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Maxillary anatomic vital structures when planning implant surgery: a critical assessment of the literature

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Abstract

Background and Objectives: Treatment and planning requires a precise anatomic observation of the targeted surgical area before any intervention is made. The aim of the present paper is to make a critical review related to anatomic landmarks of the maxilla in relation to dental implantation.
Methods: The database on MEDLINE, Cochrane Register of Controlled Clinical Trials, Cochrane Database of Systematic Reviews, and the Database of Abstracts of Review of Effect (DARE) was searched for the determined keywords in English.
Results: Incisive canal, nasal floor, maxillary sinus, sinus septa and posterior superior alveolar artery were the anatomic structures that might compromise implant surgery. Preoperative imaging with computed tomography is a valuable tool to evaluate and assess these vital structures.
Conclusions: Proper assessment and careful evaluation of the vital structures prior to surgery assists in avoiding potential surgical complications.

Introduction

Dental implants have long-term favourable survival and success in the rehabilitation of edentulous jaws. Treatment planning and surgical execution require a precise anatomic observation of the area before any intervention is made. This is especially important when there is severe bone loss, where insertion of implants may become problematic due to existing vital structures. Cone-beam computed tomography (CBCT) makes it possible to analyze anatomical structures, bone dimensions and the need for augmentation procedures prior to intervention. Because of high aesthetic and functional demands, angulation of implants may be a huge challenge especially in the atrophic anterior maxilla. Moreover, sinus lifting is commonly needed when the posterior maxilla is highly resorbed. Incisive canal, nasal floor, maxillary sinus, sinus septa and posterior superior alveolar artery are the anatomic structures that may compromise surgery. Preoperative imaging with CBCT is a valuable tool to evaluate and assess these structures and avoid potential surgical complications. The purpose of this paper is to critically review and assess the literature related to these maxillary vital structures.

Methods

The database on MEDLINE, Cochrane Register of Controlled Clinical Trials, Cochrane Database of Systematic Reviews, Database of Abstracts of Review of Effect (DARE) was searched for the keywords maxillary incisive canal, nasopalatine canal, maxillary sinus elevation, 'nasal floor elevation, dental implant', sinus septa, posterior superior alveolar artery in the English language from 1965 to March 2015. References of systematic reviews were screened. Studies regarding the pathology of these structures such as cysts and tumours were not included. Studies examining the prevalence, dimension, course, relationship to teeth and alveolar ridge were included. Case reports concerning the complications related to these anatomic structures were also included. As we aimed to present detailed knowledge about maxillary anatomic structures, cadaveric studies were also included besides CBCT examinations. Articles that were not in English were excluded. The flow of the search is shown in Figure 1.

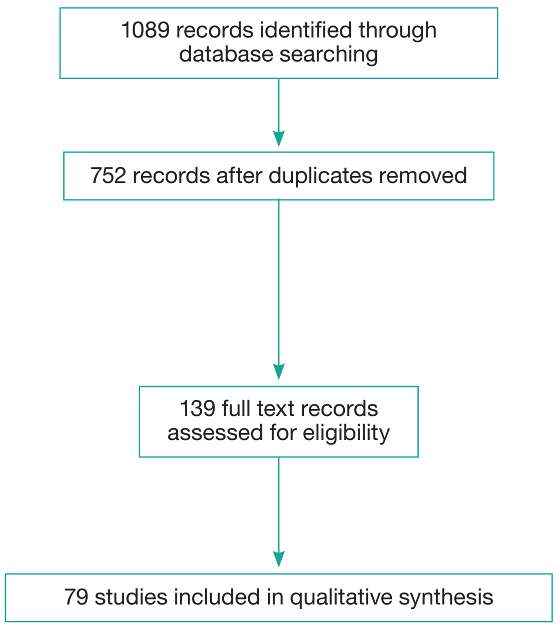

Figure 1. Search flow chart for the review of literature.

Results

The anterior part of the maxilla was discussed in subtitles as; incisive canal, accessory canals and nasal floor. The posterior maxilla included sinus septa and the posterior superior alveolar artery, which may hinder posterior maxillary surgeries. 1089 search results were identified and at least 78 studies constituted this review.

