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Prevalence and localization of *Canalis Sinuosus*: a mini review

Francesca Angiolani*, Maurizio Piattelli, Fabiola Rinaldi, Oriana Trubiani, Giuseppe Varvara

Department of Innovative Technologies in Medicine & Dentistry, University of Chieti-Pescara 'Gabriele d'Annunzio', Via dei Vestini 11, 66100 Chieti, Italy
*Corresponding author. E-mail: angiolanif@gmail.com

Abstract. In recent years, scientific literature has been focusing on the study of the *Canalis Sinuosus* (CS); this canal contains the *anterior superior alveolar nerve* (ASAN), together with bundles. Accordingly, the CS may vary its frequency and anatomical features. These variations can be identified through imaging technologies such as *cone beam computed tomography* (CBCT). The aim of this mini review is to present the current understanding of the CS, its prevalence and localization in order to decrease the potential surgical risk associated with this region. As revealed by the analysis of the international literature available, presence of CS is a crucial factor to consider in implantology and generally in oral surgery procedures in this area. In conclusions the use and analysis of CBCT imaging in the diagnosis stage is fundamental to preserve the most important anatomical structures which are present in the jaws.

Keywords: canalis sinuosus, maxillary anatomy, CBCT.

INTRODUCTION

Replacement of single or multiple missing teeth with dental implants in the anterior maxilla is a reliable treatment option, with success rates reaching as high as 95% [1]. However, the occurrence of complications remains a concern, needing an accurate preoperative planning [2]. The anterior region of the jaw exhibits significant variability in innervation and blood supply and high trabecular density, emphasizing the need for Cone Beam Computed Tomography (CBCT) and highlighting the importance of three-dimensional diagnostics.

Compared to two-dimensional radiographic techniques, CBCT is considered the most informative method for comprehensive pre and postoperative analysis of the maxillary anatomy [3]. It is crucial in avoiding complications [4], such as bleeding and neurological symptoms [5,6].

Oliveira-Santos et al. reported the relative frequent occurrence of foramina and canals in the anterior superior maxillary region underlining the need for dental surgeons to be well trained in identifying these variations [7]. One significant anatomical structure in this region is the *Canalis Sinuosus*

(CS) whose damage can lead to the aforementioned complications [8]. The CS is a small branch of the infraorbital canal that contains the anterior superior alveolar nerve and vessels, providing innervation and nutrition to the anterior maxilla [7,9]. It runs below the inferior wall of the orbit, passing below the infraorbital foramen and skirting the lateral and inferior borders of the nasal fossa, with its opening located in front of the nasopalatine canal [10,11]. The CS innervates dental elements such as incisors and the canines, as well as the corresponding soft tissues. Despite being under-discussed in scientific articles, CS and other jaw structures are still unfamiliar to most oral surgeons and dental students [12]. The aim of this study was to evaluate the course of the CS using CBCT and emphasize the importance of identifying the CS before performing surgical procedures near the canal. This awareness and knowledge of CS variability allows for increased safety during such procedures

MATERIALS AND METHODS

Study design

Literature searches were conducted trough PubMed and Web of science databases.

The terms used to identify studies were: *"canalis sinuosus"*, *"maxillary anatomy"* and "CBCT". These reporting items for the research was performed by using combinations of the following Boolean operators: *"AND", "OR".*

The mini review included only English language articles and the electronic search of publications was conducted in the last 10 years.

Inclusion criteria were: trials investigated using 3D radiographs (CBCT) that presented data on the prevalence and location of canalis sinuosus as main result.

All articles, presenting secondary results connected only to accessories canalis sinuosus (AC), canalis sinuosus orientation and meta-analysis, were ruled out.

RESULTS

The Table 1 below sum up the results of the study.

The search identified 19 articles in which the most common percentage, location and anatomical size of canalis sinuosus found, were examined, through detailed CBCT image.

The average and frequency of these values can be defined in detail by analyzing Table 1.

DISCUSSION

The increased and continuos use of implants for oral rehabilitation, together with the wider availability of CBCT imaging, has provided valuable information regarding important anatomical structures in the anterior maxillary region, where most surgeries are performed [7]. Within this area, the anterior superior alveolar nerve (ASAN) can be found, supplying innervation to the incisors, canines and their adjacent soft tissues. The ASAN is an intraosseous branch of the infraorbital nerve, originating from the maxillary nerve. The canalis sinuosus (CS) is a bony canal through which the infraorbital nerve passes to facilitate the passage of the ASAN [10]. In 1939, Frederic Wood Jones firstly described the CS, a bony canal containing neurovascular bundles that conveys the anterior superior alveolar nerve and vessels to the premaxilla [10]. The CS runs beneath the inferior margin of the orbit, medial to the anterior wall of the maxillary sinus, passing below the infraorbital foramen and skirting the lateral and inferior limits of the nasal fossa, ultimately opening into the nasal septum in front of the nasopalatine canal [13]. CBCT imaging is the most effective method for determining the location of the CS, making it highly valuable for diagnosis and implant planning [14].

In our search for studies on CS, we identified 19 publications in the PubMed database, comprising 11 case report and 6 prospective studies. These studies investigated the existence of the CS using CBCT with the number of subject ranging from 1 to 1460.

