

Radiological classification of the infraorbital canal and correlation with variants of neighboring structures

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Abstract This study aims to classify the infraorbital canal according to its position related to the maxillary sinus as observed by axial CT. It is a retrospective, cross-sectional study. This study was performed in a tertiary referral center. In this study, axial and coronal CTs of 750 patients were examined and infraorbital canals and neighboring structures were evaluated. Infraorbital canals were then classified according to their positions in relation to the maxillary sinus as seen in axial sections. Morphologic variations of neighboring structures were also noted and their correlations with specific canal types were investigated. Three types of infraorbital canal configurations were identified according to the canal's relationship with the maxillary sinus: Type 1, the infraorbital canal was totally protruding into the maxillary sinus (12.3 %); Type 2, the infraorbital canal was located at the floor of the maxillary sinus or was partially protruding into the maxillary sinus (51.2 %); Type 3, the infraorbital canal was totally embedded in the maxillary corpus or was bulging on the external face of the maxillary sinus (36.4 %). Concurrence of maxillary sinus septa and infraorbital canal type-1 was found to be statistically significant on both sides (right side $p = 0.00$, left side $p = 0.00$). The study radiologically

classified the infraorbital canal according to its position as related to the anterior wall of the maxillary sinus, and found that the type where the canal was totally protruding into the maxillary sinus (type-1) had a significant rate of 12.3 %. The rate of the protruded infraorbital canal was doubled with the presence of maxillary sinus septa (25 %).

Keywords Infraorbital canal · Computer tomography · Paranasal sinus · Maxillary sinus

Abbreviations

CT Computer tomography
IC Infraorbital canal

Introduction

The infraorbital canal (IC) runs over the orbital surface of the maxilla [1]. IC complex was first defined in 1998 by Scarfe et al. [2]. They have identified three different variants of the complex: canal only, groove only, and canal and groove together [2]. IC complex is an important determinant during dissection in orbital floor surgery, especially in endoscopic and reconstructive surgery. Although the infraorbital nerve and artery are protected by the canal, they can easily be damaged during manipulations at this region [3].

Preoperative radiological evaluation of IC complex has begun to be highly important with the development and widespread use of surgical techniques involving the maxillary antrum and the orbita. An appropriate evaluation is required to minimize surgical mishaps during interventional procedures like orbital reduction [4], zygomatic fractures [5], antrostomies [6], surgical correction of maxillofacial anomalies [7], and microsurgical

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reconstruction of the infraorbital nerve [8]. A radiological evaluation involving the IC is mandatory for patients who are referred with the numb cheek–limp lower lid syndrome [9, 10]. Computerized tomography is known to be the best imaging method for evaluating paranasal sinuses and neighboring structures [11].

Lee et al. [12] have classified the vidian nerve canal into three types according to its relation with the floor of the sphenoid sinus as seen in coronal sections, as: (1) totally protruding into the sphenoid sinus; (2) contacting or partially protruding into the sphenoid sinus; (3) located at the floor of the sinus or totally embedded in the sphenoid corpus.

The course of IC is known to be important (in maxillofacial surgery), but has not yet been clearly defined. In our study we planned to investigate and classify the course of IC as related to the maxillary sinus, and also to investigate the correlation of IC with the presence of neighboring morphological variants.

Methods

This is a retrospective study, approved by the local Clinical Research Ethics Committee, evaluating axial paranasal sinus CT (Philips Brilliance 64-slice CT scanner, Philips Medical Imaging, The Netherlands) images, taken at 3 mm sections. The axial CT scanning was done on patients positioned supinely and the head position of those patients was adjusted in such a way that the hard palate was parallel to the floor, while sagittal plane was perpendicular to the floor. All CT images were ordered for sinonasal, otologic and maxillofacial inquiries, between January 2011 and January 2014. Patients with nasal poliposis or sinus anomalies and those who had previous sinus surgery were excluded from the study.

