European Journal of Orthodontics 36 (2014) 708–718
doi:10.1093/ejo/cjt101
Advance Access publication 2 January 2014

Morphologic characteristics, location, and associated complications of maxillary and mandibular supernumerary teeth as evaluated using cone beam computed tomography

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SUMMARY

OBJECTIVES: To evaluate the location and morphologic characteristics of supernumerary teeth and to assess the frequency and extent of root resorption of adjacent teeth using cone beam computed tomography (CBCT).

MATERIALS AND METHODS: CBCT scans of 82 patients with supernumerary teeth in the maxilla and mandible were evaluated by two orthodontists independently. Data regarding the type, shape, and three-dimensional (3D) location of the supernumeraries including the frequency and extent of root resorption of adjacent teeth were recorded and evaluated for possible associations.

RESULTS: The study comprised a total of 101 supernumerary teeth. Most of the patients (80.5 per cent) exhibited one single supernumerary tooth, while 15.8 per cent had two and 3.7 per cent had three supernumeraries. Males were affected more than females with a ratio of 1.65:1. Mesiodentes were the most frequently diagnosed type of supernumerary teeth (48.52 per cent), followed by supernumerary premolars (23.76 per cent) and lateral incisors (18.81 per cent). Supernumeraries were most commonly conical in shape (42.6 per cent) with a normal or inclined vertical position (61.4 per cent). Root resorption of adjacent teeth was detected for 22.8 per cent of the supernumerary teeth, most frequently for supernumerary premolars. There was a significant association between root resorption of adjacent teeth and type and shape of tooth. Interrater agreement for the measurements performed showed kappa values ranging from 0.55 to 1 with a kappa value of 1 for type and shape of the supernumerary teeth.

CONCLUSIONS: CBCT provides 3D information about location and shape of supernumerary teeth as well as prevalence and degree of root resorption of neighbouring teeth with moderate to high interrater correlation.

Introduction

The term 'supernumerary' defines teeth that form additionally to the normal dentition. Several theories have been postulated regarding their aetiology, including atavism (evolutionary throwback), dichotomy of the tooth germ, hyperactivity of the dental lamina, and genetic and environmental factors. Localized and independent hyperactivity of the dental lamina is the most widely accepted cause for the development of supernumerary teeth today (Primosch, 1981; von Arx, 1990; Stellzig *et al.*, 1997; Rajab and Hamdan, 2002; Russell and Folwarczna, 2003; Ferrés-Padró *et al.*, 2009; Wang and Fan, 2011). Supernumerary teeth are usually detected incidentally during routine radiographic examination or when normal tooth eruption is delayed or fails.

The literature lists several studies assessing the prevalence of supernumerary teeth. Percentages ranging from 0.07 to 0.6 per cent for the primary dentition (Ravn, 1971; Järvinen and Lehtinen, 1981; Magnússon, 1984; Skrinjarić and Barac-Furtinović, 1991; Yonezu *et al.*, 1997; Chen *et al.*, 2010) and 0.3 to 3.2 per cent for the permanent dentition have been reported with geographic variation (Luten, 1967; Bäckman and Wahlin, 2001; Salcido-García *et al.*, 2004; Leco Berrocal *et al.*, 2007; Gündüz *et al.*, 2008; Yagüe-García *et al.*, 2009; Schmuckli *et al.*, 2010; Fardi *et al.*, 2011). Supernumerary teeth have been reported to be more prevalent in men than women with a ratio ranging from 1.18:1 to 4.5:1 (Rajab and Hamdan, 2002; Fernández Montenegro *et al.*, 2006; Gündüz *et al.*, 2008; Wang and Fan, 2011). They may occur as single supernumerary teeth or in multiple. Cases involving one or two supernumerary teeth are usually located in the anterior maxilla, followed by the mandibular premolar region (Rajab and Hamdan, 2002; Fernández Montenegro *et al.*, 2006).

Supernumerary teeth can remain asymptomatic. However, complications such as failure of eruption, displacement, root resorption, and crowding of adjacent teeth, as well as cyst formation have been reported. Therefore, surgical removal of supernumerary teeth may be necessary (Garvey *et al.*, 1999; Rajab and Hamdan, 2002). Proper localization of the supernumerary teeth is very important for the diagnosis, treatment planning, and operative removal. Traditionally, supernumerary teeth were diagnosed and located using two-dimensional (2D) radiographic methods such as panoramic views, cephalometric, apical, or occlusal radiographs (Garvey *et al.*, 1999; Rajab and Hamdan, 2002). Using 2D radiographic imaging modalities, determining the precise three-dimensional (3D) location of the tooth in relationship to neighbouring structures and adjacent teeth remained difficult. In order to overcome the shortcomings of 2D imaging, cone beam computed tomography (CBCT) for 3D evaluation and location of supernumerary teeth has recently been advocated (Kapila *et al.*, 2011).

Only one retrospective study (Liu *et al.*, 2007) and one series of three cases (Gurgel *et al.*, 2012) have used CBCT for the assessment of the location and complications associated with supernumerary teeth. There still is insufficient data regarding the frequency of root resorption of neighbouring teeth and little information regarding the reliability of these assessments when using CBCT. The aim of the present study was to evaluate the 3D location of supernumerary teeth, to assess the frequency, extent, and influencing factors of associated root resorption of adjacent teeth, and to analyse inter-rater agreement of the observers using CBCT imaging.

Materials and methods

Patients

The design of the present study was retrospective and included CBCT images from 82 consecutive patients referred for radiographic localization of one or more supernumerary teeth between January 2010 and December 2012 to the Section of Dental Radiology and Stomatology, Department of Oral Surgery and Stomatology, University of Bern. Patients suffering from a syndrome or a cleft lip and palate were excluded from the study. Due to the retrospective nature of the study, it was exempt from formal approval by the ethical committee of the Canton of Bern.

