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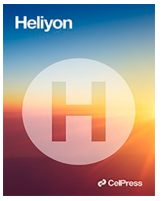

Research article

Cone-beam CT evaluation of post-extraction alveolar bone changes at the maxillary incisor sites in an East Asian population: A cross-sectional study

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ABSTRACT

Objective: Understanding the characteristics of alveolar bone resorption in an East Asian population after maxillary incisor extraction and providing a reference for implant treatment plans.
Study design: Cone-beam computerized tomography (CBCT) data of 125 East Asian patients with unilateral extraction of maxillary incisors for 3 months were collected. The alveolar bone width and height in the extraction sites were measured and compared with the corresponding contralateral sites.
Results: The differences in alveolar bone width between the extraction site and contralateral site were as follows: 4.11 mm, 2.68 mm, and 2.09 mm (3 mm, 5 mm, 7 mm apical from CEJ of the contralateral tooth). Data are expressed as the median. The horizontal resorption ratio of alveolar bone was 49.94 %, 31.5 %, and 24.46 %. The difference in alveolar bone height was 0.78 mm. The vertical resorption ratio was 7.78 %. The resorption did not differ significantly between sexes and was not significantly affected by tooth positions.
Conclusions: In the studied East Asian population, significant horizontal and vertical alveolar bone resorption occurs after natural healing of maxillary incisor extraction for 3 months. The closer to the alveolar ridge crest, the more significant the horizontal resorption, resulting in an "inverted triangle" shape residual alveolar bone.

1. Introduction

The loss of maxillary incisors impairs pronunciation and aesthetics, resulting in difficulties with social communication [1]. After

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tooth extraction and natural healing, the width and height of the alveolar bone will be resorbed. The amount of alveolar bone resorption is not uniform in different sites, resulting in significant morphological changes of alveolar bone, especially in the maxillary incisor sites [2]. Implant dentures have been shown to be effective in restoring the morphology and function of missing maxillary incisors. However, the large variation in alveolar bone changes after tooth extraction brings difficulties in preoperative evaluation and plan development, which may impair implant placement and cause unpleasant aesthetic results of the final restorations [3]. These problems may introduce many uncertainties for implant restorations in maxillary incisor sites, including the timing and angle of placement and whether to perform bone augmentation. All these factors may lead to increased surgical difficulty, prolonged procedures, or even treatment failure [4]. Therefore, it is essential to evaluate the resorption of alveolar bone after tooth extraction in this region to facilitate implant treatments.

Meanwhile, in the maxillary aesthetic area, implant treatment requires a balance with facial appearance. Alveolar bone morphology varies among different ethnic groups. One study reported that African-American subjects showed wider and longer upper and lower dental arches than whites [5]. It has also been reported that African-Americans showed different maxillofacial dimensions and upper anterior tooth exposure compared to whites [6]. Therefore, knowledge of alveolar bone resorption in people of various ethnicities is advantageous for implant restorations aesthetics. However, few studies have focused on the alveolar bone morphology of East Asians after tooth extraction. There is a lack of precise measurement and analysis of alveolar bone resorption patterns in the aesthetic area of East Asians.

In addition, there are few recent reports on alveolar bone resorption to provide sufficient information for preoperative evaluation. Recent studies have focused on immediate postoperative observation and follow-up, with the main objective of evaluating the effectiveness of alveolar ridge preservation techniques and bone augmentation materials [7,8]. There is a lack of attention not only to the specific problems associated with dental implantation in the aesthetic area (bone volume deficiency, difficulties in timing and positioning of the implant, and uncertainty in the aesthetic outcome) but also to an absence of information about effective preoperative alveolar bone assessment.

Therefore, the purpose of this study was to evaluate the characteristics of alveolar bone resorption after maxillary incisor extraction in an East Asian population and to provide a reference for implant treatments in the maxillary aesthetic area.

2. Method and materials

2.1. Study design and subject selection

This study was conducted in accordance with the Declaration of Helsinki and was designed according to the STROBE (Strengthening the Reporting of Observational Studies in Epidemiology) guidelines [9]. The protocol was approved by the Ethics Committee of the Shanghai Ninth People's Hospital (approval number: SH9H-2022-T307-1). Sample sizes were estimated using PASS software (version 11, NCSS, USA). A 90 % statistical power ($\alpha = 0.05$) was used to detect the differences in width in the preliminary test and to estimate the sample size. A minimum group of 108 subjects was needed. Between January 2015 and June 2022, 125 Chinese patients with maxillary incisors extracted for 3 months and requiring implant restoration were enrolled. The diagnosed indications for tooth extractions were caries, endodontic reasons (e.g. root fracture), prosthodontic, orthodontic and periodontal reasons. These patients had their teeth extracted in the Department of Oral and Maxillofacial Surgery, which was performed by experienced clinicians to minimize trauma to the alveolar bone.