In our attempt to classify the configuration of IC, we have based our approach on Lee et al.'s [12] classification of the vidian nerve canal as seen in coronal sections as related to the floor of the sphenoid sinus. Since IC is better visualized and followed in axial sections, we have examined 1,500 ICs of our 750 patients from their axial CT images. The classification was based on IC's configuration as related to the maxillary sinus, and three different types of morphological configurations were identified: Type-1, the canal is totally protruding into the maxillary sinus (Fig. 1); Type-2, the canal is located on the floor of the maxillary sinus or is partially protruding into the sinus (Fig. 2); Type-3, the canal is totally embedded in the maxillary corpus or is bulging on the external face of the maxillary sinus (Fig. 3).

We have also examined the 1,500 axial CT sections for the presence of maxillary sinus septa, agger nasi cell, Haller cell, middle and upper concha pneumatization and septal



Fig. 1 Infraorbital canal totally protruding into the maxillary sinus (Type 1) bilaterally, as seen in axial section



Fig. 2 Infraorbital canal located at the floor of the maxillary sinus or partially protruding into the sinus (Type 2) bilaterally, as seen in axial section

deviation. The presence of each variant was further evaluated for any correlation with specific canal types (Fig. 4).

The data were evaluated statistically by the Chi-square test. Differences at the level of $p < 0.05$ were accepted to be statistically significant.

Results

Four hundred and eighty-three (64.4 %) of the 750 patients (1,500 sides) whose axial paranasal sinus CT images were



Fig. 3 Infraorbital canal totally embedded in the maxillary sinus or bulging on the external face of the sinus (Type 3) bilaterally, as seen in axial section

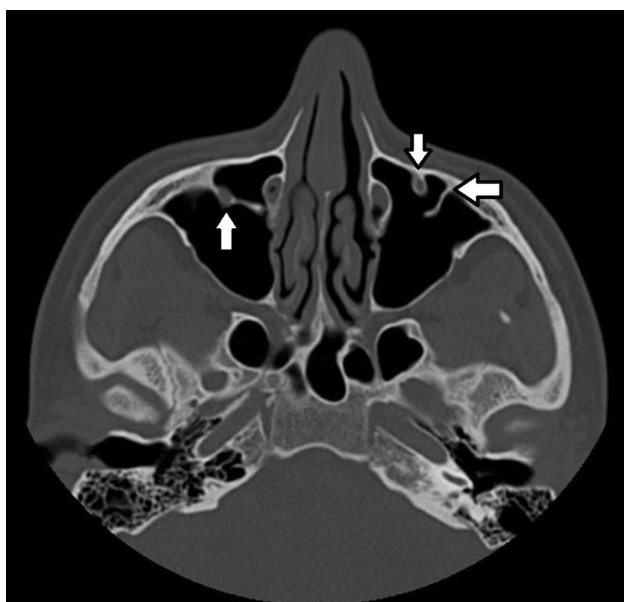


Fig. 4 Bilateral maxillary sinus septa with IC Type 1 on the left and IC Type 2 on the right side, as seen in axial section

evaluated were males and 267 (35.6 %) were women. The ages of the cases ranged between 18 and 84, the average age was 36.33 ± 14.65 .

The distributions of IC types as defined by their relation to the maxillary sinus were as follows: Type-1, 12.3 % (13.1 % at the right side, 11.6 % at left); Type-2, 51.2 % (50.3 % at the right side, 52.3 % at left), and Type-3, 36.4 % (36.7 % at the right side, 36.1 % at left).

The distribution of the morphological variants observed in the same images (1,500 sides) and the correlation of each variant with specific IC types were as follows:

Maxillary sinus septa were present in 16.5 % of the images, with very close rates on the right (16.8 %) and left (16.3 %) sides. The correlation between the presence of maxillary sinus septa and specific IC types are shown in Table 1. What is remarkable in that table is the difference in the rate of IC Type-1 with the presence of maxillary sinus septa. While the rate of IC Type-1 was 9.8 % in cases without maxillary sinus septa that rate of rises to 25 % when maxillary sinus septa are present. The correlation was found to be statistically significant (right side: $p = 0.00$, left: $p = 0.00$) (Tables 1, 2).

