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Comparative Analysis of Alveolar Crest Height Relative to the Maxillary Sinus in Upper Molars by Skeletal Classes and Sex: A Cone Beam Computed Tomography Study

Análisis Comparativo de la Altura de la Cresta Alveolar en Relación con el Seno Maxilar en Molares Superiores por Clases Esqueléticas y Sexo: Un Estudio con Tomografía Computarizada de Haz Cónico

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SUMMARY: The maxillary sinus is a bilateral pneumatic space located within the maxilla, in close proximity to the alveolar ridge that supports the upper dentition, and it plays a significant role in surgical planning due to potential complications. This study analyzed 120 Cone-Beam Computed Tomography (CBCT) scans of both males and females from San Luis Potosí, Mexico, and identified their skeletal classes. Measurements of the alveolar ridge height relative to the maxillary sinus were obtained at the mesial, middle, and distal points of the first and second molars. The results showed significant differences in alveolar ridge height between males of skeletal classes I and II, with class I exhibiting greater heights. Although sex-based differences were less pronounced and did not achieve clinical significance, the data highlight the importance of axial CBCT imaging for accurate assessment of bone morphology and its relationship with the maxillary sinus. These findings underscore the need to tailor surgical strategies to specific skeletal characteristics, thereby enhancing the planning and outcomes of procedures in the posterior maxillary region.

KEY WORDS: Alveolar crest; Maxillary sinus; Cone-beam computed tomography (CBCT).

INTRODUCTION

The relationship between the height of the alveolar bone crest and the maxillary sinus in upper molars is crucial for dentistry and maxillofacial surgery. The maxillary sinus is a cavity in the maxilla, bordered by the nasal cavity, maxillary tuberosity, orbit, and alveolar bone (Heit, 2017; Bhalla & Dym, 2021). It helps to warm inhaled air, aids in speech, and assists with aeration. Its proximity to the alveolar bone crest, which supports the upper teeth, is significant for surgical procedures. Care must be taken during surgery to avoid complications such as rhinosinusitis, chronic rhinosinusitis, retention cysts, and mucoceles (Delgadillo Ávila, 2005; Rodríguez López, 2023).

The thickness of the cortical bone and the pneumatization of the maxillary sinus are influenced by anatomical and biological factors, including sex and skeletal classification. Differences in craniofacial morphology between men and women can impact bone density and sinus pneumatization, which in turn affects the height of the alveolar bone crest (Castro-Guevara *et al*., 2015).

Skeletal classes I, II, and III, which describe the relationship between the maxilla and mandible, have implications for the morphology of the alveolar bone crest and the maxillary sinus. These classifications affect bone structure and the spatial relationship between the alveolar bone crest and the sinus. Understanding these variations is essential for planning and performing surgical procedures, such as dental implants and sinus elevations, to ensure their success and safety (Duque-Duque *et al*., 2023).

Cone-Beam Computed Tomography (CBCT) is invaluable for analyzing these morphological features. It provides high-resolution 3D images and precise axial slices,

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allowing detailed assessment of the relationship between the alveolar bone crest and the maxillary sinus. This technology helps identify anatomical variations related to sex and skeletal classes, enhancing diagnostic accuracy and the design of personalized treatment plans.

This study aims to fill this gap by analyzing the relationship between the height of the alveolar bone crest and the configuration of the maxillary sinus in upper molars. Using CBCT, we will evaluate variations associated with sex and skeletal classes in a sample from San Luis Potosí, Mexico. The goal is to provide a solid scientific basis for improving clinical protocols and tailoring interventions to individual morphological characteristics.