2.2. Inclusion criteria

(1) Adult subjects who were at least 18 years old at the time of CBCT examination.
(2) The teeth in unilateral maxillary incisal region had been extracted for 3 months.
(3) The alveolar bone at the extraction site healed naturally without any intervention (including bone augmentation surgery).
(4) The contralateral homonymous tooth of the missing tooth was basically intact.

2.3. Exclusion criteria

(1) Subjects with systemic diseases affecting bone metabolism and those taking medications affecting bone metabolism.
(2) Subjects with significant irregular or malocclusion contralateral homonymous teeth.
(3) Subjects with significant lateral jaw deformity, and pathological changes (jaw cysts, etc.) in the maxillary incisor region.
(4) The alveolar bone resorption of missing maxillary incisor reached or exceeded 1/3 or more of the contralateral homonymous teeth root length.
(5) The CBCT data showed severe metal artifacts.

2.4. CBCT measurements and outcomes

CBCT images were taken with a Kavo OP 3D Vision CBCT machine (Kavo, Germany). In accordance with the manufacturer's instructions, the scanning conditions were set as follows: 120 kV voltage, 5 mA current, 8.9 s scan time, 3.7 s exposure time, 16 cm*13 cm volume size, and 0.3 mm^3 voxel size. Data were saved in Digital Imaging and Communications in Medicine (DICOM) format.

The alveolar bone resorption was measured according to these previously reported methods. Pietrokovski et al. [10] found that the

morphology and resorption of alveolar bone after extraction and natural healing were generally similar between the left and right sides. Therefore, bone resorption of the extraction site was compared with that of the contralateral site. Moreover, the selection of the measurement planes was based on the method reported by Misawa et al. [11], and the contralateral homonymous tooth was also set as a reference.

Alveolar bone morphometry was performed using Simplant software (version 18.0, Materialise Dental, Belgium). The CBCT data were first imported into Simplant software for 3D reconstruction and elimination of metal artifacts. The reference planes were subsequently positioned. The center of the contralateral homonymous tooth was used as the reference. In the coronal plane window, the horizontal line was adjusted to be near the cemento-enamel junction (CEJ) of the contralateral homonymous tooth and perpendicular to its long axis (Fig. 1A). In the axial plane window, the horizontal line was adjusted to pass through the bilateral homonymous teeth simultaneously (Fig. 1B). In the sagittal plane window, the horizontal line was adjusted to pass through the CEJ of the contralateral homonymous tooth (Fig. 1C). In the 3D reconstruction window, the model was adjusted to be perpendicular and basically symmetrical to the horizontal plane (Fig. 1D). Then, the arch curve was drawn (Fig. 2A). A vertical line perpendicular to the arch curve was made at the homonymous contralateral tooth[11], passing through its pulp chamber (Fig. 2B). In the sagittal window, 3 horizontal lines passing 3 mm, 5 mm, and 7 mm apical from the CEJ of the contralateral homonymous tooth were drawn as references for the measurement of the width of the alveolar bone [7,8,12] (Fig. 2C). The distance from the labial alveolar bone cortical surface to the palatal surface was measured at the above planes as the width of the alveolar bone. A horizontal line parallel to the CEJ was made at the apical point of the contralateral homonymous tooth, and the vertical distance from the farthest point of alveolar bone to this line was measured as the alveolar bone height. The three horizontal lines for width measurement and the horizontal line for height measurement were extended to the corresponding extraction site. The width and height in the extraction site were measured accordingly (Fig. 2D).

The data included the width of the alveolar bone at the measurement planes 3 mm, 5 mm, and 7 mm apical from the CEJ, which was indicated by W3, W5, and W7 for the contralateral homonymous tooth site and W3′, W5′, and W7′ for the extraction site. Similarly, the height was indicated by H and H'. The data also included differences in width (ΔW3, ΔW5, ΔW7) and height (ΔH) and the horizontal and vertical resorption ratios (ΔW3/W3, ΔW5/W5, ΔW7/W7 and ΔH/H).

2.5. Examiner calibration

The researchers underwent regular calibration. At two separate time points with a 48-h interval, the alveolar bone width was measured in 5 CBCT scans. If the consistency percentage between the measurement results exceeded 90 %, the calibration results were considered acceptable. Throughout the study period, this procedure was repeated every two months.