The agger nasi cell was present in 10.6 % of the images, with very close rates on the right (10.3 %) and left (10.9 %) sides. The correlation of specific IC types and the presence of agger nasi cell was statistically significant only IC Type-1 on the left, but not on the right side or for other canal types (left side: $p = 0.00$, right: $p = 0.29$) (Table 2).

The Haller cell was present in 4.9 % of the images, with similar rates on the right (4.9 %) and left (4.9 %). No statistically significant correlation was found between specific IC types and the presence of the Haller cell (right side: $p = 0.09$, left: $p = 0.49$) (Table 2).

Middle concha pneumatization was present in 21.5 % of the images, with close rates on the right (20.9 %) and left (22.1 %) sides. No statistically significant correlation was found between specific IC types and the presence of middle concha pneumatization (right side: $p = 0.79$, left: $p = 0.77$) (Table 2).

Upper concha pneumatization was present in 2.4 % of the images, with close rates on the right (2.5 %) and left (2.3 %) sides. There were no statistically significant correlations between specific IC types and the presence of upper concha pneumatization on either side (right side: $p = 0.94$, left: $p = 0.52$) (Table 2).

Septal deviation was observed in 30.5 % (229/750) of the images. No statistically significant correlations were found between specific IC types and the presence of septal deviation on either side (right side: $p = 0.693$, left: $p = 0.865$) (Table 2).

Discussion

Zygomaticoorbital fracture is one of the most common facial traumas, with an incidence of 10.4 in 100,000 [13, 14]. The infraorbital nerve is well protected and rarely injured in direct traumas, but it may indirectly be affected by malar fractures. Fractures involving IC may cause permanent paresthesia [15, 16]. In most cases the fracture involves the infraorbital foramen, canal or fissure, thus

Table 1 Correlation of specific infraorbital canal types with the presence and absence of maxillary sinus septa

All patients	Right	Left	Total
Type 1	13.1 % (98/750)	11.6 % (87/750)	12.3 % (185/1,500)
Type 2	50.3 % (377/750)	52.3 % (392/750)	51.2 % (769/1,500)
Type 3	36.7 % (275/750)	36.1 % (271/750)	36.4 % (546/1,500)
In the presence of the antral septa			
Type 1	26.9 % (34/126)	22.9 % (28/122)	25.0 % (62/248)
Type 2	44.4 % (56/126)	51.6 % (63/122)	47.9 % (119/248)
Type 3	28.5 % (36/126)	25.4 % (31/122)	27.0 % (67/248)
In the absence of the antral septa			
Type 1	10.3 % (64/624)	9.4 % (59/628)	9.8 % (123/1,252)
Type 2	51.4 % (321/624)	52.4 % (329/628)	51.9 % (650/1,252)
Type 3	38.3 % (239/624)	38.2 % (240/628)	38.2 % (479/1,252)

Table 2 Concurrence of (specific) infraorbital canal types with neighboring morphologic variants

Variations	Infraorbital canal types right (<i>p</i>)	Infraorbital canal types left (<i>p</i>)
Maxillary sinus septa	0.00**	0.00**
Agger nasi cell	0.29	0.00**
Haller cell	0.09	0.49
Pneumatization of middle concha	0.79	0.77
Pneumatization of upper concha	0.94	0.52
Nasal septal deviation	0.69	0.86

Chi-square test * $p < 0.05$,
 ** $p < 0.001$

zygomatic complex fractures cause symptoms and post-operative complications related to the innervation area of the infraorbital nerve such as sensory neuropathy and especially hypoesthesia [17]. Diplopia, paresthesia of the infraorbital nerve and ocular problems may arise in inferior orbital wall defects [16]. A good knowledge of regional anatomy is a must for an appropriate surgical intervention in such fractures. Apart from fractures, hypoesthesia in the area innervated by the infraorbital nerve has also been frequently reported in neoplasia, endoscopic interventions or orbital decompression surgeries [18]. Taking into account that there may be personal variations in the localization of the infraorbital foramen, nerve and canal, identifying the specific localization for each case by pre-operative CT sections will increase the success rate of surgical and anesthetic interventions [19, 20]. In this study we aimed to identify the localization of IC, examining axial and coronal CT images, to classify its morphological configurations and to identify its relationship with anatomical variants of neighboring structures.

