Turkish Journal of Clinics and Laboratory

To cite this article: Ocak H, Çolpak HA. Radiographic evaluation of the relationship between maxillary sinus pneumatization and tooth extraction. Turk J Clin Lab 2025; 3: 593-599

Research Article

Radiographic evaluation of the relationship between maxillary sinus pneumatization and tooth extraction

Maksiller sinüs pnömatizasyonu ve diş çekimi arasındaki ilişkinin radyografik değerlendirmesi

Hakan Ocak*[1], Halis Ali Çolpak[2]

[1]Department of Oral and Maxillofacial Surgery, İstanbul Galata University, Faculty of Dentistry, İstanbul, Turkey
[2]Department of Oral and Maxillofacial Surgery, Private Dental Clinic, Antalya, Turkey

Abstract

Aim: To assess maxillary sinus pneumatization radiographically after posterior tooth extraction and to compare the results based on both the post-extraction time interval and the tooth type.

Material and Methods: This retrospective study included 54 patients who underwent extraction of at least one premolar or molar with roots close to the maxillary sinus floor. A total of 186 panoramic radiographs were assessed using standardized reference lines and points to measure sinus floor changes. Patients were categorized into five groups based on follow-up periods: 0–6, 7–12, 13–18, and 19–24 months. Magnification correction was applied, and mean pneumatization values were calculated by follow-up group and tooth type.

Results: Maxillary sinus pneumatization demonstrated a progressive increase with longer post-extraction intervals. The mean pneumatization values were 1.1 mm in the 0–6 month group, 1.7 mm in the 7–12 month group, 2.1 mm in the 13–18 month group, and 3.9 mm in the 19–24 month group. Analysis by tooth type revealed mean values of 1.5 mm for premolar extractions, 2.0 mm for first molars, and 2.4 mm for both second and third molars. Greater pneumatization was observed in teeth with roots in close proximity to the sinus floor and in those extracted due to chronic periapical infection.

Conclusion: Maxillary sinus pneumatization is a time-dependent process influenced by tooth type, root–sinus relationship, and pre-existing pathology. Early implant placement or ridge preservation techniques should be considered in high-risk cases to minimize bone loss and reduce the need for extensive sinus augmentation procedures.

Keywords: maxillary sinus pneumatization, tooth extraction, sinus floor, ridge preservation

Corresponding Author*: Hakan Ocak. Department of Oral and Maxillofacial Surgery, İstanbul Galata University, Faculty of Dentistry, İstanbul, Turkey
E-mail: hakanocak82@hotmail.com
Orcid: 0000-0003-1573-9628
Doi: 10.18663/tjcl.1779524
Received: 07.09.2025 Accepted: 28.09.2025

Öz

Amaç: Posterior diş çekimi sonrası maksiller sinüs pnömatizasyonunu radyografik olarak değerlendirmek ve sonuçları hem çekim sonrası geçen süreye hem de çekilen diş tipine göre karşılaştırmak.

Gereç ve Yöntemler: Bu retrospektif çalışma, kök uçları maksiller sinüs tabanına yakın konumda olan en az bir premolar veya molar dişi çekilmiş 54 hastayı kapsamaktadır. Toplam 186 panoramik radyografi, standart referans çizgileri ve noktaları kullanılarak sinüs tabanındaki değişiklikleri ölçmek amacıyla değerlendirildi. Hastalar, takip sürelerine göre 0–6, 7–12, 13–18 ve 19–24 ay olmak üzere beş gruba ayrıldı. Büyütme düzeltmesi uygulandı ve takip süresi ile diş tipine göre ortalama pnömatizasyon değerleri hesaplandı.