Anterior Maxilla

Incisive canal

The incisive canal (also named as the nasopalatine canal) located at the midline of the palate contains the nasopalatine (incisive) nerve and the terminal branch of the descending nasopalatine artery. It has been reported to host fibrous connective tissue, fat, and small salivary glands (Keith, 1979; Liang et al., 2009). The term 'nasopalatine canal' is used interchangeably with incisive canal by clinicians (Mraiwa et al., 2004; Bornstein et al., 2011; Etoz and Sisman, 2014), but incisive canal (IC) has been accepted officially according to the International Anatomical Terminology (Federative Committee on Anatomical Terminology, 1998).

The number and dimensions of canals may vary, and the canal may separate to up to 6 foraminae at the nasal opening (Sicher, 1962). Some studies reported 4 foraminae at the level of the nasal floor (Mraiwa et al., 2004; Liang et al., 2009; Thakur et al., 2013). Three foraminae can be detected at the incisive side of the canal (Fernandez-Alonso et al., 2014). However, contrary to these reports, Song et al. (2009) mentioned that the number of canals detected at the level of the nasal floor was 2 and it is single at the incisive opening; foraminae described in earlier studies were observed at the middle level of the IC or beneath the nasal floor, but not at the level of the nasal floor. Figure 2 shows single and separated incisive canals.

The opening of the canal at the nasal floor was named as the 'nasopalatine foramen' or 'foramina of Stenson'; the opening at the crest was named 'incisive foramen' (Bornstein et al., 2011; Thakur et al., 2013). One canal is the highest frequency (44%) found in the nasopalatine foramen, followed by 2 canals (39%) (Liang et al., 2009). Song et al. (2009) also reported the highest frequency of one canal, however, another study found the Y-shape canal to be most frequent, following one single canal (Fernandez-Alonso et al., 2014). There are morphologic variations of the canal; however, a universally accepted terminology for such is not available. Liang et al (2009) classified the canal shapes as cylindrical and cone-shaped. Mardinger et al. (2008) presented canal shapes as cylindrical (50.7 %), funnel-like (30.9 %), hourglass-like (14.75 %) and banana-like (3.9 %) canals in 207 CT images. Tözüm et al. (2012) and Fernandez-Alonso et al. (2014) gave the same classification and reported the most frequent canal shape as a cylindrical canal. Moreover, canal shape has also been classified based on the sagittal view direction such as slanted, vertical or combinations like slanted curved or vertical curved (Song et al., 2009). A case report showed a rare anatomical variation that involved a complete additional nasopalatine canal residing in a buccal position (Neves et al., 2013). Authors emphasize the importance of preoperative CBCT imaging so that their early detection can have a direct influence on therapeutic success.

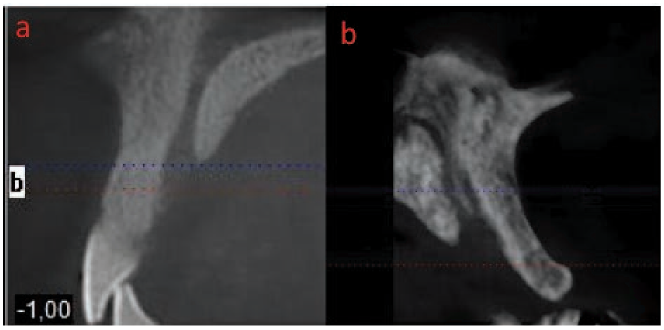

Figure 2. a: single incisive canal
b: Two incisive canals with one incisive foramen

Length and diameter of the incisive canal were measured in many studies (Table 1). Dimensions of the incisive canal were affected by dental status, age and gender of the patients (Mardinger et al., 2008; Guncu et al., 2013). Men generally had larger canal dimensions and buccal bone measurements than women (Bornstein et al., 2011; Guncu et al., 2013; Etoz and Sisman, 2014; Acar and Kamburoglu, 2015). Absence of teeth in the anterior maxilla decreased incisive canal length and buccal bone dimensions (Liang et al., 2009; Song et al., 2009; Tözüm et al., 2012; Etoz and Sisman, 2014; Acar and Kamburoglu, 2015). It has been reported that the incisive canal may occupy up to 58% (mean 36.5%) of the alveolar ridge width in the potential area of the two central incisor implants (Mardinger et al., 2008). This means that in atrophic ridges, changes in the treatment plan or augmentation procedures may be needed by complete removal or displacement of the canal contents (Rosenquist and Nystrom, 1992; Artzi et al., 2000).