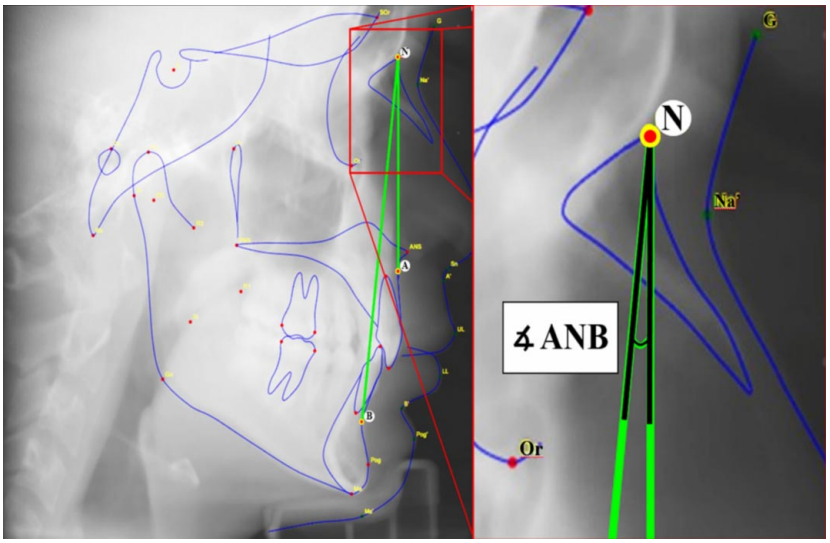

Fig. 1. Lateral skull radiograph. Craniometric points: Craniometric points: A. Point A, B. Point B, N. Nasion point, and angleANB angle.

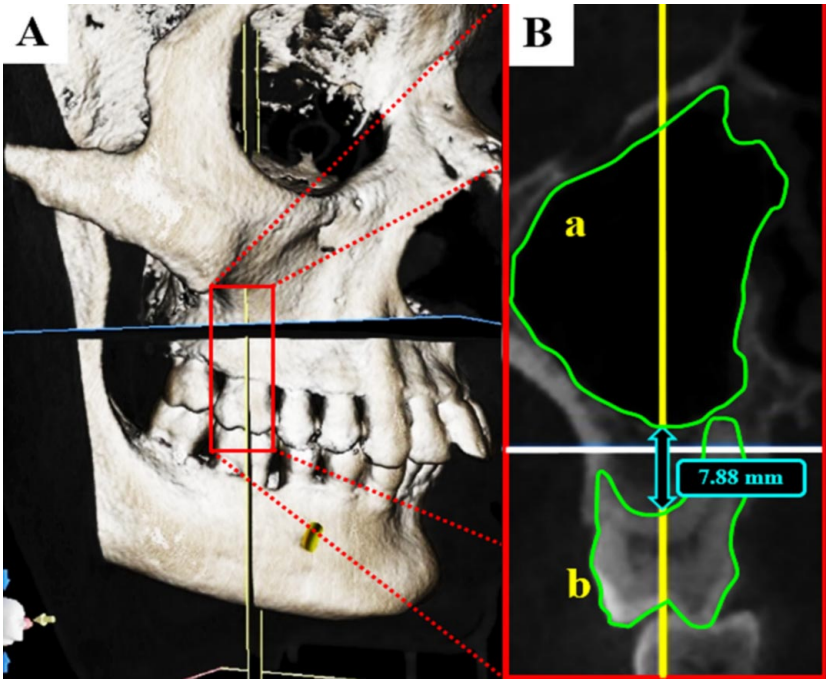

Fig. 2. Cone-beam computed tomography of the skull. A. 3D representation of the skull CT scan, B. Coronal section of computedtomography showing a. Maxillary sinus and b. Upper first molar.

MATERIAL AND METHOD

A total of 120 CBCT of the maxilla were analyzed, equally divided between male (n = 60) and female (n = 60) subjects. The study groups were classified into three skeletal classes: Class I, Class II, and Class III (n = 20 per group). Skeletal classification was determined via cephalometric tracing on lateral cephalometric radiographs using the ANB angle. The angular difference between the A-N line (from point A of the maxilla to point N of the nasomaxillary suture) and the N-B line (from point N to point B of the mandibular bone) was measured. An ANB angle ranging from 0° to 2° indicated a Class I relationship, where the mandible and maxilla are properly aligned. An ANB angle greater than 3° suggested Class II, with a retrognathic mandible relative to the maxilla, whereas an ANB angle less than 0° indicated Class III, with a prognathic mandible in relation to the maxilla (Fuentes *et al*., 2006) (Fig. 1).