CBCT imaging and analysis

All CBCT images were taken using a dentoalveolar field of view (FOV: 4 × 4, 6 × 6, or 8 × 8 cm; 3D Accuitomo XYZ Slice View Tomograph, Morita Corp., Kyoto, Japan). A basic voxel size of 0.08 mm was used for evaluation of all FOVs included. The operating parameters were set at 5.0 mA and 80 kV, and the exposure time was 17.5 seconds. The data were reconstructed in slices and examined slice by slice in all three dimensions (sagittal, coronal, and axial) using a specialized software program (i-Dixel, Morita Corp., Kyoto, Japan). When needed, the magnifying tool and the ruler of the viewer were used.

The following analyses (qualitative) and measurements (quantitative; in mm) were performed for every supernumerary tooth:

1. Type and location of the supernumerary tooth:
   (a) Type: the supernumerary teeth were grouped into supernumerary mesiodentes, lateral incisors, canines, premolars, paramolars, or distomolars.
   (b) Vertical: location of the cusp tip of the supernumerary tooth in relation to the long axis of the closest erupted adjacent tooth divided into apical to the root tip, apical third of the root, middle third of the root, cervical third of the root, or coronal.
   (c) Bucco-oral: location of the crown of the supernumerary tooth classified as labial/buccal, median/within arch, or oral (palatal/lingual).
2. Shape of the supernumerary tooth: classified into conical, tuberculate, supplemental, odontoma, or developing tooth bud (according to the definition proposed by Garvey *et al.*, 1999; see Figures 1–5).
3. Position (in relation to normal tooth eruption) of the supernumerary tooth: divided into normal, inclined, transverse, inverted, or undefinable.
4. State of eruption of the supernumerary tooth: erupted or impacted.
5. Follicle size measurement was performed (in millimetres) at the widest area of the follicle perpendicular to the crown of the impacted tooth. For a qualitative description, distances greater than 3 mm were considered to be enlarged follicles (Ericson and Bjerklin, 2001).
6. Root resorption of adjacent teeth and its location in relation to the long axis of the involved tooth, classified as the cervical, middle, or apical third of the root or the tip of the root. If root resorption was suspected, the degree of resorption was graded according to the classification based on clinical and CT data by Ericson and Kurol (2000) for each tooth separately into: no resorption, slight resorption (resorption up to half of the dentine thickness), moderate resorption (resorption of the dentine midway to the pulp or more, the pulp lining being unbroken), and severe resorption (resorption reaches the pulp).
7. The closest distance between the supernumerary tooth and the nearest adjacent tooth was measured (in millimetres). For a qualitative assessment, tooth proximity was defined by ≤0.5 mm distance between the two teeth (Walker *et al.*, 2005; Lai *et al.*, 2013b).
8. Presence of associated local aberrations/complications such as inclusion, malposition, or dismorphia of the adjacent permanent tooth.
9. For the mesiodens only, the relationship of the supernumerary tooth to the cortex of the nasal floor (no contact;

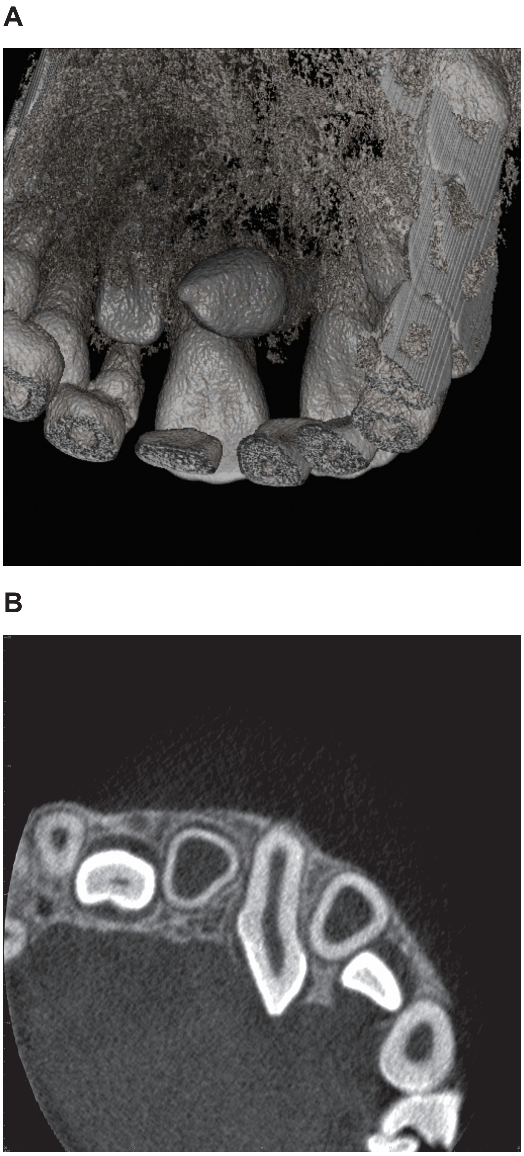

Figure 1 Representative example of a cone beam computed tomography (CBCT) scan exhibiting a conically shaped supernumerary tooth in the anterior maxilla (A: volume rendered image; B: axial CBCT image).

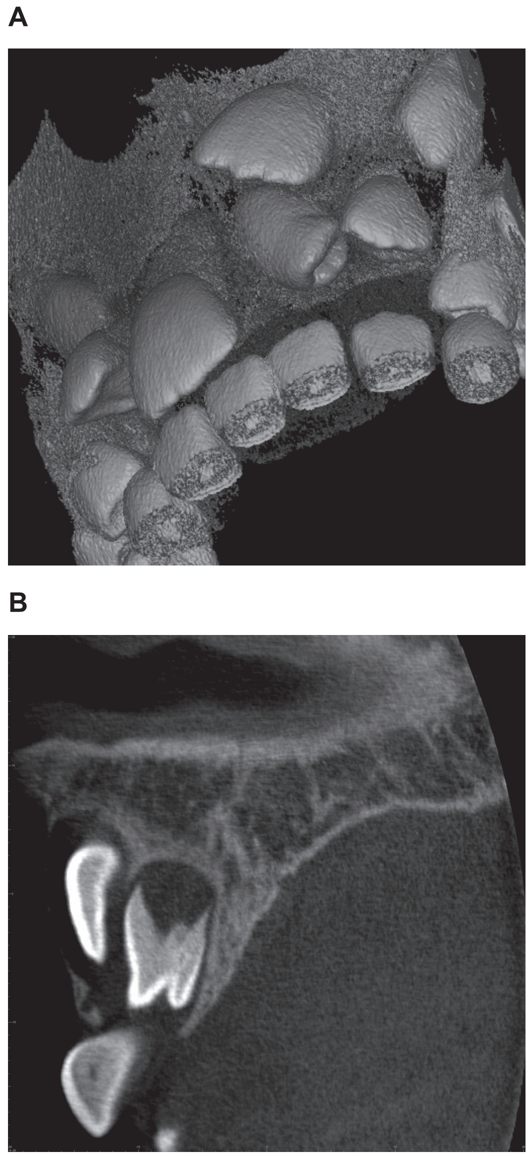

Figure 2 Representative example of a cone beam computed tomography (CBCT) scan exhibiting a tuberculate type of supernumerary tooth in the anterior maxilla (A: volume rendered image; B: sagittal CBCT image).