Enucleation of the canal contents have been suggested in atrophic ridges in order to place dental implants. Sensory alterations have been reported but disappeared after a few weeks (Penarrocha et al., 2014). On the other hand, Raghoebar et al. (2010) reported that augmentation in proximity of the incisive canal is achievable without jeopardizing the nerve and vessels. Another study examining incisive canal position relative to the maxillary central incisors suggested paying attention at the mid-root level of central incisors in women and younger patients while performing immediate implant surgery because the presence of the canal may limit the amount of bone to achieve primary implant stability (Chatriyanuyoke et al., 2012).

Anatomical variations in the pre-maxilla; accessory canals

Von Arx et al (2013) reported that there were accessory canals other than the main incisive canal with a mean diameter of 1.31 mm, most frequently located palatal to the left central incisor. They detected accessory canals in 27.8 % of 176 individuals. Patients under the age of 20 did not present with an accessory canal; occurrence of accessory canals increased with increasing age. Another study reported the prevalence of additional foraminae as 15.7 % with a mean diameter of 1.4 mm

Table 1: Incisive canal studies

	Canal number	Diameter (mm)	Length (mm)	Buccal bone (mm)	Association of diameter and length with		
					Age	Gender	Dentition
Mraiwa et al., 2004 34 CT	1-4	IF :4.6 ±1.8 NF: 4.9 ± 1.2	8.1 ± 3.4	W: 7.4 ± 2.6	No Correlation	No correlation	No correlation
Mardinger et al., 2008 207 CT		IF: 2.93 ± 0.68 to 5.50±1.08 NF: 2.55 ± 1.0 to 3.28 ± 1.04	9 to 10.7	W: 2.66 to 6.4 mm L : 9.57 to 17. 22	(-) correlation with BB W&L (+) with NF diameter		Wider NF, shorter canal in edentate
Liang et al., 2009 120 CT	1-4	3.6±1.0	9.9±2.6		Wider with aging	Longer and wider in males	Longer in dentate No relationship with diameter
Song et al., 2009 56 cadaver	1-4	1.1 to 6.7	11.5				Longer in dentate
Bornstein et al., 2010 100 CBCT	1-2	IF: 3.49 NF: 4.45	10.99	W: 6.5 to 7.6	Longer with aging	Wider Buccal bone -longer canal in males	
Tözüm et al., 2012 933 CT		2.59±0.91	10.86±2.67	19.17±3.70	(-) correlation with BB	Longer and wider in males	Shorter canal and BB in edentulous
Thakur et al., 2013 100 CBCT	1-4	IF: 3.62 ±0.94 NF: 1.75± 0.77	10.08±2.25		No Correlation	Longer in males	
Fernandez- Alonso A et al., 2014 224 CBCT	1-5		12.34±2.79	W: 6.83 ±1.28 L: 20.87±3.68	No Correlation	Longer Canal and BB length in males	Longer BB in dentate
Etoz et al., 2014 490 CBCT	1-4	IF: 5.06 ± 1.48 NF: 3.09±1.25	12.59±2.89		No Correlation	Longer and wider in males	Longer in dentate
Acar et al., 2015 252 CBCT		IF: 3.03 female; 3.72 male NF: 3.72 female; 4.14 male	9.04 female 10.20 male	W: 6.24 to 6.53 in female ; 6.57 to 7.21 in male	(-) correlation with BB W&L	IF, BB dimensions, length greater in males	wider IF in dentate

W: Width L: Length BB: Buccal bone IF: Foramen on incive opening NF: Foramen on nasal opening

(de Oliveira-Santos et al., 2013). Some of these canals had a relationship with the nasal cavity and some were a direct extension of the canalis sinuosus (von Arx et al., 2013; de Oliveira-Santos et al., 2013). This is a normal anatomical feature, which carries the anterior superior alveolar artery and nerve. The canalis sinuosus can be frequently observed as a wide canal lateral to the nasal cavity and also under the anterior part of the nasal floor with CBCT (de Oliveira-Santos et al., 2013). Although the presence of the canalis sinuosus is a normal anatomic feature, its opening in the anterior palate is a variation that has not been properly described (de Oliveira-Santos et al., 2013).