For each CBCT scan, measurements were taken of the height from the alveolar bone crest to the maxillary sinus at three points: mesial, middle, and distal of the right first and second upper molars (n = 360 measurement points). The CBCT images were imported into BlueSky Plan 4 software, where the study points were identified and marked on cross-sectional images (Fig. 2). Statistical analysis was conducted using MINITAB version 19 software. The normality of variables was assessed using the Shapiro-Wilk test. Given the non-parametric nature of the study, statistical significance was determined using the Mann-Whitney U test with a 95 % confidence interval.

RESULTS

Descriptive statistics were determined, including mean, standard error of the mean, standard deviation, median, and minimum and maximum values (Table I).

The heights of the alveolar ridge to the maxillary sinus were compared at the distal, middle, and mesial points of the right upper first and second molars across the three skeletal classes for each sex. Statistical differences were identified in comparisons between Skeletal Class I and II in males at: Distal of the second molar (Class I vs II, $p \leq 0.010$), middle of the second molar ($p \leq 0.005$), mesial of the second molar ($p \leq 0.008$), distal of the first molar ($p \leq 0.011$), and middle of the first molar ($p \leq 0.027$), but not among other study groups (Table II).

Table I. Descriptive statistics.

Dental Organ	Height	Sex	Class	Mean	Error	SD	Mínimum	Median	Máximum
Second upper molar	**Distal**	**Male**	**I**	11.033	0.693	3.099	5.680	10.655	15.940
			II	8.1310	0.613	2.742	2.570	8.3900	12.280
			III	9.7980	0.991	4.433	3.300	9.1650	19.980
		Female	**I**	10.576	0.740	3.308	5.660	9.5950	19.240
			II	10.288	0.565	2.526	3.880	10.840	14.110
			III	12.042	0.864	3.864	5.630	11.445	23.210
	Middle	**Male**	**I**	8.1080	0.522	2.335	4.700	7.5800	13.560
			II	6.0660	0.380	1.701	3.500	5.9750	8.7800
			III	7.5830	0.696	3.113	2.630	7.6200	17.120
		Female	**I**	12.270	3.75	16.76	5.120	8.1600	82.500
			II	7.9090	0.606	2.711	3.410	8.4750	12.280
			III	9.2740	0.842	3.765	3.870	8.4650	20.340
	Mesial	**Male**	**I**	10.149	0.346	1.546	7.890	9.9500	13.200
			II	8.556	0.447	1.998	5.510	8.0700	11.910
			III	10.291	0.987	4.416	3.820	10.120	18.880
		Female	**I**	9.7130	0.543	2.430	5.120	10.075	13.750
			II	9.5300	0.617	2.758	5.870	9.1700	14.850
			III	11.169	0.721	3.224	5.370	10.855	18.680
First upper molar	**Distal**	**Male**	**I**	10.140	0.367	1.641	7.700	9.9500	13.200
			II	8.5560	0.447	1.998	5.510	8.0700	11.910
			III	10.291	0.987	4.416	3.820	10.120	18.880
		Female	**I**	9.8960	0.512	2.289	5.930	10.075	13.750
			II	9.4380	0.624	2.790	5.870	8.8300	14.850
			III	11.178	0.726	3.247	5.370	10.855	18.860
	Middle	**Male**	**I**	7.4990	0.558	2.495	4.210	7.2400	12.290
			II	5.6740	0.416	1.860	2.800	5.9250	9.0200
			III	7.9480	0.904	4.044	2.910	6.9250	18.360
		Female	**I**	7.0720	0.846	3.783	2.270	6.7550	16.130
			II	7.5400	0.598	2.674	4.180	6.8450	15.040
			III	8.9900	0.844	3.777	4.770	7.8900	21.320
	Mesial	**Male**	**I**	10.845	0.540	2.414	6.960	10.720	16.490
			II	10.072	0.630	2.818	5.510	9.4500	15.110
			III	13.750	1.410	6.320	6.230	11.310	27.490
		Female	**I**	10.883	0.946	4.233	4.220	10.640	19.970
			II	44.400	33.40	149.2	7.500	9.6000	678.00
			III	12.810	1.120	5.010	6.970	11.230	30.420