Bulgular: Maksiller sinüs pnömatizasyonu, çekim sonrası geçen süre ile progresif olarak artış gösterdi. Ortalama pnömatizasyon değerleri; 0–6 aylık grupta 1,1 mm, 7–12 aylık grupta 1,7 mm, 13–18 aylık grupta 2,1 mm ve 19–24 aylık grupta 3,9 mm olarak bulundu. Diş tipine göre analizde ortalama değerler; premolar çekimlerinde 1,5 mm, birinci molar çekimlerinde 2,0 mm, ikinci ve üçüncü molar çekimlerinde ise 2,4 mm olarak saptandı. Sinüs tabanına kökleri yakın olan ve kronik periapikal enfeksiyon nedeniyle çekilen dişlerde daha fazla pnömatizasyon gözlendi.

Sonuçlar: Maksiller sinüs pnömatizasyonu, zamana bağlı ilerleyen, diş tipinden, kök–sinüs ilişkisinden ve mevcut patolojiden etkilenen bir süreçtir. Yüksek riskli olgularda erken implant uygulaması veya alveoler kret koruma teknikleri, kemik kaybını en aza indirmek ve kapsamlı sinüs yükseltme işlemlerine duyulan ihtiyacı azaltmak için önerilmelidir.

Anahtar Kelimeler: maksiller sinüs pnömatizasyonu, diş çekimi, sinüs tabanı, kret koruma

Introduction

Implant placement in the posterior maxilla is often complicated by maxillary sinus pneumatization, where the sinus expands into the space of missing teeth and reduces the available bone height for implants [1]. Following the loss of upper posterior teeth, the combined effect of normal alveolar bone resorption and sinus floor expansion can significantly diminish ridge dimensions, frequently necessitating sinus floor elevation (sinus lift) procedures to allow implant placement [2, 3]. This post-extraction enlargement of the sinus (maxillary sinus pneumatization) is thought to result from disuse atrophy – the reduction in bone density and volume due to the lack of functional loading after a tooth is removed [4]. Also, patients who undergo extraction of maxillary molars (especially multiple adjacent teeth) have a higher risk of substantial sinus expansion, particularly when the extracted tooth's roots were in close proximity to the sinus floor [5, 6].

Despite numerous studies, the literature shows inconsistent results regarding post-extraction sinus changes. Some two-dimensional radiographic assessments have found clear increases in sinus dimensions after tooth loss, whereas others reported little to no change [7-10]. This inconsistency may be due to methodological differences (e.g. panoramic X-rays superimpose structures and can be less accurate or variation in patient factors [11]. Notably, cone-beam CT analyses generally provide more definitive evidence of sinus pneumatization, and cross-sectional comparisons have shown that edentulous posterior maxillae tend to exhibit a lower sinus floor (greater pneumatization) than dentate maxillae in similar regions [5]. On the other hand, at least one study using volumetric CT measurements found no significant difference in sinus size related to dentition status, highlighting that the degree of pneumatization can be highly individual [7]. Importantly, there are preventive measures that can mitigate sinus expansion. Alveolar ridge preservation at the time of extraction has been shown to limit sinus floor resorption: for instance, sites that healed naturally for 1 year exhibited over 1 mm of vertical sinus encroachment, whereas those treated with bone grafting in the socket had only a ~0.3 mm change [12]. This suggests that the timing and management of the extraction site can influence how much the sinus pneumatizes post-extraction.

Given the potential for progressive sinus pneumatization, the timing of implant or preprosthetic surgery in the posterior maxilla is critical. It is generally recommended to allow initial healing of the extraction socket (approximately 3–6 months); beyond this period, additional sinus expansion

may occur in the absence of an implant or graft occupying the space [13]. If the sinus floor drops substantially, delayed interventions become more complex or may require larger sinus augmentation procedures. Therefore, the aim of this retrospective study was to radiographically assess maxillary sinus pneumatization following posterior tooth extraction by using reference lines and reference points on panoramic radiographs, with comparisons based on time elapsed since extraction, tooth type, and other relevant factors.

Material and Methods

This retrospective study included patients who underwent extraction of at least one premolar or molar tooth with its apex in close radiographic proximity to the maxillary sinus floor. The procedures were performed at the Department of Oral and Maxillofacial Surgery, İstanbul Galata University Faculty of Dentistry, between June 2024 and January 2025. The study was approved by the İstanbul Galata University Ethics Committee (Date: 21.02.2025, Approval No: 2025-01) and was carried out in accordance with the relevant ethical guidelines and the Helsinki Declaration (2013 Brazil revision). All patients provided written informed consent.