Nasal Floor

The nasal floor is another important anatomic structure that should be avoided while performing implant surgery in the atrophic maxilla. Raghoebar et al. (2004) reported that implants extending to the nasal floor without any bone augmentation or nasal floor elevation caused rhinosinusitis. The number of studies related to nasal floor elevation is scarce in the literature; nasal floor elevation is suggested to be a reliable method for reconstruction of the anterior atrophic maxilla (El-Ghareeb et al., 2012; Garcia-Denche et al., 2015). Garcia-Denche et al. (2015) reported no nasal or sinus membrane perforation or other complications within their follow-up period (4.7 ± 2.1 years). El-Ghareeb et al. (2012) reported no complications with a mean follow up of 14.2 months and 100% survival rate.

The nasal area should always be kept in mind and alveolar bone height should be precisely measured with CBCT before surgery to avoid any implant penetration into the nasal cavity.

Posterior Maxilla

Sinus Septa

Ridge resorption following tooth extraction and sinus pneumatization compromises implant installation procedures in the posterior maxilla. It was recommended that residual bone height of 5 mm or less requires sinus augmentation (Pjetursson and Lang, 2014). The most frequent complication during this surgery is sinus membrane perforation (Schwartz et al., 2004) and the sinus septa is one of the major contributing factors for this complication (Krennmair et al., 1999; Zijderveld et al., 2008; Chan and Wang, 2011). von Arx et al. (2014) reported membrane perforation of 42.9 % in the presence of septa, while the rate was 23.9 % without septa. Septa can be diagnosed either in panoramic radiographs or CT (Figure 3). However, compared with

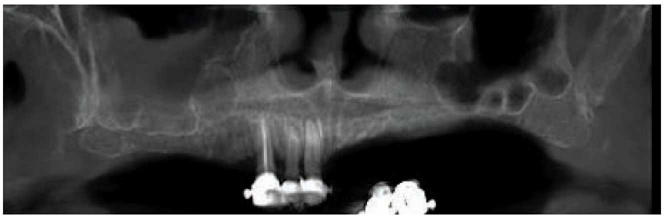

Figure 3. Sinus that needs grafting represents multiple sinus septa

CBCT, diagnosis of sinus septa using 2D panoramic radiographs yielded incorrect results in 29% of cases (Pommer et al., 2012).

The prevalence of sinus septa ranged from 9.5% to 55.2% and is more frequently a single septum (Yang et al., 2009; Ilguy et al. 2013). The sinus septa was reported to be more common in edentulous ridges than the dentate maxilla (Krennmair et al., 1999; Kim et al., 2006). On the other hand, a recent study could not detect a significant difference in the prevalence, height, location, and direction of maxillary sinus septa between dentate and edentulous patients (Jang et al., 2014). The height and location of sinus septa were examined in many studies (Table 2). The location was categorized as anterior in the first and second premolar region, middle on the first and second molars, and posterior distal to the second molar. The most frequent location was reported as middle in many studies (Table 2). When there are sinus septa, a two windows approach and/or changing the location of the lateral access window are proposed ways to avoid complications (Kang et al., 2013).

Posterior Superior Alveolar Artery

The posterior superior alveolar artery (PSAA) and nerve (PSAN) run caudally on the outside of the convexity of the maxillary tuberosity and are in close contact with bone and periosteum (Solar et al., 1999; Traxler et al., 1999). This vessel should be taken into consideration during sinus augmentation because of the potential risk of bleeding during the procedure (Ella et al, 2008). Additionally, the PSAA and infra-orbital artery form anastomoses on the lateral wall of the maxillary sinus (Rosano et al., 2009; Sato et al., 2010) and these anastomoses were reported to be at 18.9–19.6 mm distance from the alveolar crest (Solar et al., 1999; Traxler et al., 1999). Besides dental implant surgery, intense bleeding has been reported in Le Fort I fractures. It was suggested that if the oro-nasal bleeding continues in a Le Fort fracture, bleeding from the posterior superior alveolar artery should be suspected (Hwang and Choi, 2009).

