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Assessment of accessory canals of the canalis sinuosus: a study of 1000 cone beam computed tomography examinations

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Abstract. The aim of this study was to verify the presence, spatial location, and calibre of the accessory canals (AC) of the canalis sinuosus by cone beam computed tomography, and their relationship to the anterior maxilla. This retrospective analysis included the scans of 1000 subjects. Parameters registered were sex, age, number of AC, presence or absence of AC with a diameter <1.0 mm, AC diameter (only for AC with a diameter >1.0 mm), and AC location in relation to the adjacent teeth. Males showed a statistically higher frequency of AC than females. The difference in age distribution was not statistically significant. Twenty percent of all AC presented a diameter of a least 1.0 mm. The end of the AC trajectory was most frequently located palatal to the anterior maxillary teeth. All relationships analyzed here were very weak (age vs. number of AC, age vs. AC diameter, number of AC vs. sex). Overall, the results of this study showed that AC of the canalis sinuosus are a common anatomical structure in the anterior maxilla, regardless of age and sex.

Key words: maxilla; anterior superior alveolar nerve; canalis sinuosus; anatomical variation; morphometric measurements; cone beam computed tomography.

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Several surgical procedures are performed in the anterior maxilla, such as endodontic surgery, periodontal surgery, surgical removal of impacted or supernumerary teeth, the placement of dental implants, cyst therapy, and orthognathic surgery.[1] The neurovascular supply to this region is provided mainly by the infraorbital nerve. The infraorbital nerve is a branch of the maxillary nerve, and it supplies the skin and midface mucosa. At the point where it emerges on the face via the infraorbital foramen, the infraorbital nerve divides into three alveolar proximal branches and four distal branches.[2] Some publications have drawn attention to radiographically visible ramifications that may carry neurovascular structures to the anterior maxilla.[3–6] For example, the infraorbital canal issues a small branch on its lateral face close to its midpoint to allow passage of the anterior superior alveolar nerve, which is called the canalis sinuosus.[7] Fig. 1 shows examples of the canalis sinuosus leaving the

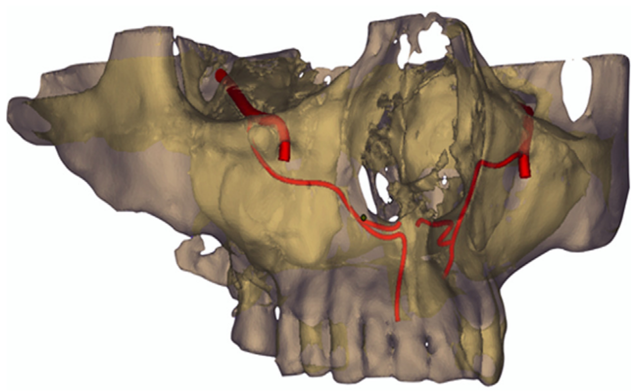

Fig. 1. Bilateral canalis sinuosus leaving the bilateral infraorbital canals (canals with the larger diameter), with some accessory canals (AC) at the end of their trajectory: two AC ending in the region of the anterior maxillary teeth and two AC ending in the nasal cavity floor.

bilateral infraorbital canals (canals with a larger diameter), with some accessory canals (AC) at the end of their trajectory: two AC ending in the region of the anterior maxillary teeth and two AC ending in the nasal cavity floor.

There are some issues associated with neurovascular bundles in the anterior maxilla. First, the lesion of such structures can cause sensory dysfunction and the risk of haemorrhage.[8,9] Second, it is hypothesized that contact with a local neurovascular bundle can lead to non-integration of a dental implant.[4] Third, such anatomical structures may also be interpreted as other anatomical structures or lesions, resulting in diagnostic confusion[3,10,11] and possibly leading to a mistaken or unnecessary procedure. Therefore, the preoperative identification of the course of nerves and vessels through radiographic evaluation is essential for safe surgical procedures.[10]

The presence of accessory foramina and canals is often neglected in clinical procedures. Precise knowledge of the location of reference points in the oral and maxillofacial area provides important data for local anaesthesia and maxillofacial operations. The most certain way to avoid damage to these structures is to know their location.[12–15] The aim of the present study was to verify the presence, spatial location, and calibre of AC of the canalis sinuosus by cone beam computed tomography (CBCT), and their relationship to the anterior maxilla.