Table II. Comparison of alveolar crest height measurements to the maxillary sinus at distal, middle, and mesial points of the right first and second upper molars across skeletal classes and sexes.

		Skeletal class					
		Male			**Female**		
Dental Organ	**Height**	**I vs II**	**I vs III**	**II vs III**	**I vs II**	**I vs III**	**II vs III**
Second upper molar	Distal	0.010*	0.199	0.344	0.137	0.213	0.579
	Middle	0.005*	0.598	0.076	0.561	0.777	0.337
	Mesial	0.008*	0.745	0.344	0.695	0.256	0.117
First upper molar	Distal	0.011*	0.766	0.344	0.449	0.285	0.110
	Middle	0.027*	0.925	0.093	0.534	0.14	0.120
	Mesial	0.387	0.279	0.072	0.543	0.262	0.273

* The asterisk denotes statistical significance ($P \leq 0.05$).

The heights of the alveolar ridge to the maxillary sinus at the study points—distal, middle, and mesial of the right upper first and second molars—were compared across skeletal classes for each sex, revealing statistical significance: For males: Class I, distal vs middle of the second molar ($p \leq 0.003$), distal vs mesial of the second molar ($p \leq 0.304$), middle vs mesial of the second molar ($p \leq 0.002$), distal vs middle of the first molar ($p \leq 0.001$), middle vs mesial of the first molar ($p \leq 0.000$); Class II: distal vs middle of the first molar ($p \leq 0.010$), middle vs mesial of the second molar ($p \leq 0.000$), distal vs middle of the second molar ($p \leq 0.000$), distal vs mesial ($p \leq 0.050$), middle vs mesial of the first molar ($p \leq 0.000$); Class III: middle vs mesial of the second molar ($p \leq 0.050$), distal vs middle ($p \leq 0.049$), distal vs mesial ($p \leq 0.049$), middle vs mesial of the first molar ($p \leq 0.001$). For females: Class I, distal vs middle of the second molar ($p \leq 0.006$), distal vs middle of the first molar ($p \leq 0.010$), middle vs mesial of the first molar ($p \leq 0.007$); Class II: distal vs middle of the second molar ($p \leq 0.006$), distal vs middle of the first molar ($p \leq 0.027$), distal vs mesial ($p \leq 0.050$), middle vs mesial of the first molar ($p \leq 0.000$); Class III: distal vs middle of the second molar ($p \leq 0.008$), middle vs mesial of the second molar ($p \leq 0.045$), distal vs middle of the first molar ($p \leq 0.009$), middle vs mesial of the first molar ($p \leq 0.001$), but not among other study groups (Table III).

The heights of the alveolar ridge to the maxillary sinus at distal, middle, and mesial points of the right upper first and second molars were compared across the three skeletal classes. In Class II: distal of the second molar ($p \leq 0.013$), middle of the second molar ($p \leq 0.024$), middle of the first molar ($p \leq 0.026$); Class III: distal of the second molar ($p \leq 0.050$), but not among other study groups (Table IV).

Table III. Comparison of heights at each study point between skeletal classes for each sex.