Study Population

A total of 54 patients, consisting of 27 women and 27 men, were included in the study. Inclusion required the availability of high-quality pre- and post-extraction panoramic radiographs, with a minimum follow-up period of 1 day and a maximum of 24 months between examinations, and provision of written informed consent. Patients were excluded if they had poor-quality or distorted radiographs preventing accurate measurement, a history or radiographic evidence of pathology in the maxillary sinus region (such as cysts, tumors, or acute/chronic sinusitis), prior implant placement, grafting, or sinus lift procedures in the region of interest, systemic diseases or medications affecting bone metabolism (e.g., osteoporosis, Paget's disease, bisphosphonate use), or if any additional surgical intervention was performed in the region during the follow-up period.

A total of 186 panoramic films from patients were examined. Based on the follow-up interval between the first and second radiographic examinations, patients were divided into four groups: 0–6 months (n = 76), 7–12 months (n = 42), 13–18 months (n = 36), and 19–24 months (n = 32). Across all cases, 90 tooth extractions were performed, including 8 premolars, 32 first molars, 36 second molars, and 14 third molars.

Radiographic Assessment

Panoramic radiographs obtained before and after tooth extraction were analyzed using Sidexis 4 dental imaging software (Dentsply Sirona, Axeos 3D imaging system, Beinsheim, Germany). Two anatomical reference points were identified on the panoramic images to determine the extent of pneumatization: the first was a line parallel to the Frankfort horizontal plane passing through the most superior point of the anterior nasal spine, and the second was a line parallel to the Frankfort horizontal plane passing through the most inferior point of the maxillary sinus. The vertical distance between these two reference lines was considered the measure of maxillary sinus pneumatization (Figure 1) [14-16].

Figure 1. The measured distance between the two reference points is considered the indicator of sinus pneumatization.

To determine the magnification factor from the panoramic radiographs taken before and after extraction, the vertical distance between two lines parallel to the Frankfort horizontal plane—one passing through the tip of the crown and the other through the root apex of the canine or premolar—was measured. In edentulous patients, this calibration was performed by measuring the height of a metal reference ball on the panoramic image. The magnification factor was then calculated using a simple ratio and applied to the post-extraction radiographs to obtain the actual pneumatization value (Figure 2). The mean pneumatization for each study group was subsequently determined by dividing the total pneumatization value by the number of participants in that group.

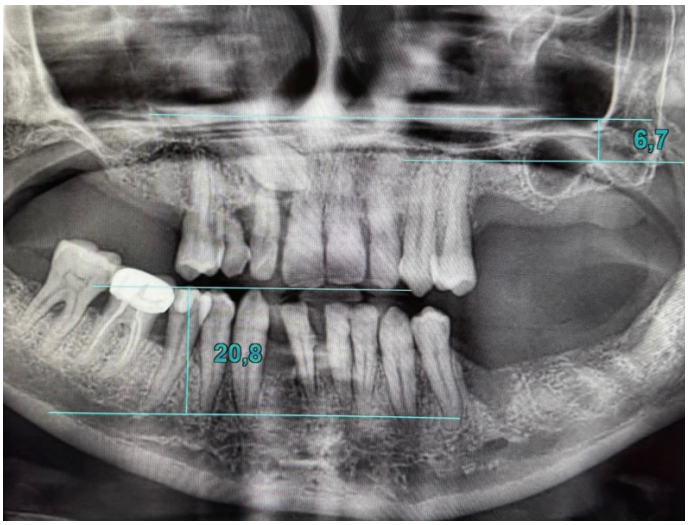

Figure 2. The extent of pneumatization was calculated using post-extraction radiographs.