2.6. Statistical analysis

Statistical analyses were performed using SPSS software (version 25.0, International Business Machines Corporation, USA). Data normality was tested using the Shapiro–Wilk test. The data reported in this study did not conform to a normal distribution by the Shapiro-Wilk test. Therefore, data were expressed as the median (interquartile range). The Mann–Whitney *U* test was used for

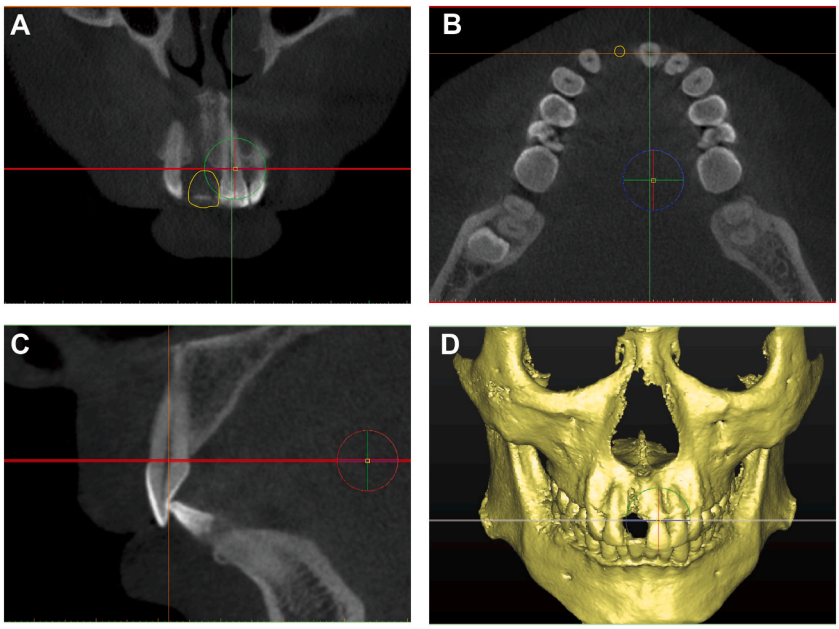

Fig. 1. Setting of the measurement reference planes A. Coronal plane. B. Axial plane. C. Sagittal plane. D. 3D reconstruction model.

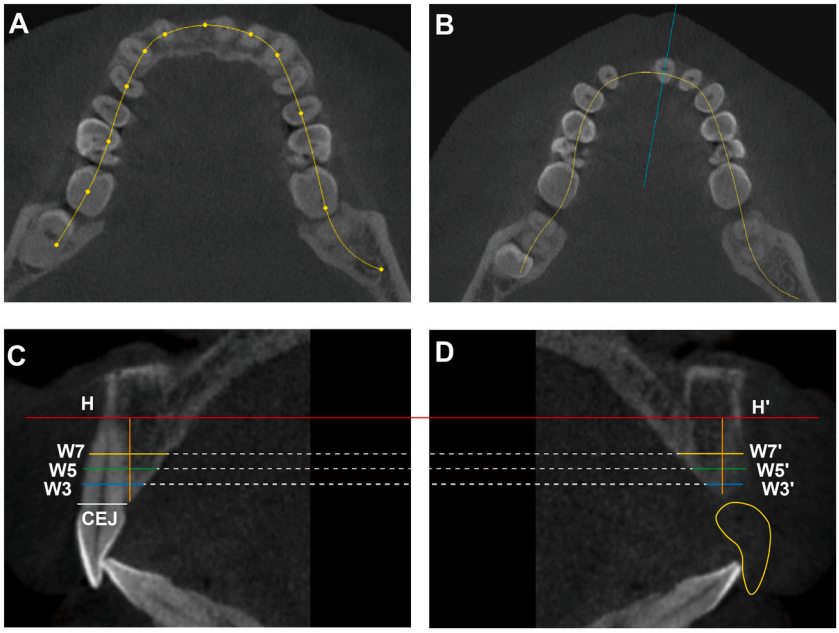

Fig. 2. Measurement of alveolar bone width and height A. The arch curve was drawn in Simplant software. **B.** A vertical line perpendicular to the arch curve at the contralateral homonymous tooth site was drawn, passing through its pulp chamber. **C.** Three horizontal lines passing 3 mm, 5 mm, and 7 mm apical from the CEJ of the contralateral homonymous tooth were drawn. The distance from the labial alveolar bone cortical surface to the palatal side was measured as the width of the alveolar bone. A horizontal line parallel to the CEJ was made at the apical point of the contralateral homonymous tooth, and the vertical distance from the farthest point of alveolar bone to this line was measured as the alveolar bone height. **D.** The three horizontal lines for width measurement and the horizontal line for height measurement were extended to the corresponding extraction site (CEJ: cemento-enamel junction. W3, W5 and W7: width measured at the planes 3 mm, 5 mm, and 7 mm apical from the CEJ of the contralateral homonymous tooth at the contralateral homonymous tooth site. W3′, W5′ and W7': width measured at the planes 3 mm, 5 mm, and 7 mm apical from the CEJ of the contralateral homonymous tooth at the extraction site. H and H': alveolar bone height at the contralateral homonymous tooth site and the extraction site).