in contact with cortical bone; partially perforated cortical bone; located within cortical bone), the nasopalatine canal (no contact; in contact with the canal; partially perforated the canal; located within the canal), and the labial cortical bone (no relation; in contact with labial cortical plate; labial perforation) was additionally evaluated.

Two orthodontists blinded to patient history, diagnosis, and therapy reviewed all CBCT scans. First, a calibration exercise took place with 10 random scans. Then, all scans were evaluated independently. Interrater agreement was evaluated for all measurements taken. After calculation of interrater agreement, disagreement in data was solved by discussion, and thereafter descriptive and statistical analyses on one data set were performed.

Statistical analysis

Descriptive statistics were calculated for all recorded parameters. To assess interrater agreement, unweighted Cohen's kappa values were calculated. Initially, univariable and multivariable random effects logistic regression models were applied using the patient as the cluster with the objective to assess potential associations between root resorption, and gender, patient age, shape, position, root proximity, follicular width (quantitative values), and associated local aberrations of the supernumerary teeth. However, the models were unstable possibly due to low sample sizes as indicated by the large standard errors and the results of the quadrature evaluation of the conditional logistic model. Based on these models, only the effect of age on root resorption could be calculated. Due

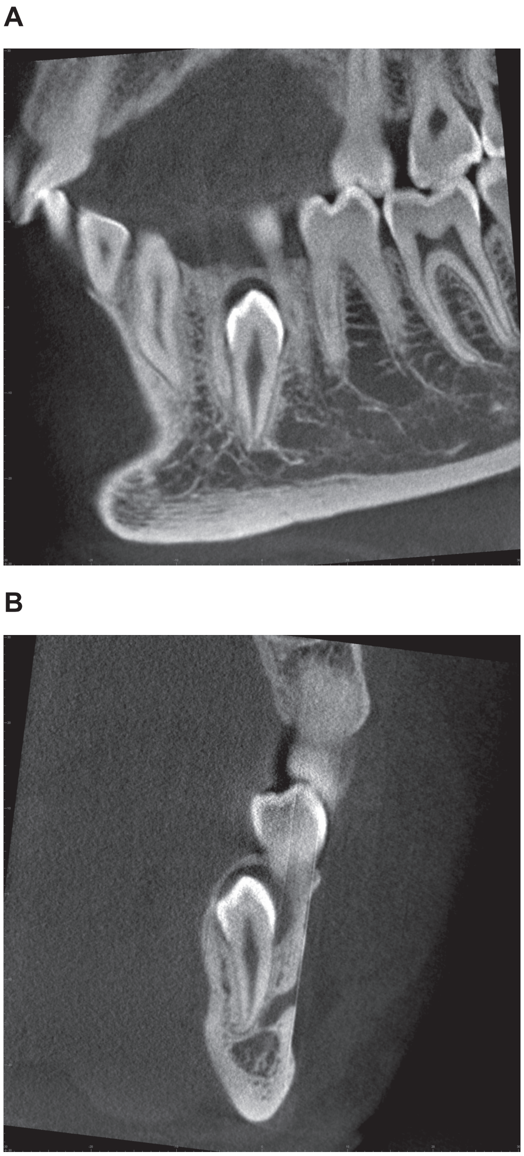

Figure 3 Representative example of a cone beam computed tomography (CBCT) scan exhibiting a supplemental type of supernumerary teeth in the left posterior mandible (A: sagittal CBCT image; B: coronal CBCT image).

to the inability to fit the random effects models on the present data, the association between follicular width and root proximity on root resorption were calculated using unconditional logistic regression. Chi-square tests accounting for clustered data were used to evaluate the association between the other variables of interest and root resorption of adjacent teeth. All statistical tests were performed using STATA 13.1 (Stata Corp., College Station, Texas, USA).

Results

Patients and sample characteristics

Of the 82 patients included, 51 (62.2 per cent) were male and 31 (37.8 per cent) were female, resulting in a gender ratio of 1.65:1. The age of the patients ranged from 6 to 72 years with a mean age of 15.8 years. Most of the patients were 20 years or younger with 23 patients aged 6–10 years (28.05 per cent), 46 patients aged 10–20 years (56.10 per cent), and only 13 patients older than 20 years (15.85 per cent).

In the 82 patients included, a total of 101 supernumerary teeth were diagnosed resulting in an average number of 1.23 teeth per person. Two-thirds of the supernumerary teeth (67/101, 66.34 per cent) were found in males and 34 in females (33.66 per cent). Most of the patients had one supernumerary tooth (66/82, 80.5 per cent), 13 patients (15.8 per cent) had two supernumeraries, and 3 patients (3.7 per cent) had three. The mesiodentes were the most frequently diagnosed type of supernumerary tooth (49/101, 48.52 per cent), followed by supernumerary premolars (24/101, 23.76 per cent) and supernumerary lateral incisors (19/101, 18.81 per cent). Of the 35 multiple supernumerary teeth, 42.9 per cent (15 teeth) were mesiodentes and 40 per cent (14 teeth) were premolars. Qualitative and quantitative data are presented in detail in Tables 1 and 2.

Interrater agreement

The Cohen's kappa for interrater agreement ranged from 0.55 to 1 (Table 3). The highest kappa values (1) were found for type and shape of the supernumerary teeth.

