ORIGINAL RESEARCH ORİJİNAL ARAŞTIRMA

DOI: 10.5336/dentalsci.2023-99252

# Evaluation of the Relationship Between Infraorbital Canal Protrusion and Alveolar Process Pneumatization of the Maxillary Sinus: A Cross-Sectional Cone Beam Computed Tomography Study

## İnfraorbital Kanal Protrüzyonu ile Maksiller Sinüsün Alveolar Proçes Pnömatizasyonu Arasındaki İlişkinin Değerlendirilmesi: Bir Kesitsel Konik Işınlı Bilgisayarlı Tomografi Çalışması

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**ABSTRACT Objective:** To investigate the infraorbital canal (IOC) protrusion into the maxillary sinus (MS) and its relationship with alveolar process (APP) pneumatization on cone-beam computed tomography (CBCT) images. **Material and Methods:** Data from 137 patients with 234 maxillary sinuses (over the age of 18) who had CBCT images including MS, IOC, maxillary molar teeth were included. The categorization of IOCs was based on their extent of protrusion from the maxillary roof into the sinus, resulting in three distinct types. In addition, the Type 3 IOC performed four distinct linear measurements. Furthermore, presence of APP pneumatization was evaluated and compared with IOC types. **Results:** This study included 137 (70 females, 67 males) patients aged between 18 and 84 years (mean±standard deviation: 33.99±16.73 years). The intra- and interobserver agreements for IOC protrusion types and APP pneumatization of MS were excellent (k>0.92 and 0.87). For the linear measurements, intraclass correlation coefficients indicating intraobserver (>0.95) and interobserver (>0.92) agreement was excellent. There was found a significant relationship between IOC types and APP pneumatization of MS (p<0.001). **Conclusion:** It's crucial to take into account the common presence of IOCs extending into the MS to avoid accidental nerve damage. Our results indicate a significant association between IOC protrusion and pneumatization of the APP.

**Keywords:** Maxillary sinus; cone-beam computed tomography; anatomic variation; alveolar process

**ÖZET Amaç:** Bu çalışmanın amacı, infraorbital kanalın maksiller sinüs protrüzyonunun ve alveolar proçes pnömatizasyonu ile ilişkisinin konik ışınlı bilgisayarlı tomografi görüntüleri üzerinde araştırılmasıdır. **Gereç ve Yöntemler:** Çalışmaya, maksiller sinüs, infraorbital kanal ve maksiller molar dişleri içeren konik ışınlı bilgisayarlı tomografi görüntüleri olan 18 yaş üstü 137 (234 maksiller sinüs) hasta dâhil edildi. İnfraorbital kanalların sınıflandırılması, maksiller sinüsün çatısından içine doğru protrüze olma derecelerine dayanılarak, 3 farklı tipe ayrıldı. Tip 3 infraorbital kanal tespit edildiğinde bu görüntülerde 4 farklı doğrusal ölçüm gerçekleştirildi. Ayrıca görüntülerde alveolar proçes pnömatizasyonu varlığı değerlendirildi ve infraorbital kanal tipleri ile karşılaştırıldı. **Bulgular:** Bu çalışmaya yaşları 18-84 arasında değişen (ortalama±standart sapma: 33,99±16,73 yıl) 137 (70 kadın, 67 erkek) hasta dâhil edildi. İnfraorbital kanal tipleri ve maksiller sinüsün alveolar proçes pnömatizasyonu için gözlemci içi ve gözlemciler arası uyum mükemmeldi (k>0,92 ve 0,87). Doğrusal ölçümler için, gözlemci içi (>0,95) ve gözlemciler arası (>0,92) uyum sınıf içi korelasyon katsayısı ile değerlendirildi ve mükemmel bulundu. IOC tipleri ile maksiller sinüsün alveolar proçes pnömatizasyonu arasında anlamlı ilişki bulundu (p<0,001). **Sonuç:** İstenmeyen yaralanmaları önlemek için sıklıkla maksiller sinüse protrüze olan infraorbital kanal varlığını dikkate almak çok önemlidir. Çalışmamızın sonuçları infraorbital kanal protrüzyonu ile alveolar proçes pnömatizasyonu arasında anlamlı ilişki olduğunu göstermektedir.

**Anahtar Kelimeler:** Maksiller sinüs; konik ışınlı bilgisayarlı tomografi; anatomik varyasyon; prosessus alveoleris

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Peer review under responsibility of Turkiye Klinikleri Journal of Dental Sciences.