Hwang et al. [21] have examined the mean angle of IC to the vertical and horizontal planes by conducting morphometric analyses of the infraorbital groove, canal and foramen. Lee et al. [22] morphologically evaluated IC in 42 skulls, and classified the canal into three types as “tube-like” (69 %), “funnel” (25 %) and “pinched” (6 %). Lee et al. [12] examined CT data and classified the configuration of the vidian nerve canal into three types, according to

its relation with the floor of the sphenoid sinus. Ozturan et al. [23] studied the morphological variations of the vidian nerve canal in 999 patients. In our study, we followed the classification described by Lee et al. [12] for the vidian nerve canal as observed in coronal sections, and adapted that classification to the infraorbital nerve canal as observed in axial CT sections. The most common type encountered in our study group was Type-2 (51.2 %); however, Type-1 where IC was protruding into the maxillary sinus was also not a rare occurrence, with a rate of 12.3 %.

Besides the classification, we have also examined the relationship of IC with variations in neighboring structures such as maxillary sinus septa, agger nasi cell, Haller cell, middle and upper concha pneumatization and septal deviation.

Maxillary sinus septa were first defined by Underwood in 1910. Thus it is also known as Underwood's septa or antral septa [24]. Cakur et al. [25], in their series of 74 patients, have reported a 26 % rate of septa in maxillary sinus. Koymen et al. [26] in their series of 205 patients observed septa in the maxillary sinus in a rate of 13–35.3 %. Their study showed that maxillary sinus septa could be encountered in any location within the maxillary sinus. Shibli et al. [27] retrospectively investigated the prevalence of maxillary sinus septa in their series of 1,024 patients, and found a 21.58 % prevalence rate for unilateral and 8.4 % rate for bilateral maxillary sinus septa. Their

study did not reveal any significant correlation between the age and the gender of the patients and the presence of maxillary sinus septa. Krennmair et al. [28] observed maxillary sinus septa in 27.7 % of their patients with atrophic maxillary sinuses and 16 % in those whose sinuses were not atrophic. Rosano et al. [29] analyzed 22 articles and found that the maxillary sinus septa prevalence rate was in the range of 14.3–33.3 %. They did not observe a significant geographical distribution of the septa inside the sinus. In our study we found a total 16.5 % of maxillary sinus septa, 16.8 % located at the right side and 16.3 % at the left. We observed a statistically significant correlation with the presence of maxillary sinus septa and IC Type-1 where the canal is protruding into the maxillary sinus (right side: $p = 0.00$, left: $p = 0.00$) (Tables 1, 2). While the overall incidence rate for IC Type-1 was 12.3 %, it rose to 25 % with the presence and decreased to 9.8 % with the absence of maxillary sinus septa. Although there are numerous studies about maxillary sinus septa and its variations, there is no clinical study yet investigating whether those variants are related to the position of the IC. In this respect, our study presents a new approach in medical literature.

In our study the simultaneous presence of agger nasi cells and IC Type-1 on the left side was found to be statistically significant, but there were no statistically significant correlations between any of the specific IC types and Haller cell, middle and upper concha pneumatization and septal deviation on either side.

Conclusion

This study presents a radiological classification based on axial CT evaluations of the IC in respect to its relation with the anterior wall of the maxillary sinus. IC Type-1 where IC is totally protruding into the maxillary sinus was observed in 12.3 % of the study group, a rate which cannot be considered rare. It was also observed that the rate of IC protrusion increased to 25.0 % with the simultaneous presence of maxillary sinus septa, a significant double fold increase. Those observations point to the necessity of a careful CT evaluation before surgical interventions to the maxillary sinus area, for planning a specific road map.

Conflict of interest None.

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