Descriptive analysis of mesiodentes

Of the 49 diagnosed mesiodentes, most had a conical (34/49, 69.4 per cent) or tuberculate shape (13/49, 26.5 per cent; Table 1). The position of the tooth was normal or inclined in 53 per cent (26 teeth) and inverted in 36.75 per cent (18 teeth). The analysis of the 3D location revealed that most mesiodentes were located palatally or within the alveolar arch (47/49, 95.9 per cent). In most cases, the vertical location of the mesiodens cusp tip in relation to the long axis of the closest erupted adjacent tooth was in the cervical third of the root (19/49, 38.8 per cent). More than two-thirds of the mesiodentes (33/49, 67.3 per cent) exhibited local aberrations of the permanent dentition such as inclusion of the permanent neighbouring tooth or dental malposition and the mean follicular width was 1.34 mm (Table 2). Of the 49 mesiodentes, 10 (20.5 per cent) were in contact with the cortical bone of the nasal floor (Supplementary figure 1) and 24 (49 per cent) with the nasopalatine canal (Table 4 and Supplementary figure 2). In seven cases, the mesiodentes were in close relation to the labial cortical plate or exhibited a labial perforation. In most cases (38/49, 77.6 per cent), the mesiodentes were located 0.5 mm or less from the roots of the neighbouring central incisors (mean distance: 0.32 mm).

Descriptive analysis of supernumerary lateral incisors

Of the 19 supernumerary lateral incisors, 13 (68.4 per cent) were located in the maxilla (Table 1). The shape and position of the teeth were distributed evenly within the different categories. As with the mesiodentes, most of the supernumerary

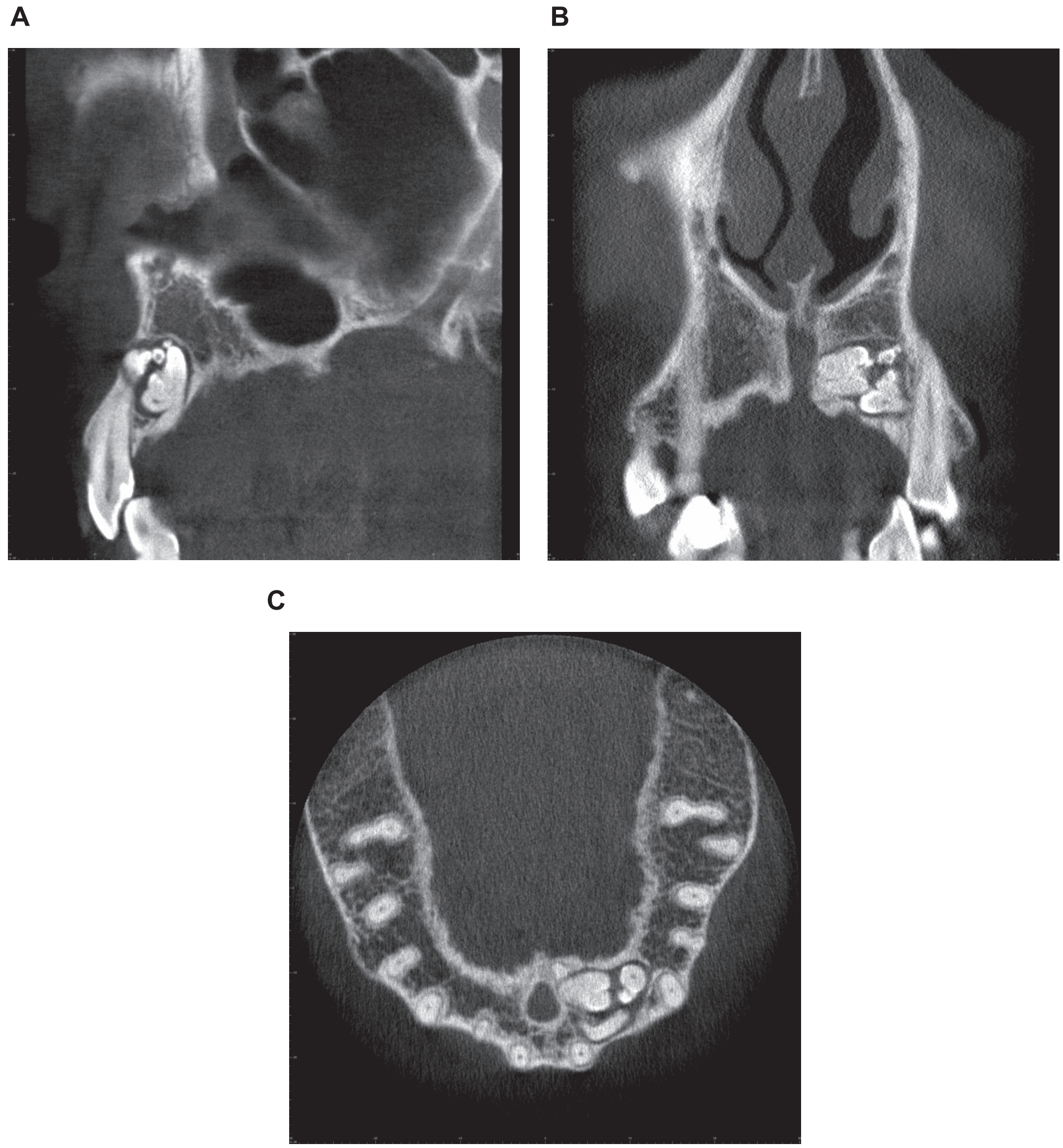

Figure 4 Representative example of a cone beam computed tomography (CBCT) scan exhibiting an odontoma type of supernumerary tooth in the anterior maxilla (A: sagittal CBCT image; B: coronal CBCT image; C: axial CBCT image).

lateral incisors (18/19, 94.7 per cent) were located palatally or within the alveolar arch. The cusp of the supernumerary incisors was mostly located in the middle third of the root of the closest adjacent tooth (7/19, 36.8 per cent), and two lateral incisors (10.5 per cent) were erupted. Of the 19 supernumerary lateral incisors, 14 (73.7 per cent) were associated with local aberrations of the permanent dentition. The mean follicular width was 1.63 mm (Table 2) and a follicular enlargement (greater than 3 mm) was present in two cases (10.5 per cent).