***Received:*** 25 Aug 2023 ***Accepted:*** 11 Sep 2023 ***Available online***: 29 Sep 2023

2146-8966 

The infraorbital canal (IOC) originates from the infraorbital groove, containing the infraorbital nerve (ION), a component of the maxillary division of the fifth cranial nerve.[1] ION is a sensory branch of the maxillary nerve. It originates from the semilunar ganglion, traverses the cavernous sinus and foramen rotundum, and enters the orbit via the infraorbital fissure. Continuing its path anteriorly within the orbit's floor through the IOC, it exits the maxillary bone through the infraorbital foramen.[2-4]

The protrusion of the IOC occurs as a result of the significance of maintaining an unobstructed maxillary sinus (MS), which is crucial in complex sinonasal procedures like endoscopic sinus surgery, Caldwell-Luc surgery, maxillary resection, and the removal of tumors located within the maxilla and the MS.[5] Authors of previously published case reports concerning IOC protrusion held the view that this variation contributes to an escalated risk in the context of endoscopic sinus surgery.[6]

Computed tomography (CT) is extensively employed for sinonasal diagnostic procedures. However, dentists and maxillofacial surgeons frequently favor cone-beam computed tomography (CBCT) over CT for maxillofacial imaging. This preference arises from CBCT's commendable spatial resolution and interactive display capabilities, while also minimizing the patient's exposure to the elevated radiation doses linked with CT scans.[7,8]

Numerous articles were assessed the relationship between the IOC and the roof of the MS, with a specific focus on the canal's extension into the sinus and its correlation with sinus septa, Haller cells, and pneumatization of the middle concha.[6,7,9-11] In a recent study by Osbon and Butaric, the relationship between IOC and MS size was evaluated.[12] However, MS pneumatization has the potential to expand into neighboring anatomical structures, with its most prevalent extension occurring towards the alveolar process (APP).[13,14] To the best of our knowledge, there has been no investigation conducted to evaluate the correlation between the protrusion of the IOC and the pneumatization of the APP within the MS.

Therefore, the objective of the present study was to assess the extent to which the IOC protrudes into the MS and its relationship with APP, using CBCT.

## MATERIAL AND METHODS

### STUDY GROUP

This retrospective study received approval from the Institutional Ethical Committee of Ankara Medipol University (date: September 5, 2023, no: 107) in compliance with the Declaration of Helsinki. The study utilized images from 137 patients who had presented to the private dental clinic between January 2022 and December 2022 for various dental reasons, including the evaluation of impacted teeth, orthognathic surgery, implant planning etc. A total of 700 CBCT images were evaluated. Of those images with artifacts and patients with missing clinical data were excluded from the study. Data from 137 patients with 234 maxillary sinuses (over the age of 18) who had CBCT images including IOC, MS, and maxillary molar teeth (to evaluate APP pneumatization) were included. The study's exclusion criteria were inadequate image quality due to artifacts, cases concerning patients with trauma or pathological conditions in the MS region, and the presence of implants. The study included a total of 234 maxillary sinuses from 137 patients, as illustrated in Figure 1 of the flowchart.

### CBCT IMAGE ASSESSMENT

All the CBCT scans involved using a Planmeca Promax CBCT device (Planmeca, Helsinki, Finland)

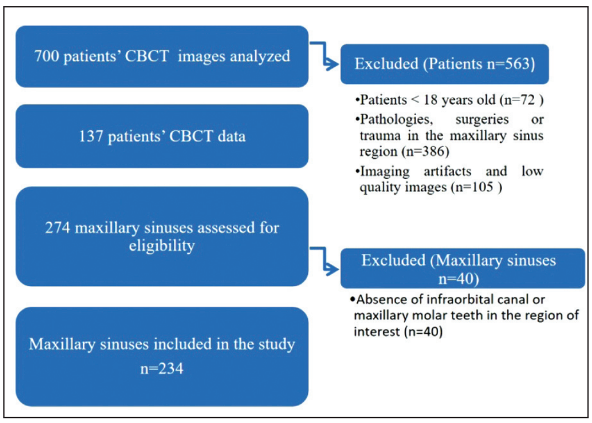


**FIGURE 1:** Flowchart.
CBCT: Cone-beam computed tomography.

with parameters of 90 kVp, 12 mA, 12 seconds, and a resolution of 0.3 mm. Image evaluation was conducted using Romexis Viewer 3.8.2 software (Planmeca, Helsinki, Finland) on an "HP Prodisplay P221 21.5" LED Backlit monitor (Hewlett-Packard, Texas, USA).