It is possible to detect the vessel-nerve canal on CBCT sections but not in panoramic radiographs (Santos et al., 2015). According to many CT studies (Table 3), the PSAA artery runs at a distance of minimum 9.6 mm to maximum 21.25 mm from the alveolar ridge (Elian et al., 2005; Mardinger et al., 2007; Sato et al., 2010; Kim et al., 2011; Guncu et al., 2011; Kang et al., 2013; Ilguy et al., 2013; Rysz et al., 2014; Anamali et al., 2015). It may run inside the bone (intra-osseous), below the Schneiderian membrane or on outer cortex of the lateral sinus wall (Figure 4). The intra-osseous type was reported to be the most frequent (Guncu et al., 2011; Kang et al., 2013). Traxler et al (1999) reported the mean calibre of PSAA to be 1.6 mm at its origin, however the diameter varied through its path as presented in CBCT studies (Table 3) (Rosano et al., 2009; Guncu et al., 2011; Ilguy et al., 2013). Kang et al (2013) determined the relationship between the lateral wall thickness and diameter of the artery. They reported that the thicker the sinus lateral wall, the greater the vessel diameter. Gender and age of the patient may affect the diameter as well. Males were reported to have larger vessels (Guncu et al., 2011; Kim et al., 2011; Kang et al., 2013). One study detected a positive relationship with age (Mardinger et al., 2007) while others could not (Guncu et al., 2011; Ilguy et al., 2013). Maridati et al (2014) presented a double window design to protect the vessel (especially when > 2 mm), where it is left covered by the bone dividing the window into two parts.

In conclusion, reported data gives the mean distances and frequencies of anatomical structures. Although variations exist in every patient, precise knowledge of the anatomy determines the limits of safe areas in surgery. Several complications related to dental implantation and augmentation surgery exist. CBCT evaluation and the anatomic knowledge of the surgeon will help avoid complications and may enhance the success of treatment.

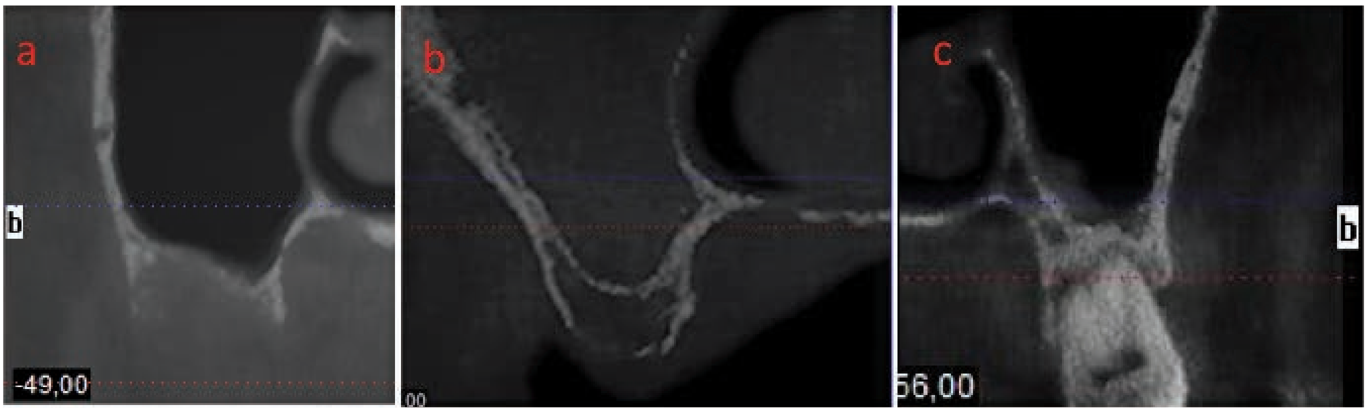

Figure 4. a: Posterior superior alveolar artery runs on the outer cortex of the lateral sinus wall
b: Artery stays below the Schneiderian membrane.
c: Artery runs inside the bone (intra-osseous course)