Descriptive analysis of supernumerary premolars

Of the 24 supernumerary premolars, 20 (83.3 per cent) were located in the mandible (Table 1). Most of them were of the supplemental type (17/24, 70.8 per cent), and they all had a normal or inclined position of eruption. The crown was usually located orally (19/24, 79.2 per cent), whereas the roots were often located in the middle of the arch. Vertically, the supernumerary cusp tip was mostly located in the middle third of the root of the adjacent tooth (14/24, 58.3 per cent). All the supernumerary premolars were located at or less than 0.6 mm away from the closest adjacent tooth (mean distance of 0.13 mm; Table 2). Associated local aberrations were diagnosed for six teeth (25.1 per cent). The mean follicular width was 1.56 mm and a follicular enlargement was detected in only one of the cases (4.2 per cent).

Descriptive analysis of supernumerary canines, paramolars, and distomolars

The supernumerary canines (three teeth) were all located in the mandible, the paramolars (two teeth) in the maxilla, and

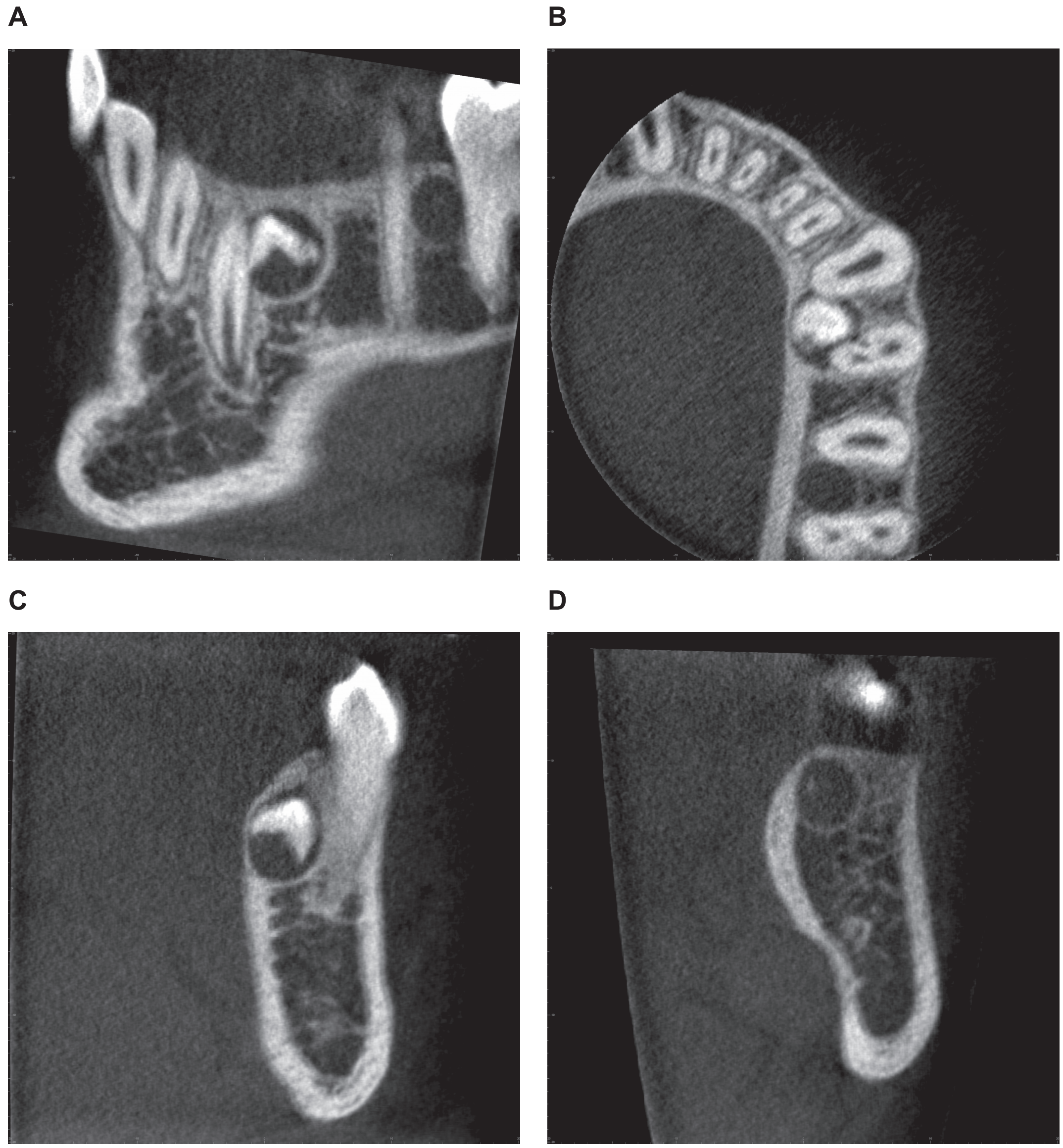

Figure 5 Representative example of a cone beam computed tomography (CBCT) scan exhibiting two supernumerary teeth classified as developing tooth buds in the left posterior mandible (between canine and first premolar, and second premolar and first molar; A: sagittal CBCT image; B: axial CBCT image; C: coronal CBCT image between canine and first premolar; D: coronal CBCT image between second premolar and first molar).

the distomolars (four teeth) were evenly distributed in both jaws. For further details, see Tables 1 and 2.

Descriptive analysis of root resorption of neighbouring permanent teeth

Root resorption of the adjacent teeth was detected for 22.8 per cent (23 teeth) of the supernumerary teeth. Root resorption of the adjacent teeth was most frequent in supernumerary premolars (62.5 per cent; Tables 1 and 5). Four premolar supernumeraries resorbed two adjacent teeth simultaneously. For mesiodentes, root resorption was detected in five cases (10.2 per cent), and for the 19 supernumerary lateral incisors, in three cases (15.8 per cent). No resorption of adjacent teeth was detected for supernumerary canines, paramolars, and distomolars.