Materials and methods

Subjects

The present retrospective analysis included the scans of a total of 1000 subjects selected randomly from 1181 out of 3298 cases that fulfilled the inclusion criteria. The database of Slice Diagnóstico Volumétrico por Imagem, in Belo Horizonte, Brazil, was used.

Inclusion and exclusion criteria

The following inclusion criteria were applied: (1) CBCT examinations from patients who allowed the use of their scans; (2) CBCT examinations of the maxilla. The following exclusion criteria were applied: (1) the presence of technical artefacts that would hinder the evaluation of the necessary structures; (2) images that had a missing tooth, an implant, or grafted alveolar ridge; (3) the presence of a supernumerary or retained tooth in the anterior maxilla; (4) the presence of a pathological lesion in the anterior maxilla; (5) patients who had previously undergone a surgical procedure in the maxilla (e.g. orthognathic surgery); (6) CBCT scans that did not show satisfactory quality of acquisition (minimum voxel size of 0.20 mm, in a 40-s examination).

Hardware and software

The CBCT scans were performed with an i-CAT CBCT system (Imaging Sciences International, Hatfield, PA, USA). The scans were acquired using the i-CAT 3D imaging system (i-CAT Vision Software; Imaging Sciences International) and included the entire maxilla. The following CBCT scan parameters were used for all patients: a tube voltage of 120 kV, 5–7 mA, field of view of 8 cm, emission of X-rays over an interval of 40 s, a 0.20-mm voxel size, and an effective dose of 136 μSV. Measurements were obtained with the use of computer software (OnDemand3D) version 1.0.10.5347 (Cybermed Inc., Tustin, CA, USA).

Procedures

The canalis sinuosus were identified on the CBCT scans according to their anatomical description in the literature.[3–5,7,10] Bony canals present in the anterior maxilla and with a clear upward direction towards the canalis sinuosus were identified. The following parameters were registered: sex, age, number of AC, presence or absence of AC with a diameter of <1.0 mm, diameter of the AC (only for those AC with a diameter of ≥ 1.0 mm), location of the AC in relation to the adjacent teeth, spatial location in the anterior maxilla (palatal, transversal, buccal), and status of the dentition in the anterior maxilla. The diameter of each canal was measured at the median distance of its total length (from the point of origin at the canalis sinuosus to the end of its trajectory). Axial, coronal, sagittal, panoramic, and cross-sectional reconstructions were analyzed in every case. Diameters were determined by measuring the palatine opening of the additional canal on both coronal and cross-sectional images. Assessment of the location of the AC was performed twice by the same observer with an interval of at least 2 months between evaluations.

Statistical analysis

A descriptive statistical analysis of the results is presented. The Student's *t*-test or Mann–Whitney test (when indicated, depending on the normality of data) and the χ^2 test were used to assess the differences between males and females. Spearman's correlation was performed to determine the relationship between the number of AC and sex. Pearson's correlation and linear regression were performed to verify the relationship between age and two other factors: the diameter of the AC and the number of AC. Cohen's kappa was used to assess intra-observer agreement for categorical data. Statistical significance was set at the level of $P < 0.05$. All data were analyzed using IBM SPSS Statistics version 20.0 software (IBM Corp., Armonk, NY, USA).

Ethical considerations

This study was approved by the local ethics committee. The patients were contacted by telephone call, and a signed informed consent form was obtained from each patient approving the use of their scans. The patients were not identifiable in any way, and a decoding list linking patient names and numbers was used and stored by the principal investigator, which

Table 1. Number of accessory canals (AC) in the anterior maxilla per subject.

Number of AC per subject	Number of male subjects (%)	Number of female subjects (%)	Total number of AC (%)
0	203 (42.0)	276 (53.4)	0 (0.0)
1	138 (28.6)	119 (23.0)	257 (26.4)
2	73 (15.1)	71 (13.7)	288 (29.6)
3	41 (8.5)	32 (6.2)	219 (22.5)
4	19 (3.9)	12 (2.3)	124 (12.7)
5	7 (1.5)	4 (0.8)	55 (5.6)
6	2 (0.4)	2 (0.4)	24 (2.5)
7	0 (0.0)	1 (0.2)	7 (0.7)
Total	483 (100.0)	517 (100.0)	974 (100.0)

was destroyed after completion of the study.