comparisons between two independent samples (comparisons of ΔW3, ΔW5, ΔW7, ΔH, ΔW3/W3, ΔW5/W5, ΔW7/W7 between sexes and tooth positions). Comparisons between two paired samples were made using the Wilcoxon test (comparisons between W3 and W3′, W5 and W5′, and W7 and W7′). Multi-paired samples were compared using the Friedman M test (comparisons among ΔW3, ΔW5 and ΔW7, and comparisons among ΔW3/W3, ΔW5/W5 and ΔW7/W7), and comparisons within groups were corrected by the Bonferroni correction. Significance levels were checked by a two-sided test, and the results were significantly different when $p < 0.05$.

3. Results

3.1. General information

The 125 subjects, 63 males and 62 females, ranged in age from 18 to 75 years, with a mean age of 38.15 years. A total of 131 missing maxillary incisors were included, of which 99 were central incisors and 32 were lateral incisors. In six of these subjects, unilateral maxillary central and lateral incisors were extracted (Table 1).

Table 1
Subject characteristics.

Subject characteristics		
Age (years)	Mean	38.15
	Range	18–75
Sex (n)	Male	63
	Female	62
Teeth (n)	Total	131
	Central incisors	99
	Lateral incisors	32

3.2. CBCT measurement outcomes

The alveolar bone width (W3′, W5′, W7′) and height (H′) in the 131 missing maxillary incisor sites and those in the contralateral homonymous tooth sites (W3, W5, W7, H) are shown in Table 2. The Wilcoxon test showed that the alveolar bone width and height in the extraction sites significantly decreased ($p < 0.01$) compared to contralateral sites (Fig. 3). It was confirmed that severe horizontal and vertical resorption of the alveolar bone occurred in the studied East Asian population after maxillary incisor extraction.

The differences in alveolar bone width (ΔW3, ΔW5, ΔW7) and bone height (ΔH) between the contralateral homonymous tooth sites and the extraction sites are shown in Table 2. The Friedman M test showed that there was a significant difference ($p < 0.01$) among the different values in alveolar bone width at the 3 different measurement planes (Fig. 4A), with the value of ΔW3 (4.11 mm, 2.58 mm–6.00 mm) being the largest, while the value of ΔW7 (2.09 mm, 1.24 mm–3.35 mm) was the smallest (Table 2).

The horizontal and vertical resorption ratios are shown in Table 2. The Friedman M test showed that there was a significant difference ($p < 0.01$) among the horizontal resorption ratios at the 3 different measurement planes (ΔW3/W3, ΔW5/W5, and ΔW7/W7) (Fig. 4B), with the ratio of ΔW3/W3 (49.94 %, 34.18 %–76.16 %) being the largest, while the ratio of ΔW7/W7 was the smallest (24.46 %, 14.29 %–35.84 %) (Table 2).

The Mann–Whitney *U* test showed that ΔW3, ΔW5, ΔW7, ΔH, ΔW3/W3, ΔW5/W5, ΔW7/W7, and ΔH/H were greater in men than in women, but the differences were not statistically significant (Table S1, Fig. 4C and D).

Similarly, the Mann–Whitney *U* test results showed that ΔW7 was significantly greater ($p < 0.05$) in the central incisor site than in the lateral incisor site (Fig. 4E and F). The remaining data were not significantly different (Table S2). The above results showed that the resorption of alveolar bone width and height is not significantly affected by tooth position.

4. Discussion

Within 3 months of tooth extraction is the period of rapid progress of alveolar bone remodeling. Significant resorption of the bundle bone occurs, accompanied by the formation of woven bone, leading to more significant resorption in the labial/buccal side due to the predominant composition of the bundle bone in this area [2]. Schropp et al. found that significant alveolar bone resorption occurs within 3 months after extraction, with little volume loss and stable morphology in the subsequent 3–12 months [13]. Based on the results of previous studies, CBCT of healed sockets after extraction for 3 months was analyzed in this study.