Association of root resorption with patient and CBCT data

Logistic regression showed no association between patient age (P = 0.72) and root resorption. Some evidence of an association between root resorption and proximity of the supernumerary tooth with the adjacent tooth [odds ratio (OR): 0.01; 95 per cent confidence interval (CI): 0.0, 0.56; P = 0.02) and follicular width (OR: 2.12; 95 per cent CI: 1.16, 3.38; P = 0.02) was observed. However, results from the unconditional logistic regression should be interpreted with caution, as standard errors are likely to be underestimated. The chi-square tests showed a statistically significant association between root resorption and type of supernumerary teeth (P = 0.001) with most resorptions found for supernumerary premolars. There was also a

Table 1 Descriptive data regarding location, morphology, and associated complications of supernumerary teeth in the maxilla and mandible in 82 patients.

Type of tooth		Mesiodens	Lateral incisor	Canine	Premolar	Paramolar	Distomolar
Number		49	19	3	24	2	4
Mean age of patients		12.38	19.3	13.89	18.99	12.84	25.92
Jaw	Maxilla	49 (100%)	13 (68.4%)	0	4 (16.7%)	2 (100%)	2 (50%)
	Mandible	0	6 (31.6%)	3 (100%)	20 (83.3%)	0	2 (50%)
Shape	Developing tooth bud	0	2 (10.5%)	1 (33.3%)	5 (20.8%)	0	0
	Conical	34 (69.4%)	6 (31.6%)	0	1 (4.2%)	1 (50%)	1 (25%)
	Tuberculate	13 (26.5%)	4 (21.05%)	0	1 (4.2%)	0	1 (25%)
	Supplemental	1 (2.05%)	3 (15.8%)	1 (33.3%)	17 (70.8%)	0	1 (25%)
	Odontoma	1 (2.05%)	4 (21.05%)	1 (33.3%)	0	1 (50%)	1 (25%)
Position/inclination	Normal	13 (26.5%)	3 (15.8%)	1 (33.3%)	9 (37.5%)	1 (50%)	1 (25%)
	Inclined	13 (26.5%)	4 (21.05%)	1 (33.3%)	15 (62.5%)	0	1 (25%)
	Transverse/horizontal	4 (8.2%)	3 (15.8%)	1 (33.3%)	0	0	1 (25%)
	Inverted	18 (36.75%)	5 (26.3%)	0	0	0	0
	Indefinable	1 (2.05%)	4 (21.05%)	0	0	1 (50%)	1 (25%)
Bucco-oral position of crown	Labial/buccal	2 (4.1%)	1 (5.3%)	1 (33.3%)	1 (4.2%)	1 (50%)	0
	Within arch/median	23 (46.9%)	10 (52.6%)	0	4 (16.7%)	1 (50%)	3 (75%)
	Oral (palatal/lingual)	24 (49%)	8 (42.1%)	2 (66.7%)	19 (79.1%)	0	1 (25%)
Vertical position of the tip of the supernumerary tooth (compared with the closest erupted adjacent tooth)	Apical to the adjacent teeth	10 (20.4%)	1 (5.3%)	0	0	0	0
	Apical third of the root of the adjacent tooth	10 (20.4%)	4 (21.05%)	0	1 (4.2%)	0	0
	Middle third of the root of the adjacent tooth	5 (10.2%)	7 (36.8%)	1 (33.3%)	14 (58.3%)	0	2 (50%)
	Cervical third of the root of the adjacent tooth	19 (38.8%)	4 (21.05%)	2 (66.7%)	6 (25%)	2 (100%)	2 (50%)
	Coronal region of the adjacent tooth	5 (10.2%)	3 (15.8%)	0	3 (12.5%)	0	0
Proximity	≤0.5 mm to adjacent tooth	38 (77.6%)	17 (89.5%)	3 (100%)	23 (95.8%)	2 (100%)	4 (100%)
State of eruption	Impacted	45 (91.8%)	17 (89.5%)	3 (100%)	23 (95.8%)	2 (100%)	4 (100%)
	Erupted	4 (8.2%)	2 (10.5%)	0	1 (4.2%)	0	0
Associated local aberrations/complications	Asymptomatic	16 (32.7%)	5 (26.3%)	0	18 (74.9%)	0	2 (50%)
	Inclusion of permanent teeth	15 (30.6%)	6 (31.6%)	0	1 (4.2%)	2 (100%)	2 (50%)
	Dental malposition	18 (36.7%)	8 (42.1%)	3 (100%)	4 (16.7%)	0	0
	Delayed/abnormal root development of permanent incisor	0	0	0	0	0	0
	Other	1* (2.05%)	0	0	1** (4.2%)	0	0
Follicle size	Follicular width >3 mm	2 (4.1%)	2 (10.5%)	0	1 (4.2%)	0	0
Root resorption	Yes	5 (10.2%)	3 (15.8%)	0	15 (62.5%)	0	0

*Geminated 21 (one patient who also had dental malposition).
**Only three lower incisors.

Table 2 Quantitative data (in millimetres) regarding follicular width of supernumerary teeth and the distance between the supernumerary tooth to the closest adjacent tooth in the maxilla and mandible in 82 patients.

Type of tooth		Mesiodens	Lateral incisor	Canine	Premolar	Paramolar	Distomolar
Follicular width	Mean	1.34	1.63	0.96	1.56	1.02	1.51
	Minimum	0	0	0.61	0.58	0.59	1.07
	Maximum	10.07	8.24	1.47	3.36	1.45	2.11
	Standard deviation	1.48	2.07	0.45	0.85	0.61	0.45
Closest distance between the supernumerary tooth and the nearest adjacent tooth	Mean	0.32	0.52	0.14	0.13	0	0.14
	Minimum	0	0	0	0	0	0
	Maximum	1.37	4.28	0.26	0.60	0	0.23
	Standard deviation	0.32	1.16	0.13	0.15	0	0.10

Table 3 Interrater agreement between the two experienced orthodontists using Cohen's kappa values.

