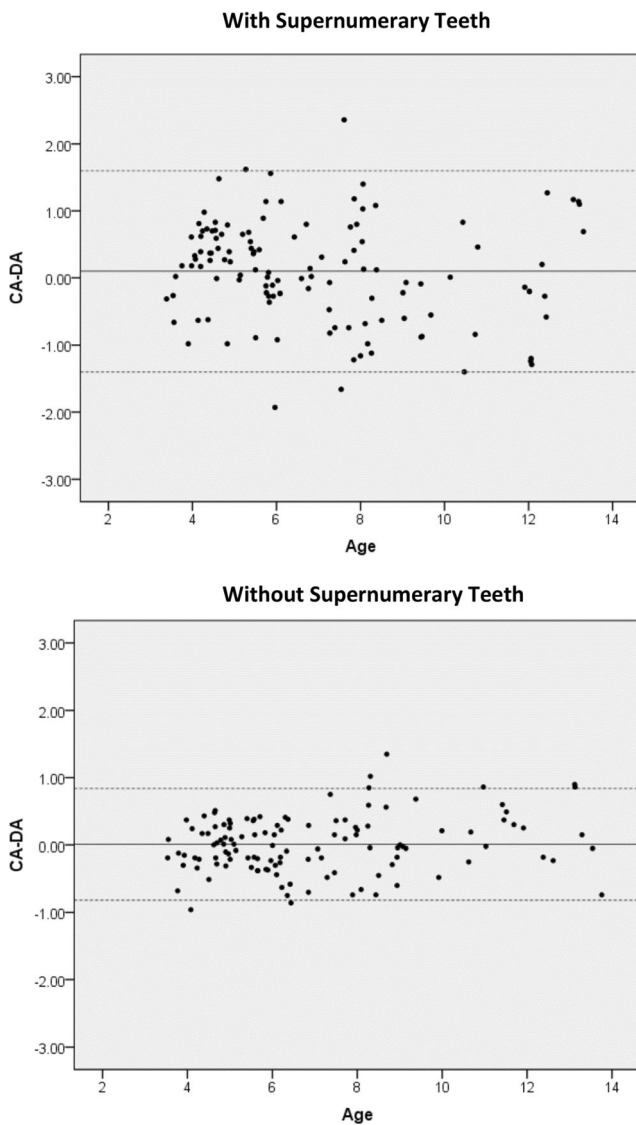


Fig. 1 Bland and Altman plots showing the difference between chronological and dental age in boys with and without supernumerary teeth