CBCT has previously been used to study alveolar bone resorption and intervention therapy after tooth extraction. In a study on post-extraction site preservation, Jung et al. performed CBCT scanning on alveolar bone immediately and 6 months after treatment [7]. In their study, the width of the alveolar ridge at different horizontal levels and its height were measured following the method reported by Araujo and Lindhe [12], where the widths of the alveolar ridge at horizontal levels 1 mm, 3 mm, and 5 mm apical from the crest and the distance from the apical to the alveolar crest of the extraction socket were measured. Clementini et al. [8] also used this measurement protocol on the post-extraction change in alveolar bone with immediate implantation. In the present study, alveolar bone resorption was measured according to these previously reported methods. Pietrokovski and Massler [10] found that the morphology and resorption of alveolar bone after extraction and natural healing were generally similar between the left and right sides. Therefore, in the present study, only one CBCT was taken, and the bone resorption of the extraction site was compared with that of the contralateral site. Moreover, the selection of the measurement planes was based on the method reported by Misawa et al. [11], where CBCT data of patients with unilateral maxillary anterior teeth extracted more than 1 year ago were selected. The contralateral homonymous tooth was set as a reference. The widths of the alveolar bone at the levels 3 mm, 5 mm, and 7 mm apical from the CEJ of the contralateral tooth were measured. Meanwhile, the distance between the alveolar crest and the horizontal line passing through the root apex and parallel to the CEJ was measured as the height. Chappuis et al. [14] found that the alveolar bone was most significantly resorbed in the center of the extraction site. Therefore, only the changes in the central areas of both the extraction and reference sites were investigated in the present study.

The present study found significant horizontal and vertical resorption at the maxillary incisor sites after extraction for 3 months in the studied East Asian population. These results are similar to those reported by Tan et al. [15] Both the difference values in width and the horizontal resorption ratio were also significantly different among the 3 different measurement planes, showing that the closer to

Table 2
Alveolar bone width/height analysis in the extraction sites and the contralateral homonymous tooth sites.

	Width of alveolar bone			Height of alveolar bone
	3 mm apical from the CEJ	5 mm apical from the CEJ	7 mm apical from the CEJ	
Contralateral homonymous tooth site (mm)	7.95 (7.39–8.56)[a]	8.66 (8.11–9.38)[a]	9.01 (8.28–9.91)[a]	10.29 (9.13–11.3)[a]
Extraction site (mm)	4.01 (1.87–5.29)	5.98 (4.75–7.10)	6.69 (5.72–7.9)	9.16 (7.72–10.38)
Difference (mm)	4.11 (2.58–6)	2.68 (1.73–4.03)	2.09 (1.24–3.35)	0.78 (0.25–1.57)
Resorption ratio	49.94 % (34.18 %–76.16 %)	31.5 % (19.22 %–43.62 %)	24.46 % (14.29 %–35.84 %)	7.78 % (2.79 %–15.61 %)

Data are expressed as the median (interquartile range).
CEJ: cemento-enamel junction.
[a] $p < 0.01$ vs values of extraction site.

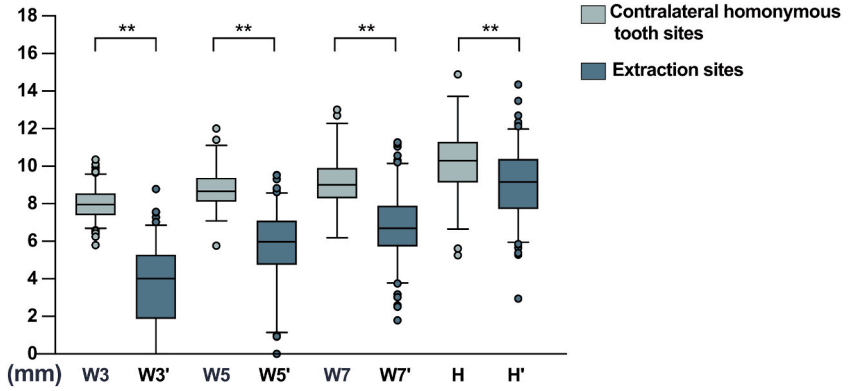

Fig. 3. Alveolar bone width/height at the extraction sites and contralateral homonymous tooth sites. The results showed that the alveolar bone widths (W3′, W5′, W7′) and height (H′) at the extraction sites were significantly decreased compared to those at the contralateral homonymous tooth sites (W3, W5, W7, H) (W3, W5, W7 and W3′, W5′, W7′: widths measured at the planes 3 mm, 5 mm, 7 mm apical from the CEJ of the contralateral homonymous tooth at the contralateral homonymous tooth site and extraction site, respectively. H and H′: alveolar bone height at the contralateral homonymous tooth site and the extraction site, respectively. **: $p < 0.01$).