Variable	Kappa values
Mesio-distal location of supernumerary (type of supernumerary)	1.00
Bucco-oral position of the crown	0.89
Vertical position of crown tip of supernumerary	0.55
Shape	1.00
Direction of eruption	0.80
State of eruption	0.85
Prevalence of associated local aberrations	0.97
Prevalence of root resorption	0.65
Severity of root resorption	0.89
Location of root resorption	0.74
Relation of the mesiodens to the cortex of the nasal floor	0.83
Relation of the mesiodens to nasopalatine canal	0.76
Labial perforation of the mesiodens	0.66

Kappa values: no agreement, <0; slight, 0–0.2; fair, 0.21–0.40; moderate, 0.41–0.60; substantial, 0.61–0.80; almost perfect, 0.81–1 (Landis and Koch, 1977).

Table 4 Detailed descriptive analysis of three-dimensional location and position of the 49 mesiodentes.

Relation to the cortical bone of the nasal floor	No contact	39 (79.5%)
	In contact with cortical bone	4 (8.2%)
	Partially perforated cortical bone	4 (8.2%)
	Located within the cortical bone	2 (4.1%)
Relation to nasopalatine canal	No contact	25 (51%)
	In contact with the canal	19 (38.8%)
	Partially perforated the canal	4 (8.2%)
	Located within the canal	1 (2%)
Relation to labial/buccal bone of the alveolar process	No contact	42 (85.7%)
	In contact with labial cortical plate	3 (6.1%)
	Labial perforation	4 (8.2%)

statistically significant association between the shape of the supernumerary tooth and root resorption ($P = 0.01$) with resorptions being more frequent in the proximity of supplemental supernumeraries. No significant association was found between root resorption and gender ($P = 0.43$), 3D location of the supernumerary teeth in the vertical ($P = 0.17$) and oro-buccal plane ($P = 0.74$), and associated local aberration ($P = 0.08$).

Discussion

This study resulted in an almost perfect interrater agreement (kappa values) with regards to the type (1) and shape of the supernumerary teeth (1), and the prevalence of associated local aberrations (0.97; Landis and Koch, 1977). Furthermore, there was a high agreement between the two orthodontists in assessing the location, prevalence, and the severity of root resorption on adjacent teeth. This was similar to results reported by Lai and co-workers (2013b) for root resorption of adjacent teeth in the anterior maxilla caused by impacted canines.

In this study, the male:female ratio was 1.61:1 for supernumerary teeth, a value that corroborates the gender ratios previously reported (Rajab and Hamdan, 2002; Fernández Montenegro *et al.*, 2006; Gündüz *et al.*, 2008; Wang and Fan, 2011) but lower than the 2.6:1 (von Arx, 1990) and 2.75:1 (Schmuckli *et al.*, 2010) ratios reported previously for Switzerland. In the present study, 16 patients (out of 82) had two or more supernumerary teeth, which is in accordance with previous studies (von Arx, 1990; Rajab and Hamdan, 2002; Fernández Montenegro *et al.*, 2006; Liu *et al.*, 2007; Gündüz *et al.*, 2008; Ferrés-Padró *et al.*, 2009; Hyun *et al.*, 2009). In the current investigation, 61.4 per cent of the supernumerary teeth were located in the anterior maxilla. Several studies have reported higher (Liu *et al.*, 2007/92 per cent; Rajab and Hamdan, 2002/89.6 per cent; Schmuckli *et al.*, 2010/86 per cent; Ferrés-Padró *et al.*, 2009/72.2 per cent) and two lower percentages (Fernández Montenegro *et al.*, 2006/48.3 per cent; Salcido-García *et al.*, 2004/46.8 per cent). Nevertheless, it has to be taken into consideration that the population investigated in the present study was specifically referred for further diagnosis and treatment of supernumerary teeth, which may explain some of the differences found.

Supernumeraries appeared in a variety of shapes, with conical being the most common in this study (42.6 per cent). This confirms data reported in other studies (Rajab and Hamdan, 2002; Liu *et al.*, 2007; Gündüz *et al.*, 2008; Ferrés-Padró *et al.*, 2009; Hyun *et al.*, 2009; Schmuckli *et al.*, 2010). In the present study, approximately one-third of the supernumeraries in the anterior maxilla were inverted, which was similar to findings from other studies (Koch *et al.*, 1986; Liu *et al.*, 2007; Gündüz *et al.*, 2008). On the contrary, Rajab and Hamdan (2002) reported that most supernumerary teeth were normally oriented. A significant number of mesiodentes were located in close contact to the cortex of the nasal floor (20.5 per cent) or the nasopalatine canal (49 per cent) and within a 0.5 mm distance to the roots of one of the central incisors (77.6 per cent). These findings underline the importance of a thorough 3D analysis of supernumerary teeth for treatment planning to decide upon the appropriate surgical approach prior to removal.

In this study, approximately two-thirds (67.3 per cent) of the mesiodentes were associated with local aberrations of the dentition such as dental malposition or impaction of permanent teeth. Higher (77.7–80.9 per cent; Tay *et al.*, 1984; Gündüz *et al.*, 2008) and lower (46.9–59 per cent; von Arx, 1990; Liu *et al.*, 2007; Hyun *et al.*, 2009) percentages have previously been reported in the literature. These findings demonstrate that in approximately one-third of the patients, supernumerary teeth are an incidental finding during a routine radiographic examination without clinical symptoms. This also explains the wide range of patient ages (6–72 years) included.

Table 5 Descriptive data regarding location and extent of root resorption.

Type of tooth		Mesiodens	Lateral incisor	Premolar
Number of supernumerary causing resorption		5	3	15
Number of supernumerary causing resorption on two adjacent teeth		1 (20%)	0	4 (26.7%)
Total of resorbed adjacent teeth		6	3	19
Direct contact between supernumerary and adjacent tooth at resorption location		3 (60%)	2 (66.6%)	15 (100%)
Extent of resorption	Slight (up to half of the dentine thickness to the pulp)	4 (66.7%)	0	16 (84.2%)
	Moderate (resorption midway to the pulp or more, the pulp lining being unbroken)	2 (33.3%)	1 (33.3%)	3 (15.8%)
	Severe (the pulp is exposed by the resorption)	0	2 (66.7%)	0
Location of resorption	Apical tip of the root	0	1 (33.3%)	2 (10.5%)
	Apical third of the root	3 (50%)	0	8 (42.1%)
	Middle third of the root	1 (16.7%)	1 (33.3%)	8 (42.1%)
	Coronal third of the root	2 (33.3%)	0	1 (5.3%)
	Several regions	0	1 (33.3%)	0