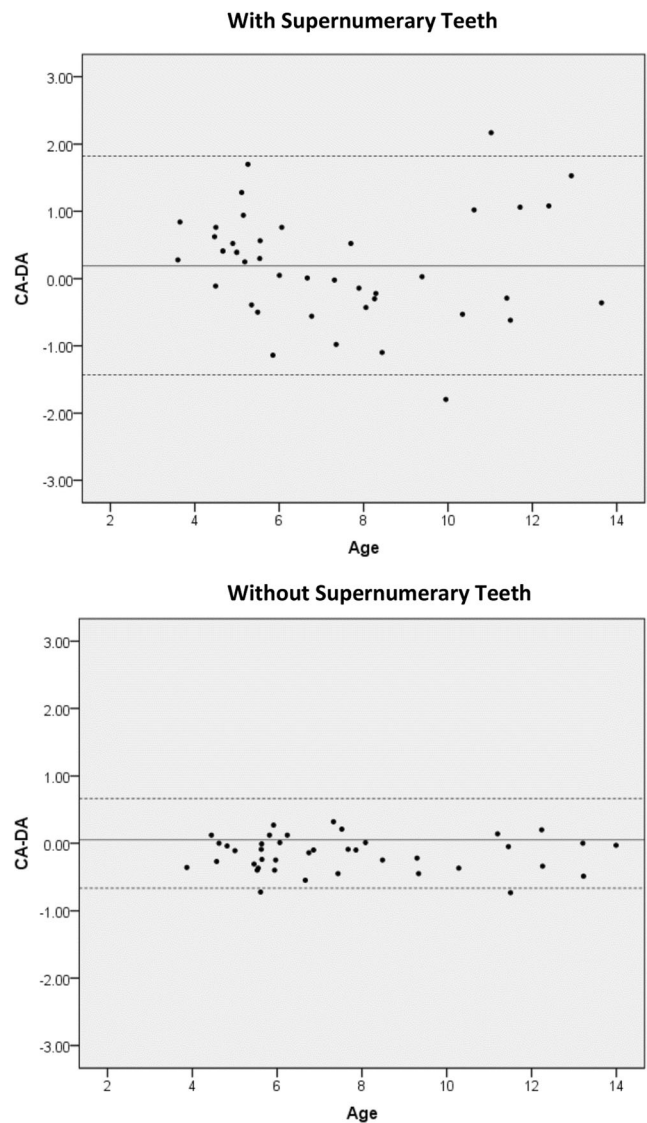


Fig. 2 Bland and Altman plots showing the difference between chronological and dental age in girls with and without supernumerary teeth

delay in dental development compared to boys (0.23 years) and girls (0.56 years) with bilateral supernumerary teeth. A greater delay in dental development was observed in girls compared to boys in both unilateral and bilateral ST categories. Amongst subjects with unilateral ST, the number of subjects with palatal ST was far higher than those with buccal ST. Only 4 boys and 4 girls had ST in a transverse position. No significant variation in dental age was noticed amongst the children in relation to the position of unilateral ST (buccal, palatal and transverse); see Table 4.

A working example of dental age estimation for an 8.95-year-old southern Chinese boy with unilateral supernumerary teeth was presented; see Table 5. Dental panoramic tomograph was obtained at standard exposing settings (Gendex Ortholix 9200, TX, USA); see Fig. 3. The scores were obtained from the

southern Chinese reference dataset, and the dental age was calculated as 8.65 years with the standard deviation of 1.10 years [18]. The difference between the CA and DA was 0.30 years indicating slight delay in dental development. In addition, cone beam computed tomograph (CBCT) of the subject was taken (Kavo 3D Exam, Kavo Dental GmbH, Germany) and analysed using imaging software (Osiri X MD, Pixmeo SARL, Bernex, Switzerland). This showed supernumerary tooth with fully developed root (stage H); see Fig. 4.

Discussion

Supernumerary teeth are often identified at a routine radiographic examination and some cases have symptoms that

Table 3 Difference between chronological age (CA) and dental age (DA) in subjects with unilateral and bilateral supernumerary teeth

Supernumerary teeth	Number	CA	DA	Mean difference	<i>p</i> value ^a	SE difference	95% CI of the difference	
							Lower	Upper
<i>Boys</i>								
Unilateral	76	7.22	7.20	0.02	0.803	0.09	-0.16	0.20
Bilateral	44	6.60	6.37	0.23	0.031*	0.10	0.02	0.44
<i>Girls</i>								
Unilateral	32	7.08	7.01	0.07	0.632	0.14	-0.21	0.34
Bilateral	8	8.36	7.80	0.56	0.113	0.30	-0.17	1.29

SE standard error, CI confidence interval

**p* value < 0.05

^a Paired *t* test

suggest their presence [20]. Early studies revealed that ST are more commonly seen in boys than girls [7, 21]. In agreement with prior studies, the present study showed a higher male predilection (3:1). We attempted to analyse all the available radiographs of subjects with ST; however, the distribution of the subjects with unilateral and bilateral ST were found uneven particularly in girls with bilateral ST. This was the case in children with buccal and transverse ST; the numbers were slightly lower than the palatal ST. This can be considered as a common finding because higher predilection of ST in the palatal region has been reported [7].

Delay in dental development is identified when dental age (DA) of a subject is lower than the chronological age (CA). Both boys and girls with ST showed slight delay dental development compared to those without ST as the difference was 0.10 and 0.19 years respectively. A similar presentation was observed in subjects with unilateral ST who showed lower dental ages than the chronological ages (*p* > 0.05). This result can be compared with studies conducted on subjects with impacted canines. A study conducted in Poland reported retarded dental development in patients with both buccal and palatal impacted canines in the maxillary arch [15]. This was confirmed by Sajjani and King [14] who found retarded dental development in southern Chinese population with impacted canines. Jain and

co-workers’ study on Indian subjects found that girls had hindered dental development compared with the boys, and the results were statistically significant [22]. In our study, subjects with ST showed slightly lower dental age, although the results were not statistically significant. It is to be noted that significant delay in dental maturation was observed only in boys with bilateral ST. Townsend and co-workers stated that the developmental problem in one tooth may reasonably be expected to affect all the other teeth to some degree [23]. The developmental process is common to all teeth in both dentitions; it is unlikely that the development changes of different teeth are due to the action of different genes. Our present study revealed that presence of ST does not have much influence on dental age except for children with bilateral ST.