The frequency of CS occurrence varied significantly, ranging from 15.7% to 100%.

Regarding its specific locations, according to Oliveira-Santos et al's classification, the end of the CS trajectory, was found in several sites, with the highest occurrence observed in the maxillary intercentral region, particularly close to the lateral incisor, followed by the central incisor, between the central and lateral incisors, canine, posterior to the incisive foramen, and first premolar [7,10,15,16].

The majority of the studies in the literature describe cases of CS with diameter greater than or equal to 1 mm. However, Ghandourah et a, Fernandes et al and Khojastepour et al, reported cases with a diameter less than 1 mm.

Gender and age did not appear to influence the diameter, spatial location or and of the CS trajectory. While some studies suggests a higher prevalence of CS in males compared to females, no statistically no statistically significant differences were found [3,10,16,17].

Oliveira-Santos et al concluded that: "over 15% of the population studied had additional foramina in the ante-

Table 1.

Author	Year	Type of article	CBCT images evalueted	Presence of at least one CS	%	Localization End of CS	Size diameter
Aoki at al	2019	Prospective study	200	133	66.5	Central incisor (*n* = 91; 44.39%), Lateral incisor (*n* = 45; 21.95%) Canine (*n* = 29; 14.15%)	1 mm (*n* = 198/205; 96.6%) > 1 mm (*n* =6; 3.4%)
Anatoly at al	2019	Prospective study	150	101	67	Central incisor (n=36; 24.2%) Between central and lateral incisors (n=16; 10.7%) Lateral incisor (n=50; 33.5%) Canine (n=32; 21.5%) First premolar (n=14; 9.4%) Lateral to incisive foramen (n=1; 0.7%) Posterior to incisive foramen (n=0; 0%)	0.5-1 mm
Manhaes et al	2015	Prospective study	500	181	36.2	Central incisor (n=8;4.42%). Between central and lateral incisors (n=51;28.18%) Lateral incisor (n=28;15.46%) Canine (n=38;21%) First premolar (n=50;2762%) Lateral to Incisive foramen (n=35;19.33%) Posterior to incisive foramen (n=15;8.3%)	NS
Gurler et al	2017	Prospective study	111	111	100	Central incisor (n=1;1%) Between central and lateral incisors (n=o;o%) Lateral incisor (n=o;o%) Canine (n=o;o%) First premolar (n=0;0%) Lateral to incisive foramen (n=110;99%). Posterior to incisive foramen (n=o;o%)	(0.75-2.25 mm) 1.37 mm
Ruso et al	2017	Case report	1	1	100	NS	NS
Ghandourah et al	2017	Prospective study	219	144	65.75	NS	<1 mm
Wanzeler et al	2014	Prospective study	100	88	88	NS	0.7-0.8 mm
Machado et al	2016	Prospective study	1000	521	52.1		1.0-1.5 mm
Leven et al	2018	Case report	1	1	100	Lateral incisor	1.5 mm
McCrea et al	2017	Case report	1	1	100	Canine Posterior to incisive foramen	
Von Arx et al	2013	Prospective study	176	97	55.1	NS	NS
Oliveira-Santos et al	2013	Prospective study	178	28	15.7	Incisor Canine	(1-1.9 mm) 1.4 mm
Torres et al	2015	Case report	1	1	100	Medial at canine	2.5mm
Orhan et al	2018	Prospective study	1460	1460	100	Maxillary intercentral region	NS
Fernandes et al	2022	Prospective study	100	18	18	Palatal to the maxillary lateral incisor	<1 mm
Rosano et al	2020	Case report	1	1	100	Central incisor	NS
Harumiti Shintaku et al	2020	Case report	3	3	100	Canine Central incisor Lateral incisor	NS
Khojastepour et al	2023	Prospective study	485	380	78.35	Lateral incisor	<1 mm
Shan et al	2020	Prospective study	1007	372	36.9	Central incisor Lateral incisor	1.2 ± 0.1 mm

rior palate, ranging from 1 mm and 1.9 mm in width and located variably. In most cases, the canals associated with these foramina either served as a direct extension of the CS or traveled towards the nasal cavity floor [7]." Torres et al presents a case of dental implant placement in the anterior maxilla. The patient experienced neurovascular dis-

turbances, profuse postoperative nasal bleeding, pain, subnasal swelling, and a sense of "blockage" and "ethmoidal sinusitis" after 6 months [18]. When postoperative bleeding and prolonged paresthesia occur following dental implant placement in the anterior maxilla, neurovascular injury should be suspected [19] Shelley A et al, discussed a case in which an accessory canal (AC) was encountered during surgical implant placement, which could potentially result in persistent postoperative pain [3].

The presence of CS should be highlighted not only when planning surgery in the maxillary anterior, as it can affect implant success, but also when interpreting intraoral radiographs, as it may be mistaken for a periapical pathologic condition [20].

In conclusions, the CS is an anatomical structure which presence is relevant for oral surgery procedures in the anterior maxillary area. The awareness of it from clinicians lead to a more accurate diagnosis and treatment planning.

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