The classification of IOCs into 3 types; Type 1-a canal is entirely located within the confines of the MS border, Type 2-the canal is positioned under the roof of the MS while still contact with it, Type 3-the canal totally protruded into MS with a bony septum (Figure 2).[15]

For Type 3 IOC, four distinct distances were assessed according to Kalabalık et al.[9] The first measurement involved determining the length of the septum on axial section (D1), subsequently, on parasagittal images, distance from point where IOC begins to protrude into the MS on sagittal section (D2) was measured. Further measurements were taken on coronal images, including the maximum distance from the IOC to the MS roof (D3) and the corresponding distance from the IOC to the MS floor (D4), as illustrated in Figure 3.

In APP of the MS, the roots of the maxillary molar teeth are in contact with the MS floor and the roots are located medial and lateral to it.[16]

## INTRA- AND INTEROBSERVER RELIABILITY

A dentomaxillofacial radiologist with eleven years' experience (CKS) in CBCT imaging was evaluated each of the images and performed the measurements. For the purpose of measuring the agreement within a single observer, a set of 50 patient images was randomly extracted from the sample. The main observer assessed these images on 2 separate occasions, with a 30-day interval between assessments. To establish the reliability across different observers, a second observer (SG), possessing equivalent clinical experience to the main observer, also evaluated the same set of images.

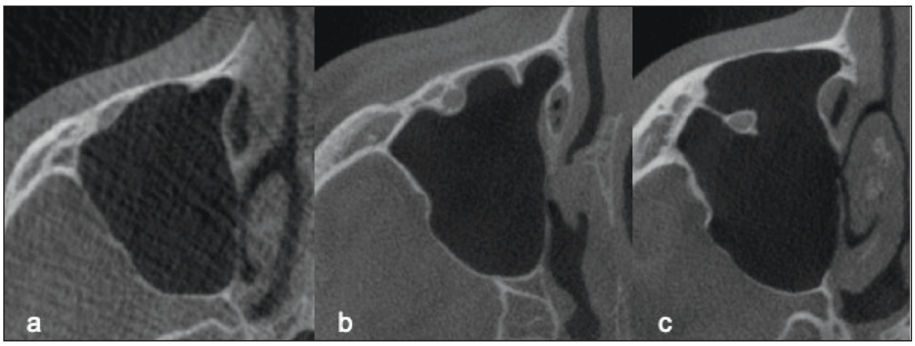


**FIGURE 2:** Axial section images of infraorbital canal types based on the protrusion degree into the maxillary sinus; **a)** Type 1, **b)** Type 2, **c)** Type 3.

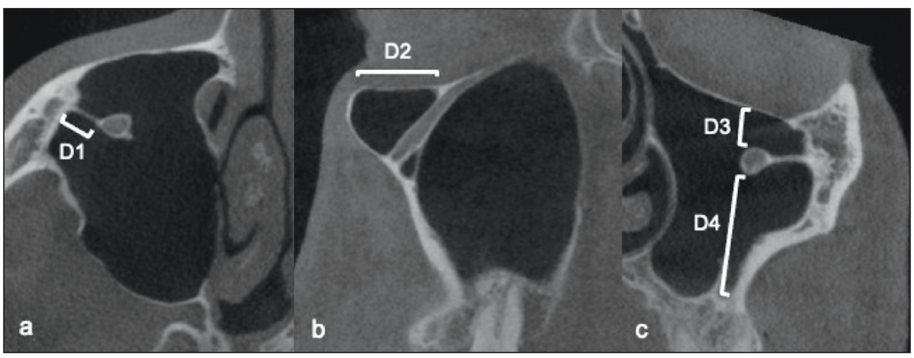


**FIGURE 3: a)** D1: The maximum length of the bony septum from the canal to the wall of the maxillary sinus on axial sections; **b)** D2: On parasagittal sections, the distance from the inferior orbital rim where the infraorbital canal begins to protrude into the maxillary sinus; **c)** D3: On the coronal sections, the maximum vertical distances from the canal to the sinus roof, D4: The maximum vertical distances from the canal to the sinus floor.

The assessment of agreement within the same observer and across different observers involved the utilization of k-statistics to evaluate IOC protrusion types and the presence of APP pneumatization. Additionally, intraclass correlation coefficient (ICC) analysis was employed to assess the agreement for linear measurements.