Statistical analysis

Data analysis was conducted with IBM SPSS Statistics for Windows, version 20.0 (IBM Corp., Armonk, NY, USA). The normality of the data distribution was evaluated using the Shapiro–Wilk test. Data are expressed as the mean along with the minimum and maximum values. The Kruskal–Wallis test was used to compare tooth types, time intervals, and cases of multiple tooth extractions. A p-value of <0.05 was considered statistically significant for all analyses.

Results

The mean age of the patients included in the study was 58.4 ± 10.2 years. The mean amount of maxillary sinus pneumatization increased progressively with longer follow-up periods after tooth extraction. In the 0–6 month group, the mean pneumatization was 1.1 mm (range: 0.2–3.2 mm). This increased to 1.7 mm (range: 0.2–4.6 mm) in the 7–12 month group and to 2.1 mm (range: 0.1–5.1 mm) in the 13–18 month group. The highest mean pneumatization was observed in the 19–24 month group, with a value of 3.9 mm (range: 0.8–6.2 mm). Table 1 presents the amount of pneumatization and the number of teeth that caused pneumatization after extraction.

Analysis according to tooth type demonstrated notable differences in the extent of maxillary sinus pneumatization. The smallest mean value was observed following premolar extractions (1.5 mm, range: 0.1–4.5 mm). First molar extractions resulted in a mean pneumatization of 2.0 mm (range: 0.1–6.2 mm), whereas second and third molar extractions both showed the highest mean values of 2.4 mm. Maxillary sinus pneumatization was greater in the first molar group than in the premolar group. While no significant difference was detected between the second and third molar groups, both demonstrated higher values compared with the remaining groups (Table 2). Pneumatization was greater after extracting teeth with infected roots and molars whose curved roots lifted the sinus membrane.

Table 1. Distribution of maxillary sinus pneumatization across time intervals.

Time Period (Months)	Number of	Pneumatization (mm)			P-value
		Mean	Min	Max	
experiments	76	1.1	0.2	3.2	<0.001*
		1.7	0.2	4.6	
13–18	29	2.1	0.1	5.1	
19–24	27	3.9	0.8	6.2	

Numerical variables are mean and min-max. * P-value <0.05 shows statistical significance. Bold values denote statistically significant differences between groups.

Table 2. Distribution of maxillary sinus pneumatization by tooth type.

Tooth Type	Number of experiments	Pneumatization (mm)			P-value
		Mean	Min	Max	
Premolar	8	1.5	0.1	4.5	<0.001*
1st Molar	32	2.0	0.1	6.2	
2nd Molar	36	2.4	0.1	4.5	
3rd Molar	14	2.4	0.3	4.6	

Numerical variables are mean and min-max. * P-value <0.05 shows statistical significance. Bold values denote statistically significant differences between groups.

Discussion

This study provides important insights into the time-dependent nature of maxillary sinus pneumatization following posterior maxillary tooth extraction. By quantitatively evaluating changes at different post-extraction intervals and comparing them across tooth types, we identified clear patterns that have direct implications for implant planning. Our results show that sinus floor descent is minimal within the first 6 months (~1.1 mm) but increases progressively over time, reaching an average of 3.9 mm at 19–24 months. Moreover, molar extractions—particularly second and third molars—were associated with the greatest degree of pneumatization, while premolars exhibited the smallest changes. We also found that teeth with infected roots or roots closely related to the sinus floor were more prone to pronounced expansion. These findings highlight the critical importance of early intervention or ridge preservation techniques to minimize bone loss in high-risk cases.