Results

The age of the patients was normally distributed in the male and female groups ($P = 0.186$ and $P = 0.161$, respectively; Kolmogorov–Smirnov test). The subjects (483 male, 517 female) had a mean age of 51.85 ± 14.78 years at the time of the examination (male 52.38 ± 14.22 years; female 51.35 ± 15.27 years). There were no statistically significant differences in the study variables according to sex (almost the same number of males and females) or age between the sexes ($P = 0.274$, Student's *t*-test), suggesting that the final differences between the groups were not influenced by the initial characteristics, thus allowing the results to be compared.

Five-hundred and twenty-one patients (52.1%) presented a total of 974 AC in the anterior maxilla (Table 1). The frequency of AC was higher in males (58.0%; 280/483) than in females (46.6%; 241/517), and this difference was statistically significant ($P < 0.001$, $\chi^2 = 12.904$). Males had 530 AC, while females had 444 AC.

The ends of the AC trajectories were located most frequently palatal to the anterior maxillary teeth (91.1%; 887/974), and less frequently in a buccal position (5.1%; 50/974) and in a transversal position (3.8%; 37/974). Details of the distribution of the ends of the AC can be seen in Fig. 2.

Seven of the patients in the youngest age group (≤20 years) presented AC (33.3%; 7/21). The age groups 21–40 years, 41–60 years, and >60 years, demonstrated an occurrence of AC of 48.6% (88/181), 55.1% (282/512), and 50.2% (144/286), respectively. This difference in age distribution was not statistically significant ($P = 0.100$, $\chi^2 = 6.257$). There were 195 AC with a diameter of at least 1.0 mm (20.0% of all AC); the mean diameter of these AC was 1.19 mm (median 1.15 mm, range 1.00–2.58 mm, standard deviation ±0.22 mm).

The relationship between age and the number of AC was found to be very weak ($R = 0.003$, $P = 0.932$), as was the relationship between age and the diameter of the AC ($R = 0.066$, $P = 0.407$) and the relationship between the number of AC and sex (Spearman's coefficient = −0.103, *P = 0.001).*

With regard to the intra-observer comparison of the two assessments for the location of accessory canals, Cohen's kappa value was 0.857, representing a very good correlation.

Some examples of AC of the canalis sinuosus found in the present study are shown in Fig. 3. Figs. 4 and 5 show images of two clinical cases of patients who received dental implants in the premaxilla and who presented postoperative pain. The postoperative CBCTs showed a close relationship of the implants with AC of the canalis sinuosus. Case patient 2 (Fig. 5) experienced immediate pain relief after removal of the implant.

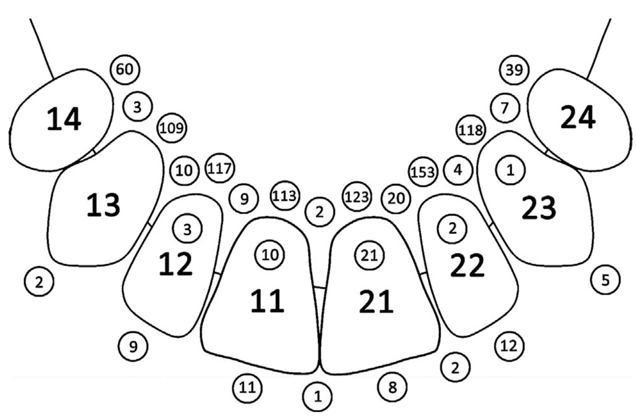

Fig. 2. Schematic representation of the distribution of accessory canals observed in the anterior maxilla, according to their location relative to the teeth and spatial location (palatal, transversal, and buccal). The number inside the circle indicates the number of cases found. Teeth are numbered according to the ISO system of the World Health Organization.

Discussion

The present study using CBCT scans found AC in the anterior maxilla in 51.7% of 1000 patients. This frequency is higher than that reported in two other studies, of 15.7%[5] and 27.8%.[1] An explanation for this difference in frequency may be that a 0.50-mm voxel size was used in one of the studies,[1] and thus the quality of acquisition was worse. Moreover, these numbers are valid when both studies included only AC with a diameter ≥1.0 mm.[1,5] When von Arx et al. also considered AC of a smaller diameter, the percentage was similar to that in the present study (55.1%).[1]

In this study, more AC were found in males (58.0%) than in females (46.6%), as was also observed in another study.[1] There was a tendency towards seeing more AC in older subjects than in younger subjects. The presence of AC was not correlated with age or sex, in agreement with the observations of two other studies.[1,5]