Surgical removal of a supernumerary tooth is indicated when eruption of the adjacent tooth has been delayed or inhibited, when altered eruption or displacement of the adjacent tooth is evident, when the supernumerary tooth interferes with active orthodontic treatment, if associated pathology (neighbouring root resoprtion, cyst formation, etc.) exists, or if spontaneous eruption of the supernumerary has occurred (Garvey *et al.*, 1999). The ideal time point for removal, particularly in the premaxillary region, remains controversial. Whereas some authors recommend immediate removal of the supernumerary teeth following diagnosis (Primosch, 1981; Nazif *et al.*, 1983; Mason *et al.*, 2000), others prefer to postpone surgery until the age of at least 8–10 years, when the root development of the central and lateral incisor is nearly complete in order to minimize injury to those teeth (Koch *et al.*, 1986). In some instances, unerupted and asymptomatic supernumerary teeth are left in place and kept under clinical and radiographic observation (Kurol, 2006). Garvey and co-workers (1999) recommended monitoring of supernumerary teeth without surgical removal where satisfactory eruption of the neighbouring teeth has occurred, no active orthodontic treatment is planned, no associated pathology is diagnosed, and where removal would risk damaging teeth in the vicinity.

In the present investigation, root resorption of adjacent teeth was detected for 22.8 per cent of the supernumerary teeth. A much lower frequency of root resorption of adjacent teeth (1.6 per cent) was reported in a study from China evaluating CBCT scans (Liu *et al.*, 2007). In contrast to the present study, root resorption was not a primary outcome variable of this study, and no information was given on the extent of resorption. Therefore, this study could have omitted slight or moderate root resorption, which could at least in part explain the differences in the percentages reported. Studies evaluating panoramic views for root resorption caused by mesiodentes reported resorption rates between 4.7 (Gündüz *et al.*, 2008) and 7.6 per cent (Hyun *et al.*, 2009). Tyrologou and co-workers (2005) even reported no resorption found. However, these studies only looked at mesiodentes, where root resorption of adjacent teeth seems to be less frequent. Furthermore, the reported incidence of root resorption also depends on the radiographic imaging method used. 2D radiographs have been demonstrated to be inaccurate for diagnosing root resorption and overlooking pathosis in 50 per cent of the cases (Ericson and Kurol, 1987; Heimisdottir *et al.*, 2005; Botticelli *et al.*, 2011; Alqerban *et al.*, 2011a).

By using 3D visualization, CBCT provides information in all three planes and thus enhances diagnostic accuracy (Becker *et al.*, 2010; Pazera *et al.*, 2011; Lai *et al.*, 2013b), which is quite an important parameter when considering surgical removal (Becker *et al.*, 2010). When taking into account the proximity of supernumerary teeth to vital anatomical structures such as the nasal floor, the nasopalatine canal, or the floor of the mouth, the need for accurate diagnostic 3D information prior to surgical and interdisciplinary interventions becomes evident. Recent studies comparing traditional radiography with CBCT concluded that 3D imaging provides more information on the presence and severity of root resorption (Alqerban *et al.*, 2009; Katheria *et al.*, 2010; Botticelli *et al.*, 2011; Alqerban *et al.*, 2011a; Lai *et al.*, 2013a). Another study (Haney *et al.*, 2010) reported that orthodontists had a substantially different perception of localization and severity of root damage, and a significantly higher confidence in diagnosis and treatment planning using CBCT images compared with conventional radiographs alone. A recent *in vitro* study on human skulls has shown no significant differences between different CBCT systems for assessing the severity of root resorptions (Alqerban *et al.*, 2011b).

The aetiology of root resorption following ectopic eruption of a tooth is still unclear. In earlier studies, it has been postulated that an enlarged dental follicle, as well as the pressure caused by an erupting tooth, may be responsible for root resorption of adjacent teeth (Bidwell *et al.* 1995; Marks *et al.*, 1997). However, Ericson and co-workers (2001) have concluded, based on CT examinations of impacted canines, that it is probably the direct physical contact of the ectopic canine with the permanent adjacent tooth and the direct pressure from the canine as a part of the eruption process that cause root resorption, and not the dental follicle. In the present study, there was some evidence of an association between enlarged follicles and supernumerary proximity to adjacent teeth and the occurrence of root resorption. However, these results should be interpreted with caution due to small sample size.

There was no association between age or gender of the patient and risk of root resorption. Root resorption showed a statistically significant association with the type of supernumerary tooth with root resorption being more prevalent in supernumerary premolars (15 out of 24). This could be explained by the fact that most premolar supernumeraries were found in the lower jaw (83.3 per cent), where they are often in close contact with adjacent teeth due to the anatomy of the mandible. The association between shape of the supernumerary tooth and root resorption is probably partially due to the fact that supernumerary premolars had predominantly a supplemental shape. In one-third of the cases, dental malposition of adjacent permanent teeth was detected when root resorption was present (8 out of 23 supernumerary teeth). On the other hand, root resorption was never detected in cases where the supernumerary teeth caused the inclusion of the adjacent tooth probably because in these cases the supernumerary teeth were mostly located coronally to the permanent tooth.

Conclusions

On the basis of the data from the present study, the following can be concluded:

- Supernumerary teeth occur alone or in multiple in any region of the jaws. They are most often located in the anterior maxilla (mesiodentes) and are conical in shape.
- CBCT provides 3D information with regards to the type, shape, and position of the supernumerary tooth as well as local aberrations and root resorption of adjacent permanent teeth with moderate to high interrater correlation.
- Root resorption of adjacent teeth is most likely to be diagnosed in the premolar region.
- Root resorption of adjacent teeth was associated to tooth type (premolars) and shape (supplemental) of supernumerary teeth.
- A significant number of mesiodentes were located either in close contact to the cortical bone of the nasal floor, the nasopalatine canal, and the roots of one of the adjacent central incisors. Therefore, a radiographic 3D analysis may be important for exact localization and treatment planning including surgical removal of mesiodentes.

Supplementary material

Supplementary material is available at *European Journal of Orthodontics* online.

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