Several radiographic studies have quantified the extent of sinus floor descent after posterior tooth extractions, but their findings vary. One longitudinal study reported a mean sinus pneumatization of ~1.56 mm when comparing pre- and post-extraction panoramic radiographs, with the greatest changes noted in the molar regions [17]. Consistent with this, Sharan and Madjar (2008) observed an inferior displacement of the sinus floor averaging ~1.8 mm at 6–67 months post-extraction (compared to the pre-extraction position), and ~2.2 mm when comparing edentulous sites to contralateral dentate sites [5]. Notably, in certain anatomic situations they reported even greater pneumatization – teeth whose roots were enveloped by a superiorly curved sinus floor showed ~5.3 mm of sinus expansion on average [5]. This aligns with our observation that extractions of molars with closely related sinus anatomy (e.g. curved roots lifting the sinus membrane) led to the highest pneumatization values in our series. Indeed, we found second and third molar extractions yielded mean sinus floor depressions of ~2.4 mm, higher than first molars (~2.0 mm) and far greater than premolar sites (~1.5 mm). This trend is well-supported by prior studies: Wehrbein and Diedrich noted that molar extractions induce significantly more sinus pneumatization than premolar extractions [18], likely because molars occupy a larger volume and are often closer to the sinus floor. Our results are in line with this, underscoring tooth type as an important factor.

Using three-dimensional cone-beam computed tomography (CBCT) scans, Hameed et al. found that only around 12% of the vertical bone reduction 6 months after a maxillary molar extraction was due to sinus floor depression – the vast majority of bone loss came from crestal/alveolar resorption [19]. In their study, the sinus floor shifted by a mean of just 0.47 mm upward, whereas the overlying alveolar crest resorbed over 3 mm during the same period [19]. Another cross-sectional CBCT study comparing edentulous vs. dentate sides similarly detected a minor sinus pneumatization of about 0.9 mm on average at sites of a single missing upper posterior tooth [11]. These findings suggest that in many cases of isolated tooth loss, the sinus does not dramatically expand – at least not in the early post-extraction phase. Indeed, some researchers have reported that the time elapsed beyond the initial healing (~6 months) has little further effect on sinus floor position [19], implying that most dimensional changes occur soon after extraction. These smaller values (on the order of 0.5–1 mm) contrast with the larger mean changes observed in our study (and others), and the discrepancy may be due to differences in observation period and methodology. Studies with shorter follow-ups or cross-sectional designs might capture a snapshot before full pneumatization occurs, whereas our data indicate that more substantial sinus expansion can develop by ~2 years post-extraction. Methodological factors are also important: our measurements were done on radiographic images with reference lines, which could be influenced by magnification or patient positioning [7-10]. In fact, 2D panoramic radiographs have inherent distortion, though vertical measurements on panoramic images are considered reasonably reliable when standardized [20, 21]. By contrast, 3D cone-beam CT provides more precise volumetric assessment; CBCT-based studies might report smaller linear changes simply because they can differentiate true sinus floor remodeling from overall ridge reduction [1, 17, 22]. Despite these differences, the consensus in the literature is that some degree of sinus floor descent does occur post-extraction in many cases, even if the magnitude varies. Our findings extend this knowledge by quantifying how that pneumatization progresses over time and by tooth type.

Another key finding was that sinus expansion was greater when the extracted tooth had an infected or structurally compromised root, and when roots were in close contact with

or protruded into the sinus floor. Such cases—often molars with divergent, curved roots—showed more vertical sinus floor displacement, consistent with Lim et al. who reported the highest pneumatization after removal of endodontically compromised teeth [17]. Both local anatomical factors (root–sinus proximity, sinus floor morphology) and pathological factors (infection) appear to influence the extent of pneumatization. Proposed mechanisms include disuse atrophy—where loss of functional loading triggers bone resorption in line with Wolff's law—and the breach or thinning of the sinus floor during extraction, facilitating membrane prolapse into the socket [5, 18, 23]. Additional contributors may be changes in sinus air pressure and chronic inflammation, which can weaken the sinus floor through osteolysis. Overall, post-extraction sinus pneumatization is likely multifactorial, shaped by mechanical, anatomical, and inflammatory influences.