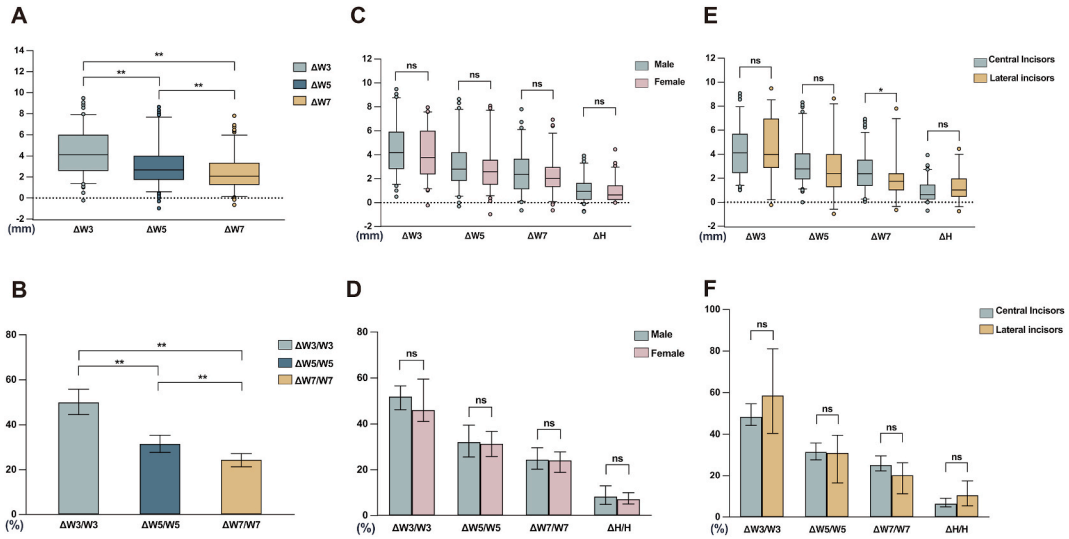

Fig. 4. Differences in the alveolar bone widths and horizontal resorption ratio at the extraction sites and the contralateral homonymous tooth sites **A.** There were significant differences between the differences in alveolar bone widths at different measuring planes apical from the CEJ of the contralateral homonymous tooth (ΔW3, ΔW5 and ΔW7). The value of ΔW3 was the largest, while the value of ΔW7 was the smallest. **B.** There were significant differences in the horizontal resorption ratio of alveolar bone at different measuring planes apical from the CEJ of the contralateral homonymous tooth (ΔW3/W3, ΔW5/W5, and ΔW7/W7). The ΔW3/W3 was the largest, and ΔW7/W7 was the smallest. **C, D.** The relevant data were greater in men than in women, but the differences were not statistically significant. **E, F.** The results showed that ΔW7 was significantly greater in the central incisors than in the lateral incisors ($p < 0.05$). The remaining data were not significantly different between the central and lateral incisors (ΔW3, ΔW5, ΔW7: difference between the widths of the alveolar bone at the contralateral homonymous tooth site and the extraction site measured at the planes 3 mm, 5 mm, and 7 mm apical from the CEJ of the contralateral homonymous tooth, respectively. ΔH: difference between the alveolar bone heights at the contralateral homonymous tooth site and the extraction site. ns: no statistical significance. *: $p < 0.05$. **: $p < 0.01$).

the alveolar ridge crest, the more significant the horizontal resorption in the alveolar bone. The most significant horizontal resorption occurred near the alveolar ridge crest, which reached almost 50 %, resulting in an "inverted triangle" shape of the residual alveolar bone (Fig. 5A–C), which is consistent with the previous findings of Misawa et al. [11].

The present study found that the studied East Asians experience more significant horizontal resorption at maxillary incisor sites after tooth extraction. Camargo et al. reported a horizontal resorption of 3.06 mm ± 2.41 mm 6 months after extraction of the maxillary anterior teeth in research conducted in the United States [16]. In a site-preservation study, Iasella et al. also found a horizontal resorption of 2.63 ± 2.29 mm 6 months after extraction in research conducted in the United States [17]. Although there are few studies related to different ethnic groups, it can be seen that the above amount of alveolar bone resorption is far below the resorption value of 4.11 mm reported in this study. Other studies of post-extraction alveolar bone resorption by ethnicity and study area are