### STATISTICAL ANALYSIS

The statistical analysis was performed using SPSS for Windows (SPSS 25, Chicago, IL). Descriptive analysis involved summarizing categorical variables using counts and percentages (%), while continuous variables were presented as mean and standard deviation (SD). The distribution and occurrence of the IOC in relation to gender, the presence of alveol process pneumatization were assessed using the chi-square test to determine the type and frequency of association, with the significance level set at 5% (p<0.05). The ETA coefficient test was employed to assess the correlation between the extent of IOC protrusion (D1) and APP in the study.

## RESULTS

This study included 137 patients (70 females, 67 males) aged between 18 and 84 years (mean±SD: 33.99±16.73 years). The intra- and interobserver agreements for IOC protrusion types and APP pneumatization of MS were excellent (k>0.92 and 0.87). For the linear measurements, ICCs indicating intraobserver (>0.95) and interobserver (>0.92) agreement was excellent.

The distribution of IOC types was shown in Table 1. Comparisons of the linear measurement between males and females was demonstrated in Table 2.

The APP was present in 54.2% out of 234 MS. The frequency of APP presence according to IOC types predominantly indicated Type 3, followed sequentially by Type 2 and Type 1. There was found a significant relationship between IOC types and APP of MS (p<0.001) (Table 3). Moreover, there was a weak positive correlation between IOC protrusion degree (D1) and APP (coefficient value: 0.334).

## DISCUSSION

The clinical significance of IOC protrusion lies in its necessity for evaluation regarding its location, morphological variations, and potential complications within the relevant region. The ION holds significant importance in delivering sensory innervation to a

**TABLE 1:** The distribution of infraorbital canal types according to gender and side.

| | Female | Male | | Right side | Left side | |
|---|---|---|---|---|---|---|
| Canal type | n (%) | n (%) | p value | n (%) | n (%) | p value |
| Type 1 | 14 (11.77) | 16 (12.5) | | 14 (11.67) | 16 (12.60) | |
| Type 2 | 96 (80.68) | 102 (79.69) | 0.980* | 98 (81.7) | 100 (78.74) | 0.807* |
| Type 3 | 9 (7.57) | 10 (7.81) | | 8 (6.67) | 11 (8.67) | |
| Total | 119 (100) | 128 (100) | | 120 (100) | 127 (100) | |

*Not significant, chi-square test (significance level p<0.05)

**TABLE 2:** Comparisons of the distances (mm) between males and females.

| | Males | Females | All cases | |
|---|---|---|---|---|
| Distance | X̄ (SD) | X̄ (SD) | X̄ (SD) | p value |
| D1 | 3.91 (1.3) | 3.19 (1.12) | 3.72 (1.27) | 0.296* |
| D2 | 8.97 (3.91) | 8.09 (2.53) | 8.74 (3.56) | 0.746* |
| D3 | 3.94 (1.25) | 4.42 (2.40) | 4.07 (1.57) | 0.574* |
| D4 | 21.85 (5.48) | 21.00 (3.98) | 21.63 (5.03) | 0.757* |

*Not significant, independent samples t-test (significance level p<0.05); D1: Maximum length of the bony septum from the canal to the wall of the maxillary sinus; D2: Distance from the inferior orbital rim where the infraorbital canal begins to protrude into the maxillary sinus; D3: Maximum vertical distances from the canal to the sinus roof; D4: Maximum vertical distances from the canal to the sinus floor; SD: Standard deviation.

**TABLE 3:** Distribution of the infraorbital canal types according to absence and presence of alveolar process pneumatization.

| | | Type 1 | Type 2 | Type 3 | |
|---|---|---|---|---|---|
| | | n (%) | n (%) | n (%) | p value |
| Alveolar process pneumatization | Present | 4 (15.39) | 106 (56.08) | 17 (89.47) | <0.001* |
| | Absent | 22 (84.61) | 83 (43.92) | 2 (10.53) | |

*Significant, chi-square test (significance level $p<0.05$).

range of regions. These encompass the maxillary incisor, canine, and premolar teeth, and at times, even the mesiobuccal root of the first molar tooth. Additionally, it extends its sensory function to the skin of the upper cheek and the mucosa of the MS.[17]

In endoscopic sinus surgery, it's important to take into account the length of the nerve opening into the MS and the distance between the IOC and the MS roof. For instance, in cases of an extended endoscopic approach that necessitates infratemporal fossa access, removing the posterior wall of the MS exposes the ION to potential risk.[18,19]

The pathway of ION is important for some surgeries in dentistry. Blocking the ION is a preferred local approach for the initial correction of cleft lip and during MS surgeries.[17] During the zygomatic implant placement, ION should be positioned at a safe distance.[20]

There were a lot of studies evaluated the prevalence of IOC types as Type 1, 2, and 3.[7,9-11,15] Among these studies, Type 1 was reported most frequently by Kalabalık et al. (55.2%) and Ference et al. (60.5%).[9,15] On the other hand, Haghnegahdar et al., Yenigun et al., and Serindere and Serindere found Type 2 as the most common (50.3%, 51.2%, and 62.9%, respectively) observed type.[7,10,11] Similarly, the most common type observed in our study was Type 2 (80.1%). The variation in prevalence rates of IOC types could originate from differences in racial or regional demographics among observed populations, variations in patient age groups, and differences in sample sizes.