Table 2: Maxillary Sinus septa Studies

	Method	N sinus	Prevalance of Septa according to sinus (%)	Prevalance of septa due to dentition (%) (according to sinus)	Height (mean) (mm)	Most frequent Location
Ulm et al., 1995, Vienna	Clinic visualisation	82	18.3%	All edentulous	7.9	Middle
Krenmair et al., 1997, Austria	CT	200	16%	TE: 26.88% in 41 sinus D: 13.2% in 159 sinus	6.8±1.6	
Krenmair et al., 1999, Austria	CT/cadaver	92/41	Cadaver:36.6% CT: 20.65%	TE:32.5 in 83 sinus PE&D: 14% in 50 sinus	Cadaver: 7.9±4.2 CT: 7.7± 3.8 for TE 12.2± 7.5 PE&D	Anterior
Kasabah et al., 2002, Chezc Republic	CT	68	35.3%			
Velásquez-Plata et al.,2002, USA	CT	312	24%	TE: 30.48 % in 82 sinus PE: 21.73% in 230 sinus	3.54 ± 3.35 to 7.59 ± 3.76	Middle
Kasabah et al., 2003, Chezc Republic	CT	146	13%			
Schwardz-Arad et al., 2004, Israil	CT	81	28.4%			
Kim et al., 2006 Korea	CT	200	29.5 %	TE: 31.76 % in 85 D: 21.61% in 115	0 to 20.18	Middle
Gonzales-Santana et al., 2007 Spain	CT	60	28.3 %		2.5 to 6	Middle
Shibli et al., 2007 Brazil	Panaromic	2048	15 %	All edentulous		
Ella et al., 2008 France	Cadaver/CT	80/70	32.66%			
Selçuk et al., 2008, Turkey	CT	660	22.8%			
Becker et al., 2008, Germany	CT	201	22%			
Koymen et al.,2009 Turkey	CT	410	40.2%	TE: 51.41% in 177 PE: 92.85% in 28		Middle
Gosauet al., 2009, Germany	Cadaver	130	25.4%		5.4 (2.5 to 11mm)	Middle
Kfir et al., 2009, Israil	CT	57	45.6%			
Naitoh et al., 2009, Japan	CT	30	36.7%	All dentate	3.8 ± 1.8	
Rysz et al., 2009, Poland	CT	222	26%			
Van Zyl et al., 2009, South Africa	CT	400	56%		6.2 ± 3.7	Middle
Yang et al., 2009, South Korea	Cadaver	74	9.5%			Middle
Rosano et al., 2010, Italy	Cadaver	60	33%		14.06±3.37 transvers septa 8.72±4.26 antral septa	Middle
Neugebauer et al., 2010, Germany	CT	2058	33.2%		11.7 ± 6.08 sagittal septa 7.3 ± 5.08 transvers septa	Middle
Sbordone et al., 2010, Italy	CT	10	40%			
Toscano et al., 2010, USA	Clinic visualisation	56	30%			
Lee et al., 2010, Korea	CT	236		TE: 27.7% in 148 D: 19.3% in 88		Middle
Park et al., 2011, Korea	CT	400	27.7 %		7.78±2.99 R 7.89±3.09 L	Middle
Güncü et al., 2011, Turkey	CT	242	16.1%			
Maestre-Ferrin et al., 2011, Italy	CT	60	66.7%	TE: 83.3% in 18 PE: 61.1% in 36 D: 50% in 6	4.78±1.76	Middle
Pelinsari Lana et al., 2012, Brasil	CT	500	44%			
Shen et al., 2012, Taiwan	CT	846	20.45%	PE: 18.08% in 271 D: 21.56% in 575		Middle
Ilgüy et al., 2013, Turkey	CBCT	270	55.2 %			
Kang et al., 2013, Korea	CT	150	44%			
Gandhi et al.,2015, India	CT	210	28.1%	TE&PE: 55% in 89 D: 10% in 121	10.32±6.12 to 16.37±3.29	Middle

TE: Total edentulous PE: Partial edentulous D: Dentate R: Right L: Left

Table 3: Summary of Studies on Posterior Superior Alveolar Artery

	N sinus	Prevalance	Diameter (mm)	Distance from the ridge (mm)	Association of diameter and length with		
					Age	Gender	Dentititon
Elian et al., 2005, CT	50	52.9%		16.4 ± 3.5			
Mardinger et al., 2007, CT	208	55%	%26 <1 %22.1 1-2 %6-7 2-3	9.6 – 21.25 (E to A+B ridges)	(+) correlation		
Ella et al., 2008, Cadaver/CT	134	10.5%	1.20 mm				
Rosano et al., 2011, CT	200	47%	%55.3 <1 %40.4 1<2 %4.3 ≥2	11.25 ± 2.99			
Kang et al., 2013, CBCT	150		1.18 ±0.45	17.03 ± 3.53		Larger in males	
Kim et al., 2011, CT	400	52%	1.52 ±0.47	18.90 ± 4.21 in premolar 15.45 ± 4.04 in molar		Larger in males More prevalent in males	
Güncü, et al., 2011, CT	242	64.5%	1.3 ± 0.5	18 ± 4.9	No correlation	Larger in males	
Ilguy et al., 2013, CT	270	89.3%	0.94 ±0.26	16.88 ± 3.46	No correlation		More in dentate
Rysz et al., 2014, CT	202	50%		15.99 to 19.91 in edentulous 18.03 to 20.47 in dentate			40% in dentate 70% in edentulous
Anamali et al.,2015, CT	508	94.4 % left 91.1 % right					

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