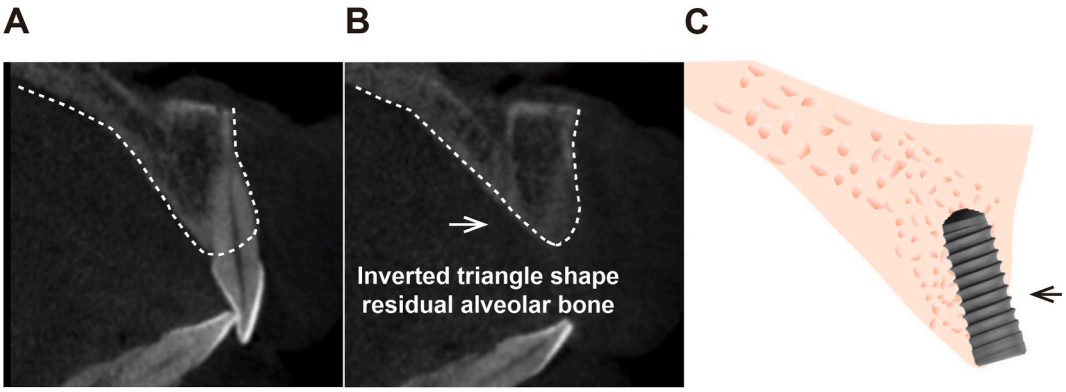

Fig. 5. Diagram of the inverted triangle shape residual alveolar bone after extraction in the maxillary incisor sites of the studied East Asian population **A, B.** The bone resorption after extraction of the maxillary incisor resulted in an inverted triangle shape residual alveolar bone, as visualized in CBCT. **C.** The inverted triangle shape residual alveolar bone may lead to a severe insufficiency of bone volume for dental implantation in this site.

summarized in Table 3 [18–20]. Rojo-Sanchis et al. [21] reported that horizontal resorption after extraction correlated with the thickness of the labial/buccal bone wall before extraction. Thinner labial/buccal bone walls resulted in more significant resorption. Anatomically, the maxillary incisor and canine showed thinner labial bone walls than other tooth positions [22], which might be the reason for the prominent horizontal resorption. Moreover, maxilla and maxillary anterior teeth protrusion is very common in East Asians, leading to a thinner labial bone wall compared to Europeans [23,24], which might have resulted in much more prominent horizontal resorption. All these results suggested that this "inverted triangle" shape residual alveolar bone may lead to a severe insufficiency of bone volume in the maxillary incisor sites, especially in East Asians.

The present study found that sex does not affect the difference in the amount or resorption proportion of alveolar bone. Nowzari et al. [25] found that the thickness of the labial alveolar bone wall of the maxillary central incisor was similar between men and women. Due to the previously discussed theory that horizontal resorption after extraction correlates with the thickness of the labial/buccal bone wall before extraction [21], the absence of sex-based differences in the present study is reasonable.

Among the different tooth positions, this study found significant differences only in the difference value of width at 7 mm apical from the CEJ. This indicates that resorption is not significantly influenced by tooth position. Couso-Queiruga et al. [4] found that the vertical resorption of the labial/buccal alveolar bone was greater in the anterior teeth and premolar regions than in the molar region. They pointed out that the thickness of the labial/buccal bone wall before extraction greatly affected both horizontal and vertical resorption. The horizontal and vertical bone resorption in teeth sites with labial and buccal wall thickness more than 1 mm was significantly less than that less than 1 mm.[4] Therefore, clinicians should take care to preserve the labial/buccal alveolar bone wall during tooth extraction, particularly in maxillary anterior tooth sites.

Alveolar bone resorption after tooth extraction has been associated with various factors, including surgical trauma, lack of functional stimulation of the bone wall, reduction of the bundle bone and periodontal ligaments, and systemic condition [2]. The present study shows the importance of protecting buccal bone wall during tooth extraction in the maxillary incisal region, and the following approach may be beneficial. The first is a minimally invasive surgical procedure. It has been shown that elevation of a full-thickness flap during tooth extraction may lead to bone wall resorption [26]. Reduction of full-thickness flaps in the maxillary incisal region may help to preserve the buccal bone wall. It is also risky to apply excessive force to the buccal side in the maxillary incisor region. This procedure may lead to expansion and fracture of the thin buccal bone wall. Moreover, the use of minimally invasive instruments such as periotomes is also helpful. Next is the application of bone substitute materials. A number of studies have shown that implantation of bone substitute materials after extraction significantly reduced bone resorption on the buccal side, as well as reducing the need for pre-implant bone augmentation [19,27,28]. It has also been claimed that site preservation mainly reduced horizontal bone resorption on the buccal side and showed a minor effect on vertical resorption [8].