The end of the AC was found to be diversified, and the terminal portions were most frequently found palatal to the anterior maxillary teeth (91.1%). von Arx et al. also found a predominance of canal location palatal to the teeth, especially to the central incisors (56.7%).[1]

Only 20% of all identified AC had a diameter of ≥1.0 mm. The percentage was 16% in another study,[5] and this difference compared to the present study is probably because the previous study took into account only the anterior palate. The mean diameter of the AC was 1.19 mm in the present study, which is similar to the mean diameter of 1.31 mm reported by von Arx et al.,[1] 1.23 mm in the analysis by

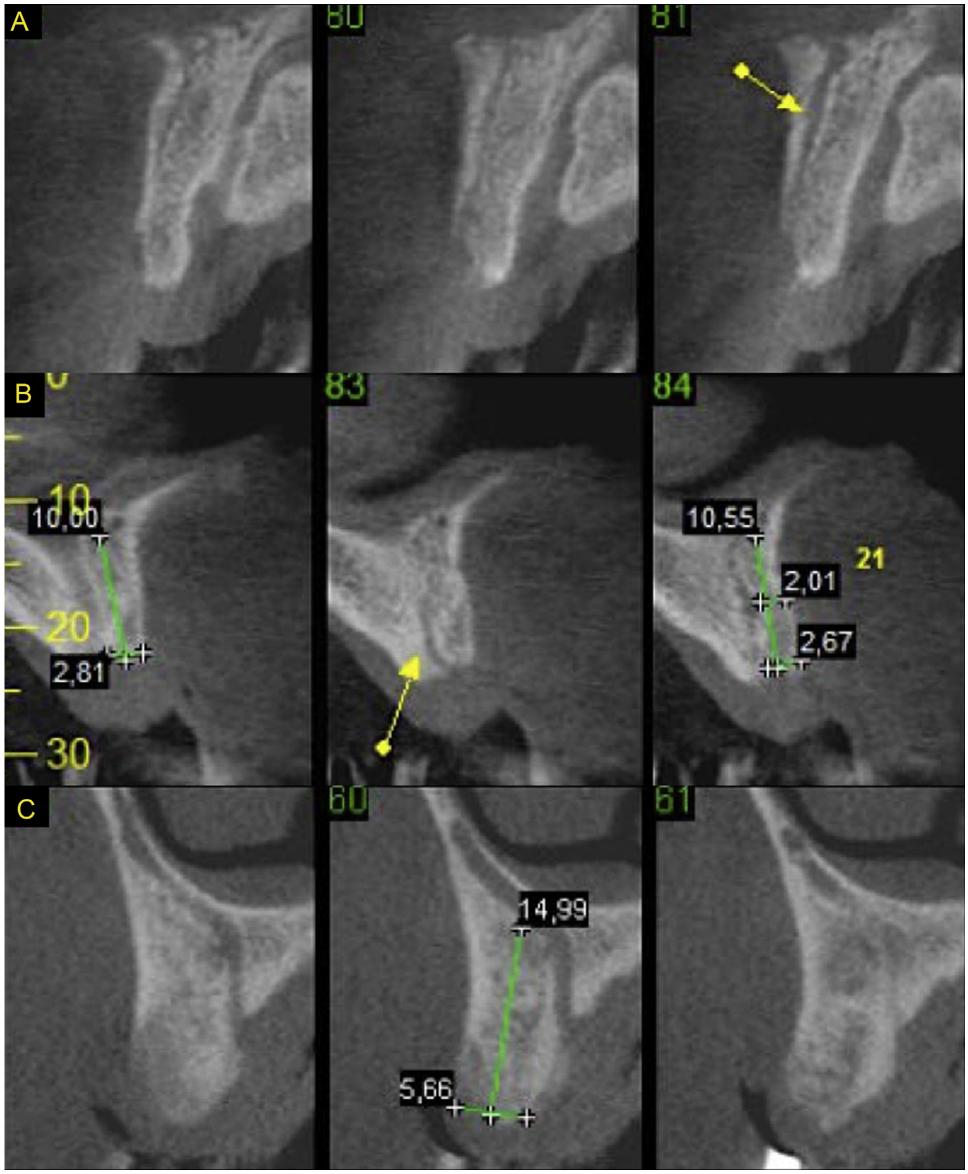

Fig. 3. CBCT images showing anatomical variations in the accessory canals of the canalis sinuosus in the premaxilla: (A) cross-sections of the buccal position; (B) cross-sections of the transversal position; (C) cross-sections of the palatal position.