		Skeletal class					
		Male			Female		
Dental Organ	**Height**	**I**	**II**	**III**	**I**	**II**	**III**
Second upper molar	**Distal vs Medio**	0.003*	0.010*	0.108	0.006*	0.006*	0.008*
	Distal vs Mesial	0.304*	0.756	0.776	0.818	0.245	0.525
	Medio vs Mesial	0.002*	0.000*	0.050*	0.223	1.000	0.045*
First upper molar	**Distal vs Medio**	0.001*	0.000*	0.049*	0.010*	0.027*	0.009*
	Distal vs Mesial	0.351	0.050*	0.049*	0.695	0.050*	0.298
	Medio vs Mesial	0.000*	0.000*	0.001*	0.007*	0.000*	0.001*

* The asterisk denotes statistical significance ($P \leq 0.05$).

Table IV. Comparison of heights at each study point between male and female in each skeletal class.

	Skeletal class								
	I			II			III		
Dental Organ	**Distal**	**Middle**	**Mesial**	**Distal**	**Middle**	**Mesial**	**Distal**	**Middle**	**Mesial**
Second upper molar	0.372	0.534	0.725	0.013*	0.024*	0.317	0.050*	0.164	0.441
First upper molar	0.745	0.516	0.766	0.417	0.026*	0.473	0.441	0.317	0.968

* The asterisk denotes statistical significance ($P \leq 0.05$).

DISCUSSION

Choi *et al*.'s study investigated the anatomical relationship between the maxillary molars and the maxillary sinus, focusing on the height of the alveolar bone at different tooth positions. Their findings demonstrated that the proximity of the maxillary sinus to the roots of the upper molars significantly affects the height of the alveolar bone, which has direct implications for dental implant placement and other surgical procedures in the posterior maxilla. It was observed that the height of the alveolar bone tends to be lower in areas where the maxillary sinus is closer to the molar roots, potentially limiting treatment options if not properly considered during preoperative planning. Our results extend this research by identifying significant differences in the height of the bone crest relative to the maxillary sinus between men of Skeletal Classes I and II, with greater height observed in Class I. This suggests that skeletal morphology also influences the availability of alveolar bone. Although sexual differences in the height of alveolar crests between the first and second molars in men and women are minimal and not clinically significant, our observations highlight the importance of considering additional variables such as skeletal class in the analysis. These differences may reflect variations in skeletal growth and development affecting the disposition and density of alveolar bone, emphasizing the need for a multidimensional evaluation that incorporates anatomical relationships as well as skeletal and sexual characteristics in planning interventions in the posterior maxilla (Choi *et al*., 2020).

Demirel & Akbulut (2020) study examined the height of the alveolar crest and the maxillary sinus mucosa using cone-beam computed tomography (CBCT), finding that the proximity of the maxillary sinus and the condition of the sinus mucosa significantly influence the height of the alveolar bone, complicating the planning of surgical procedures. This approach provides valuable insights into the relationship between the maxillary sinus and the alveolar bone but does not account for skeletal class, which could limit a comprehensive understanding of bone height variations. In contrast, our research revealed significant differences in the height of the bone crest relative to the maxillary sinus between men of Skeletal Classes I and II, with greater height observed in Class I, indicating that skeletal morphology also plays a crucial role. This discrepancy may be explained by our methodology, which incorporates detailed skeletal classification and multidimensional analysis encompassing both the anatomical features of the maxillary sinus and skeletal morphology. While Demirel & Akbulut (2020) focused on specific anatomical aspects and mucosal conditions, our approach extends the evaluation to consider how variations in skeletal morphology can affect alveolar bone availability. These findings highlight the need for surgical planning that takes into account not only the anatomical features of the maxillary sinus but also individual morphological specifics to optimize treatment outcomes in the posterior maxillary region.