Investigators who studied the dental maturation patterns of subjects with dental anomalies utilised reference standards not belonging to the population of interest. For example, one study that assessed the dental age of subjects with impacted maxillary canines of southern Chinese and Turkish populations employed French-Canadian dataset as the reference standard [14, 15]. This also applies to studies on chronic renal failure and epidermolysis bullosa [9, 10]. An inherent problem associated with this approach is the utilisation of Demirjian’s French-Canadian data for dental age estimation [16]. It is to be noted

Table 4 Dental age of subjects with unilateral supernumerary tooth based on the buccal, palatal and transverse location

Supernumerary teeth	Number	CA	DA	Mean difference	<i>p</i> value ^a	SE difference	95% CI of the difference	
							Lower	Upper
Palatal	69	7.37	7.33	0.04	0.693	0.10	-0.16	0.24
Buccal	4	6.75	6.84	-0.09	0.798	0.31	-1.08	0.91
Transverse	4	5.25	5.48	-0.23	0.286	0.17	-0.79	0.33
Palatal	28	7.00	6.91	0.09	0.513	0.14	-0.20	0.38
Bilateral	4	8.64	8.24	0.40	0.165	0.11	-0.17	0.94

SE standard error, CI confidence interval

^a Paired *t* test

Table 5 Dental age estimation for an 8.95-year-old Chinese boy presented in Figs. 3 and 4

Tooth number ^a	Stage ^b	n-tds ^c	x-tds ^c	SD-tds ^c
21	F	116	7.69	1.15
22	F	85	8.54	1.10
23	E	90	7.78	1.02
24	F	84	10.55	1.08
25	F	195	10.74	1.27
26	G	81	7.53	1.05
27	D	164	8.11	1.32
28	A	28	9.91	0.94
38	A	52	9.90	1.03
37	D	134	8.03	1.27
36	G	90	7.63	1.06
35	E	57	8.76	1.02
34	E	70	8.37	0.96
33	E	84	7.51	1.11
32	G	76	8.61	1.09
31	H	–	–	–
Dental age	–	–	8.65	1.10

n number, x mean, SD standard deviation of tooth development stages (tds)

^a FDI tooth numbering system

^b Anglo-Canadian classification system

^c Values obtained from the southern Chinese reference dataset [18]

that this reference data was not indicated for dental age estimation, and a systematic review has clearly shown that this method results in an over-estimation on global population groups [24]. At the time of preparation of this report, a consensus was achieved to abandon this method of age estimation [25]. Hence, the validity of the studies that employed Demirjian's dataset for age estimation has become questionable.

In a study testing the applicability of Demirjian's French-Canadian dataset on southern Chinese children, it was found

**Fig. 3** Dental Panoramic Tomograph showing development of dentition of 8.95-year-old Chinese boy with unilateral supernumerary tooth**Fig. 4** Axial slice of cone beam computed tomography (CBCT) image showing fully developed supernumerary tooth in an 8.95-year-old Chinese boy

that the dataset overestimated the age of southern Chinese boys and girls by 0.62 and 0.36 years respectively [26]. As a consequence of this finding, a new reference dataset based on a sample pool of 2306 subjects of southern Chinese origin was developed and subsequently validated. The authors were able to accurately estimate the age of the subjects as the test and validation samples were from the same ethnic group [17]. We utilised this newly developed reference dataset for dental age estimation of subjects with supernumerary teeth. It is important to note that both the reference dataset and the subjects included in the current study belong to southern Chinese ancestry. To the best of our understanding, this is the first study to employ this method and so overcame any bias that might have arisen due to population differences in dental development. This is also evident from the minimal difference between the chronological and dental age in subjects without ST.