Previous studies have reported diverse prevalence rates for IOC Type 3, ranging from 8.8% to 23.2%.[6,7,9,11,15,21] Consistent with Kalabalık et al., in the present study, the prevalence of Type 3 was 8.1%.[9]

The linear measurements were documented by various authors. Kalabalık et al. recorded mean dimensions of D1 (3.75 mm), D2 (9.51 mm), D3 (6.76 mm), and D4 (25.44 mm).[9] Serindere and Serindere also reported the mean values for the measurements.[10] Ference et al. and Haghnegahdar et al. reported D3 measurements of 8.58 mm and 11.61 mm, respectively.[11,15] Gautam et al. and Lantos et al. noted median protruding component (D1) lengths as 4.9 mm and 4 mm, respectively, with Lantos et al. additionally reporting a D2 measurement of 11 mm.[6,21] In our study, the mean D1, D2, D3, D4 was 3.7, 8.7, 4, 21.6 mm, respectively. According to our knowledge, apart from the research conducted by Kalabalık et al. and Serindere and Serindere, no other study specifically measuring the D4 distance has been in the existing literature.[9,10]

Kalabalık et al. conducted a comparison of measurements between genders in their study.[9] The mean D1, D2, and D3 showed no significant difference for gender. However, the D4 was notably greater in males compared to females. In addition, in the study of Serindere and Serindere, no significant difference was observed in any measurements based on gender.[10] Similarly, in the present study, there was no significant difference in the mean D1, D2, D3 and D4 between genders.

In the literature, there were a few studies regarding the association between the IOC types and variations in adjacent anatomical formations (such as MS septa, Haller cell, middle concha pneumatization, etc.) have been found.[7,10,15] Moreover, Osbon and Butaric investigated relationships between MS dimensions and IOC types.[12] In their study, the authors investigated the association between the length of the MS and the different types of IOC. Their results revealed that individuals with a higher antero-posterior length of the sinuses were more prone to having a Type-III IOC extending into the MS.[12] In the present study, authors have thought that the extensive pneumatization of MS may be related with IOC protrusion. As the APP is the most common MS extension, we evaluated and found a significant relationship between IOC protrusion and APP ($p<0.001$).[14,16,22]

Understanding the role of IOC protrusion into MS on APP requires an in-depth understanding of the physiology of development as well as the clinical and imaging anatomy of the MS. Further studies with larger sample size and in different races were required.

## CONCLUSION

The present study revealed a significant relationship between IOC protrusion and APP of MS ($p<0.001$), representing the first investigation, to our knowledge, into the potential association between IOC protrusion and APP of MS. To reduce iatrogenic injuries and surgical complications, it is advisable to assess preoperative 3D analysis of this region using CBCT.


### *Source of Finance*

*During this study, no financial or spiritual support was received neither from any pharmaceutical company that has a direct connection with the research subject, nor from a company that provides or produces medical instruments and materials which may negatively affect the evaluation process of this study.*

### *Conflict of Interest*

*No conflicts of interest between the authors and / or family members of the scientific and medical committee members or members of the potential conflicts of interest, counseling, expertise, working conditions, share holding and similar situations in any firm.*

### *Authorship Contributions*

***Idea/Concept:** Sevde Göksel; **Design:** Cansu Köseoğlu Seçgin, Sevde Göksel; **Control/Supervision:** Cansu Köseoğlu Seçgin, Sevde Göksel; **Data Collection and/or Processing:** Cansu Köseoğlu Seçgin, Sevde Göksel; **Analysis and/or Interpretation:** Arif Yiğit Güler, Sevde Göksel; **Literature Review:** Cansu Köseoğlu Seçgin, Sevde Göksel; **Writing the Article:** Cansu Köseoğlu Seçgin, Sevde Göksel; **Critical Review:** Arif Yiğit Güler, Sevde Göksel, Cansu Köseoğlu Seçgin.*


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