Temmerman et al.,[16] and 1.4 mm in the study by de Oliveira-Santos et al.[5] However, according to an observation made by von Arx et al.,[1] the study by de Oliveira-Santos et al.[5] measured the diameter of the palatal opening of the AC rather than the diameter of the canal, which might explain the difference in size. Although the mean diameter of the AC in the present study was 1.19 mm, the maximum diameter found was 2.58 mm, a considerable calibre. Despite the inferiority of the AC diameter when compared to the diameter of the other structures such as the incisive foramen,[17] it should not be ignored during surgical procedures, particularly in situations where computed tomography is not used, since anatomical structures of a smaller size are more difficult to visualize correctly in regular radiographic examinations.[6] It is important to take into consideration the presence of these neurovascular structures in the anterior maxilla during the placement of dental implants, due to the increased demand for this kind of surgical procedure over recent decades. Cases of severe haemorrhage associated with an accessory foramina with a diameter of <1 mm during dental implant placement have been reported in the literature.[18,19] The identification of such individual anatomical variations on CBCT may help the surgeon to avoid injuries to nerves during the placement of implants.[4]

In conclusion, AC of the canalis sinuosus are a common anatomical structure regardless of age and sex, and thus present clinical relevance to surgery in the region due to their relatively high prevalence. The identification of such individual anatomical variations may help the surgeon to avoid injuries to nerves during the placement of dental implants. Cases of AC of a considerable diameter located within the planned path of a dental implant will require a joint decision by the surgeon and the patient to consider either transposing the neurovascular bundle in order not to compromise the planned prosthetic rehabilitation, or to look for alternative restorative solutions. Males showed a