Prior studies have reported variation in morphology of tooth, in both shape and size resulting from ST [27, 28]. Khalaf and co-workers found larger tooth dimensions in subjects with ST compared to those without ST [29]. Nevertheless, none of the researchers investigated the effect of dental age in subjects with ST. A recent study reported delay in dental age of 0.57 years in females and 0.61 years in males with congenitally missing permanent teeth when compared to children with normal complement of teeth [30]. In their study, only females exhibited significant correlation between the number of missing teeth and severity of delay of development. In the present study, no significant difference in dental age was observed between boys and girls with and without ST. In the current study, supernumerary tooth was primarily identified by its size, orientation and location in the anterior region of maxilla. Most of the supernumerary tooth exhibited advanced development compared to the

adjacent central incisors; however, some variations were observed (Fig. 3). A detailed analysis on the development pattern of supernumerary teeth and the adjacent permanent teeth will be presented in a separate study.

The age of subjects included in this study ranged from 2 to 14 years. We had difficulty in obtaining radiographs for 2-, 3- and 4-year-old subjects as panoramic radiographs are usually not indicated for very young children. Those available panoramic radiographs were taken as an alternate to intra-oral images as young children at times resist to taking intra-oral radiographs. It is to be noted that all the radiographs in both ST and non-ST groups had been previously taken to assist in diagnosis and treatment planning of dental conditions. It has been established that surgical removal of unerupted ST in the anterior region is best performed at 6 to 7 years of age so as to minimise surgical complications [7]. This study evaluated dental maturity status in patients with ST; however, the investigators utilised the chronological age of the subjects to correlate their findings rather than the dental age. In contrast, we estimated the dental age to portray the overall dental maturation of subjects with ST. Two studies investigating impacted canines showed that the position of the impacted tooth may have a slight influence on the dental age [14, 15]. The position of ST did not have any influence on the dental age in the present study but the dental age was delayed by 0.11 years for boys and 0.19 years for girls. This finding was in accordance with the study conducted in southern Chinese children with maxillary canine impaction that showed delayed maturation by 0.40 years [14]. The outcome of this research have significant influence on clinical practice and also when assessing dental age in a legal circumstance. In the present study, only subjects with ST in the anterior region of the maxillary arch were included. It has been reported that 95% of the ST would present in anterior region of the maxilla [7], and hence, it is possible to generalise the results of this study to ST in other areas of maxilla and mandible. To the best of our knowledge, there are no reports in the literature that have assessed the dental development of subjects with supernumerary teeth and so we explored this issue by conducting a retrospective analysis. This study was conducted exclusively on southern Chinese children, and the findings could be considered as being preliminary until verified in other ethnic groups.

Conclusions

No significant difference was observed in the dental development of children with and without ST. Although the degree of delay in development was more pronounced in children with bilateral ST compared to unilateral ST, the location of the ST did not influence on the dental development.

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Compliance with ethical standards

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

Ethical approval Ethics approval for this study was obtained from the Institutional Review Board of the University of Hong Kong (Reference Number UW 12-280). All procedures performed in studies involving human participants were in accordance with the ethical standards of the institutional and/or national research committee and with the 1964 Helsinki declaration and its later amendments or comparable ethical standards.

Informed consent For this type of study, formal consent is not required.

References

- Garn SM, Lewis AB, Kerewsky RS (1965) Size interrelationships of the mesial and distal teeth. *J Dent Res* 44:350–354
- Anderson DL, Thompson GW, Popovich F (1975) Interrelationships of dental maturity, skeletal maturity, height and weight from age 4 to 14 years. *Growth* 39:453–462
- Jayaraman J, Roberts GJ, King NM, Wong HM (2012) Dental age assessment of southern Chinese using the United Kingdom Caucasian reference dataset. *Forensic Sci Int* 216:68–72
- Omer RS, Anthonappa RP, King NM (2010) Determination of the optimum time for surgical removal of unerupted anterior supernumerary teeth. *Pediatr Dent* 32:14–20
- King NM, Tsai JSJ, Wong HM (2010) Morphological and numerical characteristics of the southern Chinese dentitions. Part I: anomalies in the permanent dentition. *Open Anthropology J* 3:54–64
- Huang WH, Tsai TP, Su HL (1992) Mesiodens in the primary dentition stage: a radiographic study. *J Dent Child* 59:186–189
- Anthonappa RP, Omer RS, King NM (2008) Characteristics of 283 supernumerary teeth in southern Chinese children. *Oral Surg Oral Med Oral Pathol Oral Radiol Endod* 105:e48–e54
- Mallinen SK, Jayaraman J, Yiu CK, King NM (2012) Concomitant occurrence of hypohyperdontia in a patient with Marfan syndrome: a review of the literature and report of a case. *J Investig Clin Dent* 3: 253–257
- Liversidge HM, Kosmidou A, Hector MP, Roberts GJ (2005) Epidermolysisbullosa and dental developmental age. *Int J Paediatr Dent* 15:335–341
- Jaffe EC, Roberts GJ, Chantler C, Carter JE (1990) Dental maturity in children with chronic renal failure assessed from dental panoramic tomographs. *J Int Assoc Dent Child* 20:54–58
- Primosch RE (1980) Dental and skeletal maturation in patients with cystic fibrosis. *J Oral Med* 35:7–13
- Dahllof G, Nasman M, Borgstrom A, Modeer T (1989) Effect of chemotherapy on dental maturity in children with hematological malignancies. *Pediatr Dent* 11:303–306