This study has certain limitations. First, changes in alveolar ridge and maxillary sinus dimensions were assessed using panoramic radiographs. Although standardized reference points were employed to superimpose images taken at different time points, the use of CBCT would allow for more precise, three-dimensional evaluation and verification of sinus pneumatization changes. Second, sinus pneumatization is known to be influenced by a variety of factors beyond tooth extraction in the posterior maxilla. In this study, we focused exclusively on the relationship between extraction and pneumatization, and the relatively small sample size may limit the generalizability of our findings. Future studies with larger populations, incorporating CBCT imaging and evaluating additional contributing variables—such as sinus anatomy, bone density, and patient-specific factors—are warranted to validate and expand upon these results.

In conclusion, this study demonstrates that maxillary sinus pneumatization is a progressive, time-dependent process following posterior maxillary tooth extraction. While changes are minimal in the early healing phase, they become more pronounced over time. Molar extractions—particularly second and third molars—are associated with greater expansion than premolars, and the risk is higher when roots are close to the sinus or when extraction is due to chronic infection. Our results emphasize the clinical relevance of early intervention or ridge preservation strategies to help maintain bone volume in the posterior maxilla.

Ethical Approval

The study was performed in accordance with the Declaration of Helsinki, and was approved by the İstanbul Galata University Ethics Committee (Date: 21.02.2025, Approval No: 2025-01).

Funding

The authors declared that this study has received no financial support.

Conflicts of Interest

Authors declare that they have no conflicts of interest.

Authors' Contribution

Concept – H.O. and H.A.Ç., Design- H.O. and H.A.Ç., Data collection and/or processing – H.O. and H.A.Ç., Analysis and/or interpretation - H.O. and H.A.Ç., Writing – H.O., Critical review – H.A.Ç., All authors read and approved the final version of the manuscript.

Acknowledgements

None

References

1. Farina R, Pramstraller M, Franceschetti G, Pramstraller C, and Trombelli L. Alveolar ridge dimensions in maxillary posterior sextants: a retrospective comparative study of dentate and edentulous sites using computerized tomography data. Clin Oral Implants Res. 2011;22(10):1138-44. DOI: 10.1111/j.1600-0501.2010.02087.x.
2. Alayan J, Vaquette C, Farah C, and Ivanovski S. A histomorphometric assessment of collagen-stabilized anorganic bovine bone mineral in maxillary sinus augmentation - a prospective clinical trial. Clin Oral Implants Res. 2016;27(7):850-8. DOI: 10.1111/clr.12694.
3. Tan WL, Wong TL, Wong MC, and Lang NP. A systematic review of post-extractional alveolar hard and soft tissue dimensional changes in humans. Clin Oral Implants Res. 2012;23 Suppl 5:1-21. DOI: 10.1111/j.1600-0501.2011.02375.x.
4. Lam L, Ivanovski S, and Lee RSB. Alveolar ridge preservation in posterior maxillary teeth for reduction in the potential need for sinus floor elevation procedures: A pilot study. Clin Oral Implants Res. 2024;35(12):1568-84. DOI: 10.1111/clr.14344.
5. Sharan A and Madjar D. Maxillary sinus pneumatization following extractions: a radiographic study. Int J Oral Maxillofac Implants. 2008;23(1):48-56.