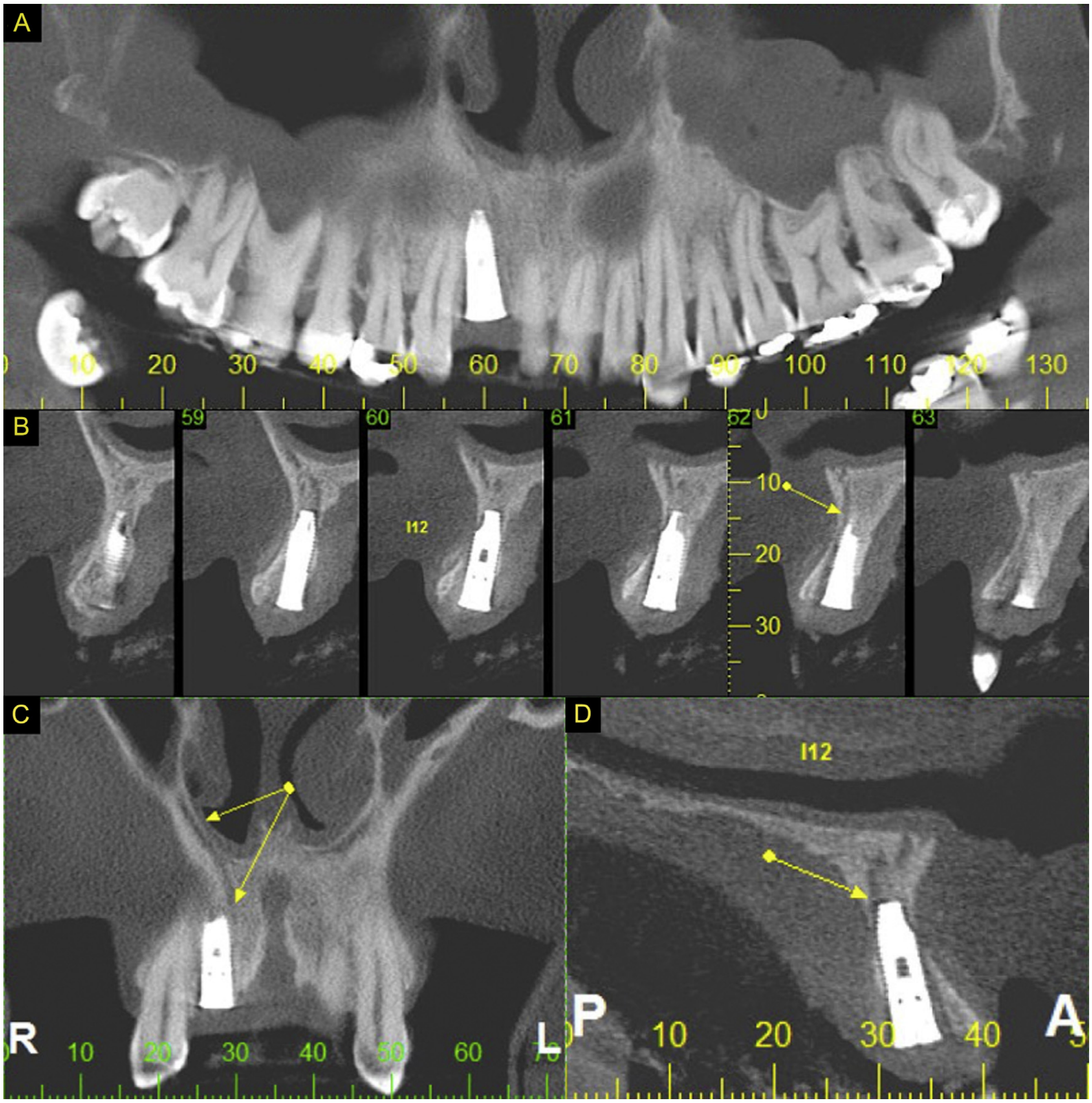

Fig. 4. Clinical case 1: postoperative pain after the placement of a dental implant in the premaxilla. (A) Panoramic view; (B) cross-sections; (C) coronal view; (D) sagittal view.

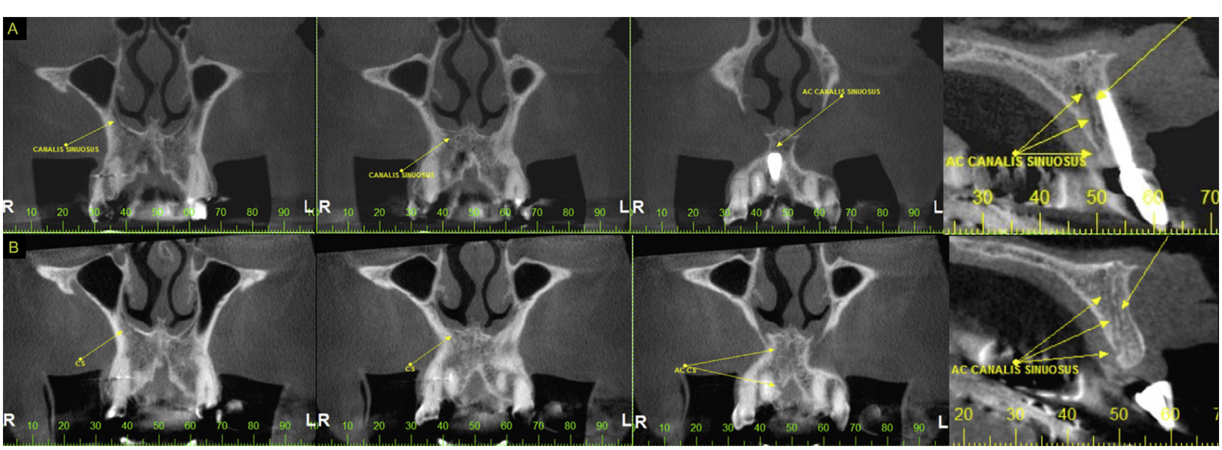

Fig. 5. Clinical case 2: immediate pain relief after removal of a premaxillary dental implant compromising an accessory canal of the canalis sinuosus. (A) MPR view before dental implant removal; (B) MPR view after dental implant removal, with decompression of the transversal accessory canal of the canalis sinuosus. (MPR, multiplanar reconstruction.).

statistically higher frequency of AC than females. The difference in age distribution was not statistically significant. Twenty percent of all AC presented a diameter of a least 1.0 mm. The end of the AC trajectory was found most frequently to be located palatal to the anterior maxillary teeth. All relationships analyzed here were very weak (age vs. number of AC, age vs. AC diameter, number of AC vs. sex).

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Competing interests

Not applicable.

Ethical approval

Ethical approval was granted by São José dos Campos Dental School, UNESP, São Paulo, Brazil (protocol number 245.817).

Patient consent

Not required.

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