Some limitations of the present study exist. First, a few patients (6/125) had both maxillary central and lateral incisors extracted. The loss of multiple teeth may have an impact on bone resorption compared to the loss of a single tooth. Second, as for the condition of single tooth missing, more central incisors were included than lateral incisors. Therefore, the results for the comparison between tooth positions may be statistically biased. Furthermore, due to the limitations of retrospective studies, we had no access to the past medical history of the subjects beyond the present hospital. Therefore, phenotype, bone angulation, history of infection, and original bone characteristics were not reported in this study. These initial characteristics may affect the results of bone resorption. In addition, considering the need for early implantation at maxillary incisal region and the principle of radiation dose optimization, the present data was collected at a single time point. This also shows the limitations of cross-sectional studies, which means that the present study is inadequate for the assessment of long-term healing and remodeling of the alveolar bone. Additionally, the error in CBCT scanning and measuring cannot be ignored, which will lead to some differences with the real alveolar bone situation. Follow-up studies on post-extraction alveolar bone changes in maxillary incisor sites with larger samples and including more tooth positions are still needed.

Table 3
Alveolar bone resorption among different ethnic groups and study areas.

Research	Ethnicity/Study areas (sample size)	Tooth Extraction Area	Resorption type (mm, median/mean ± SD)	Measurement method
Lee AMH et al., 2017	Chinese (20)	Maxillary anterior teeth	W < 6 mm: n = 13 (65 %) W ≥ 6 mm: n = 7 (35 %)	CBCT
Acharya A et al., 2014	Chinese (C, 232) Asian Indian (I, 225)	Maxillary first molar	H: 10.0 (C), 6.75 (I) W1 (1 mm from bone crest): 7.4 (C),7.0 (I)	CBCT
Iasella JM et al., 2003	The United States (12)	Maxillary anterior teeth & premolar	ΔW: 2.63 ± 2.29 ΔH: 0.90 ± 1.60	Clinical measurement
Camargo, PM et al., 2000	The United States (16)	Maxillary anterior teeth & premolar	ΔW: 3.06 ± 2.41 ΔH: 1.00 ± 2.25	Clinical measurement
Lekovic V et al., 1997	The United States (7)	Maxillary anterior teeth & premolar	ΔW: 4.43 ± 0.72 ΔH: 1.00 ± 0.00	Clinical measurement
Current study	Chinese (125)	Maxillary anterior teeth	ΔW3: 4.11, ΔW5: 2.68, ΔW7: 2.09 ΔH: 0.78	CBCT

W: the width of the alveolar bone at the extraction site.
H: the height of the alveolar bone at the extraction site.
ΔW: difference between the widths of the alveolar bone at the control tooth site and the extraction site.
ΔH: difference between the heights of the alveolar bone in the contralateral homonymous tooth site and the extraction site.
ΔW3, ΔW5, ΔW7: difference between the widths of the alveolar bone at the contralateral homonymous tooth site and the extraction site measured at the planes 3 mm, 5 mm, and 7 mm apical from the CEJ of the contralateral homonymous tooth.

5. Conclusions

After maxillary incisor extraction in the studied East Asian population for 3 months and natural healing, significant horizontal and vertical resorption of alveolar bone occurred in the extraction sites. The closer to the alveolar ridge crest, the more severe the horizontal resorption, resulting in an “inverted triangle” shape residual alveolar bone. The horizontal and vertical resorption did not differ significantly between sexes and was not significantly affected by tooth position. In summary, we suggest that clinicians should pay attention to the preservation of the bone wall during tooth extraction in East Asians, especially in maxillary incisors. In particular, during early and delayed implant treatment in these sites, attention should be given to the influence of the “inverted triangle” shape residual alveolar bone.

Ethics statement

This research protocol was approved by the Ethics Committee of the Shanghai Ninth People’s Hospital (approval number: SH9H-2022-T307-1). Written informed consent was not required for the following reasons. First, the CBCT images in this study are examples from the Simplant software and are intended to illustrate the measurement methods in this study. It is not intended to show the medical and personal information of a specific individual. According to the Elsevier Policy on the Use of Images or Personal Information of Patients or Other Individuals, formal consents are not required for the use of entirely anonymised images from which the individual cannot be identified. The CBCT images in this study do not contain any identifying marks and are not accompanied by text that might identify the individual concerned.

Data availability statement

The data of this study are available upon reasonable request from the corresponding author. Researchers interested in the data may contact Prof. Chun Xu via email at imxuchun@sjtu.edu.cn.

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CRediT authorship contribution statement

Fang Qu: Writing – original draft, Formal analysis. **Yu-Jie Huang:** Investigation, Formal analysis. **Ying-Ying Wang:** Validation. **Xi-Meng Cao:** Data curation. **Ying-Yi Shen:** Visualization. **Zi-Ang Wu:** Supervision. **Ya-Qin Wu:** Conceptualization. **Chun Xu:** Writing – review & editing.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.heliyon.2024.e32027.

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