Aktuna Belgin *et al*. (2021) analyzed the height of the alveolar bone in relation to the molars and the maxillary sinus, finding that the proximity between the molar roots and the maxillary sinus is associated with a significant reduction in available bone height, which has important implications for dental implant planning and other surgical interventions. In contrast, our research provided additional insights by identifying significant differences in the height of the bone crest relative to the maxillary sinus between men of Skeletal Classes I and II, with greater height observed in Class I, suggesting that skeletal morphology plays a crucial role in alveolar bone availability. While the authors focused on the anatomical proximity between the molars and the maxillary sinus, our analysis incorporated skeletal classification, offering a more comprehensive view of how skeletal morphological characteristics affect bone height. Additionally, our observations of variations in the height of alveolar crests between first and second molars in men and women revealed minor differences that did not reach clinical significance, suggesting that sex-related variations might be less prominent compared to skeletal morphological influences. These differences underscore the need for a multidimensional evaluation combining both specific anatomical features of the molars and the maxillary sinus and variations in skeletal morphology for more precise and personalized surgical planning in the posterior maxillary region.

Jung *et al*. (2020) evaluated the effectiveness of cone-beam computed tomography compared to panoramic radiography for detecting root protrusions into the maxillary sinus, concluding that tomography provides more accurate and detailed visualization. This is due to its ability to offer three-dimensional images that reveal complex anatomical relationships between the dental roots and the maxillary sinus more clearly. Our research, which also utilized computed tomography, identified significant differences in the height of the bone crest relative to the maxillary sinus between men of Skeletal Classes I and II, with greater height in Class I, and observed minor variations in the height of alveolar crests between the first and second molars and between sexes. These differences underscore the importance of tomography in the precise evaluation of bone morphology and its relationship with the maxillary sinus. CBCT proved essential in our study by allowing a more detailed assessment of differences between skeletal classes and alveolar crest heights. This ability to provide precise three-dimensional images is crucial for understanding how specific anatomical features affect available bone height, facilitating more accurate and personalized surgical planning. Our results support those of the authors by reinforcing the importance of using cone-beam computed tomography to obtain a completer and more detailed image, improving accuracy in preoperative evaluation and treatment planning in the maxillary regions.

Kamar Affendi *et al*.'s article offers a narrative review on the analysis of alveolar bone and classification using cone-beam computed tomography (CBCT) in the immediate placement of implants in the anterior maxilla. This review highlights CBCT's capability to provide accurate three-dimensional evaluations of alveolar bone, essential for successful implant placement planning. Compared to our findings, which identified significant differences in the height of the bone crest relative to the maxillary sinus between men of different skeletal classes, as well as minor variations in alveolar crest heights between molars and sexes, the authors emphasize CBCT's importance in obtaining detailed images for a comprehensive assessment of bone morphology. While our research focused on the anatomical features of the maxillary sinus and their clinical implications, the review emphasizes how CBCT can enhance immediate implant planning by offering a more complete view of the alveolar bone. Integrating both approaches underscores the importance of computed tomography for more precise and personalized surgical planning, ensuring more effective interventions tailored to individual patient characteristics (Kamar Affendi *et al*., (2022).

CONCLUSION

This study identified significant differences in the height of the alveolar crest relative to the maxillary sinus between Skeletal Classes I and II in men, with Class I exhibiting greater height. Additionally, there were minor differences in the height of the alveolar crest between the first and second molars across both sexes. These findings, derived from computed tomography, offer a detailed morphological perspective that can significantly influence the diagnosis and treatment planning for patients across different skeletal classes. The results underscore the importance of incorporating morphological variations into clinical dental planning and emphasize the need for further research to explore the implications of these anatomical differences in greater depth.

SERRANO, B. E.; GUTIÉRREZ, C. F. J.; OLIVA, R. R.; GARCÍA, C. J. O. & MARIEL, C. J. Análisis comparativo de la altura de la cresta alveolar en relación con el seno maxilar en molares superiores por clases esqueléticas y sexo: Un estudio con tomografía computarizada de haz cónico. *Int. J. Morphol., 43(1)*:311-316, 2025.