6. Jung Y-H, Nah K-S, and Cho B-H. Maxillary sinus pneumatization after maxillary molar extraction assessed with cone beam computed tomography. Korean Journal of Oral and Maxillofacial Radiology. 2009:109-13.
7. Padhye NM, Shirsekar VU, Bhange PD, Nikam SS, and Marathe AS. Three-dimensional linear and volumetric assessment of the maxillary sinus following posterior teeth extraction with implications for dental implant: a split mouth cross-sectional cone-beam computed tomographic study. Journal of Dental Implants. 2021;11(1):30-35.
8. Ariji Y, Ariji E, Yoshiura K, and Kanda S. Computed tomographic indices for maxillary sinus size in comparison with the sinus volume. Dentomaxillofac Radiol. 1996;25(1):19-24. DOI: 10.1259/dmfr.25.1.9084281.
9. Rosen MD and Sarnat BG. Change of volume of the maxillary sinus of the dog after extraction of adjacent teeth. Oral Surg Oral Med Oral Pathol. 1955;8(4):420-9. DOI: 10.1016/0030-4220(55)90111-0.
10. Ariji Y, Kuroki T, Moriguchi S, Ariji E, and Kanda S. Age changes in the volume of the human maxillary sinus: a study using computed tomography. Dentomaxillofac Radiol. 1994;23(3):163-8. DOI: 10.1259/dmfr.23.3.7835518.
11. Cavalcanti MC, Guirado TE, Sapata VM, et al. Maxillary sinus floor pneumatization and alveolar ridge resorption after tooth loss: a cross-sectional study. Brazilian oral research. 2018;32:e64.
12. Levi I, Halperin-Sternfeld M, Horwitz J, Zigdon-Giladi H, and Machtei EE. Dimensional changes of the maxillary sinus following tooth extraction in the posterior maxilla with and without socket preservation. Clin Implant Dent Relat Res. 2017;19(5):952-58. DOI: 10.1111/cid.12521.
13. Schropp L, Wenzel A, Kostopoulos L, and Karring T. Bone healing and soft tissue contour changes following single-tooth extraction: a clinical and radiographic 12-month prospective study. Int J Periodontics Restorative Dent. 2003;23(4):313-23.
14. Packota GV, Hoover JN, and Neufeld BD. A study of the height of intact alveolar bone on panoramic radiographs of adult patients. J Prosthet Dent. 1988;60(4):504-9. DOI: 10.1016/0022-3913(88)90258-2.
15. Jung YH, Cho BH, and Hwang JJ. Comparison of panoramic radiography and cone-beam computed tomography for assessing radiographic signs indicating root protrusion into the maxillary sinus. Imaging Sci Dent. 2020;50(4):309-18. DOI: 10.5624/isd.2020.50.4.309.
16. Eberhardt JA, Torabinejad M, and Christiansen EL. A computed tomographic study of the distances between the maxillary sinus floor and the apices of the maxillary posterior teeth. Oral Surg Oral Med Oral Pathol. 1992;73(3):345-6. DOI: 10.1016/0030-4220(92)90133-b.
17. Lim HC, Kim S, Kim DH, Herr Y, Chung JH, and Shin SI. Factors affecting maxillary sinus pneumatization following posterior maxillary tooth extraction. J Periodontal Implant Sci. 2021;51(4):285-95. DOI: 10.5051/jpis.2007220361.
18. Wehrbein H and Diedrich P. [Progressive pneumatization of the basal maxillary sinus after extraction and space closure]. Fortschr Kieferorthop. 1992;53(2):77-83. DOI: 10.1007/BF02164641.
19. Hameed S, Bakhshalian N, Alwazan E, Wallace SS, and Zadeh HH. Maxillary Sinus Floor and Alveolar Crest Alterations Following Extraction of Single Maxillary Molars: A Retrospective CBCT Analysis. Int J Periodontics Restorative Dent. 2019;39(4):545-51. DOI: 10.11607/prd.3865.
20. Vazquez L, Nizamaldin Y, Combescure C, et al. Accuracy of vertical height measurements on direct digital panoramic radiographs using posterior mandibular implants and metal balls as reference objects. Dentomaxillofac Radiol. 2013;42(2):20110429. DOI: 10.1259/dmfr.20110429.
21. Reddy MS, Mayfield-Donahoo T, Vanderven FJ, and Jeffcoat MK. A comparison of the diagnostic advantages of panoramic radiography and computed tomography scanning for placement of root form dental implants. Clin Oral Implants Res. 1994;5(4):229-38. DOI: 10.1034/j.1600-0501.1994.050406.x.
22. Cha JK, Song YW, Park SH, Jung RE, Jung UW, and Thoma DS. Alveolar ridge preservation in the posterior maxilla reduces vertical dimensional change: A randomized controlled clinical trial. Clin Oral Implants Res. 2019;30(6):515-23. DOI: 10.1111/clr.13436.
23. Misch CE. Contemporary implant dentistry. Implant Dentistry. 1999;8(1):90.