13. Lai MC, King NM, Wong HM (2008) Dental development of Chinese children with cleft lip and palate. *Cleft Palate Craniofac J* 45:289–296
14. Sajjani A, King N (2010) Dental age of children and adolescents with impacted maxillary canines. *J Orofac Orthop* 73: 359–364
15. Rozylo-Kalinowska I, Kolasa-Raczka A, Kalinowski P (2011) Dental age in patients with impacted maxillary canines related to the position of the impacted teeth. *Eur J Orthod* 33:492–497
16. Demirjian A, Goldstein H, Tanner JM (1973) A new system of dental age assessment. *Hum Biol* 45:211–227
17. Roberts GJ, Parekh S, Petrie A, Lucas VS (2008) Dental age assessment (DAA): a simple method for children and emerging adults. *Br Dent J* 204:E7
18. Jayaraman J, Wong HM, King NM, Roberts GJ (2016) Development of a reference data set (RDS) for dental age estimation (DAE) and testing of this with a separate validation set (VS) in a southern Chinese population. *J Forensic Legal Med* 43:26–33
19. Landis JR, Koch GG (1977) The measurement of observer agreement for categorical data. *Biometrics* 33:159–174
20. Anthonappa RP, King NM, Rabie AB, Mallineni SK (2012) Reliability of panoramic radiographs for identifying supernumerary teeth in children. *Int J Paediatr Dent* 22:37–43
21. Mallineni SK, Anthonappa RP, King NM (2016) Reliability of horizontal and vertical tube shift techniques in the localisation of supernumerary teeth. *Eur Arch Paediatr Dent* 17:455–460
22. Jain S, Shetty KS, Jain S, Jain S, Prakash AT, Agrawal M (2015) Evaluation of dental age and associated developmental anomalies in subjects with impacted mandibular canines. *Angle Orthod* 85: 638–644
23. Townsend G, Harris EF, Lesot H, Clauss F, Brook A (2009) Morphogenetic fields within the human dentition: a new, clinically relevant synthesis of an old concept. *Arch Oral Biol* 54:S34–S44
24. Jayaraman J, Roberts G (2016) Demirjian's method is unsuitable for dental age estimation. *Forensic Sci Med Pathol* 12:532–533
25. Quaremba G, Buccelli C, Graziano V, Laino A, Laino L, Paternoster M, Petrone P (2018) Some inconsistencies in Demirjian's method. *Forensic Sci Int* 283:190–199
26. Jayaraman J, King NM, Roberts GJ, Wong HM (2011) Dental age assessment: are Demirjian's standards appropriate for southern Chinese children? *J Forensic Odontostomatol* 29:22–28
27. Brook AH, Elcock C, Al-Sharood MH, McKeown HF, Khalaf K, Smith RN (2002) Further studies of a model for the etiology of anomalies of tooth number and size in humans. *Connect Tissue Res* 43:289–295
28. Brook AH, Griffin RC, Smith RN, Townsend GC, Kaur G, Davis GR, Fearn J (2009) Tooth size patterns in patients with supernumerary teeth and hypodontia. *Arch Oral Biol* 54:S63–S70
29. Khalaf K, Robinson DL, Elcock C, Smith RN, Brook AH (2005) Tooth size in patients with supernumerary teeth and a control group measured by an image analysis system. *Arch Oral Biol* 50:243–248
30. Badrov J, Lauc T, Nakaš E, Galić I (2017) Dental age and tooth development in orthodontic patients with agenesis of permanent teeth. *Biomed Res Int* 2017:8683970