RESUMEN: El seno maxilar es un espacio neumático bilateral ubicado en los maxilares, su proximidad a la cresta alveolar que soporta a los dientes superiores, tiene un papel importante en la planificación quirúrgica debido a posibles complicaciones. Se analizaron 120 tomografías computarizadas de hombres y mujeres en San Luis Potosí, México, y se identificaron las clases esqueletales. Las medidas de altura de la cresta alveolar al seno maxilar se obtuvieron en los puntos mesial, medio y distal de los primeros y segundos molares. Los resultados mostraron diferencias significativas en la altura de la cresta alveolar entre hombres de clases esqueléticas I y II, siendo mayor en la clase I, aunque las diferencias entre sexos fueron menores y no alcanzaron significancia clínica, los datos resaltan la importancia de la tomografía axial computarizada para una evaluación precisa de la morfología ósea y su relación con el seno maxilar. Estos hallazgos destacan la necesidad de adaptar las estrategias quirúrgicas a las características esqueléticas específicas, mejorando la planificación y resultados de procedimientos en la región maxilar posterior.

PALABRAS CLAVE: Cresta alveolar; Seno maxilar; Tomografía computarizada de haz cónico.

REFERENCES

Aktuna Belgin, C.; Bayrak, S. & Atakan, C. Determination of alveolar bone height according to the relationship between molar teeth and maxillary sinus. *Oral Maxillofac. Surg., 25(2)*:175-80, 2021.

Bhalla, N. & Dym, H. Update on maxillary sinus augmentation. *Dent. Clin. North Am., 65(1)*:197-210, 2021.

Castro-Guevara, N. E.; Muñoz-Durán, J. V.; López-Pérez, L. A. & Infante-Contreras, C. Variation in craniofacial morphological patterns in skeletal Classes I, II, and III. *Rev. Fac. Odontol. Univ. Antioquia, 26(2)*:292-313, 2015.

Choi, Y. J.; Kim, Y. H.; Han, S. S.; Jung, U. W.; Lee, C.; Lee, A. & Jeon, K. J. Alveolar bone height according to the anatomical relationship between the maxillary molars and sinus. *J. Periodontal Implant Sci., 50(1)*:38-47, 2020.

Delgadillo Ávila, J. R. Growth and development of the maxillary sinus and its relationship with dental roots. *Kiru, 2(1)*:46-51, 2005.

Demirel, O. & Akbulut, A. Alveolar crest height and maxillary sinus mucosa: A cone-beam computed tomography assessment. *Ege Univ. Dis. Hekimligi Fak. Derg., 41(3)*:179-86, 2020.

Duque-Duque, I. J.; Xamayris Perea, Puerta, G. & Gutiérrez-Quiceno, B. Position of the lower incisor in patients with skeletal Classes I and II according to their facial biotype in a sample from a private clinic, Cali 2014-2020. *Medicas UIS, 36(2)*:59-70, 2023.

Fuentes, R.; Silva, H.; Sandoval, P.; Cuevas, F. & Rodríguez, M. Condylar process height in patients with different skeletal classes requiring orthodontictreatment. *Int. J. Morphol., 24(3)*:499-503, 2006.

Heit, O. Anatomy of the maxillary sinus: Clinical importance of the antral arteries and septa. *Rev. Col. Odontol. Entre Rios, (161)*:6-10, 2017.

Jung, Y. H.; Cho, B. H. & Hwang, J. J. Comparison of panoramic radiography and cone-beam computed tomography for assessing radiographic signs indicating root protrusion into the maxillary sinus. *Imaging Sci. Dent., 50(4)*:309-318, 2020.

Kamar Affendi, N. H.; Babiker, J. & Mohd Yusof, M. Y. A narrative review of alveolar bone analysis and CBCT classification related to immediate implant placement in the anterior maxilla. Malays. *J. Med. Health Sci., 18*:311-323, 2022.

Rodríguez López, M. A. Maxillary sinus lesions and their association with apical lesions observed by cone-beam computed tomography: A retrospective cross-sectional study. *Rev. Cient. Odontol. Lima, 11(1)*:e139, 2023.

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