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Original Article

Evaluation of factors affecting alveolar ridge height and facial bone thickness in Chinese maxillary central incisors by cone beam CT

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KEYWORDS
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Abstract *Background/purpose:* In the immediate implantation of maxillary central incisors, the height of the alveolar bone is lost, and there is often a risk of bone fracture due to the thin buccal bone wall (BBW). The purpose of this study was to assess the effects of smoking, age, and root position in the alveolar bone on the BBW and the distance between the cemento-enamel junction (CEJ) and the facial bone crest (FBC) of Chinese maxillary central incisors.
Materials and methods: The patients were divided by smoking, gender, age, and root sagittal position in the alveolar bone. BBW thickness was measured at the following sites: the 4 mm apical to the CEJ, the middle of the root, and the apex. The distance from the CEJ to the FBC was also evaluated.
Results: Cone beam CT (CBCT) data for the maxillary central incisors of 645 patients (323 males and 322 females) were selected and analyzed. The CEJ-FBC distance in patients who smoked (2.79 ± 0.78 mm) was significantly greater than that of non-smokers (2.54 ± 0.69 mm). The BBW in subtype III (0.74 ± 0.43 mm, 0.81 ± 0.36 mm) was thinner than that in subtypes I and II at 4 mm apical to the CEJ and in the middle of the root, with a statistically significant difference ($p < 0.05$).

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Conclusion: In most Chinese people, smoking, gender, age, and the position of the root in alveolar bone are all important factors that must be considered before immediate implantation is undertaken.

Introduction

In most cases, the thickness of the buccal bone wall (BBW) of maxillary central incisors is less than 1 mm.[1,2] The BBW is composed primarily of bundle bone. Once the teeth are extracted, the thin bundle bone will be absorbed and will dissipate.[3,4] Therefore, the thickness of the BBW is of great significance for maintenance of the shape of the extraction socket.[5,6]

The shape of the extraction socket is determined by the position of the root in alveolar bone.[7] The thickness of the BBW varies with the location of the root in the alveolar bone. Therefore, before measurement of the thickness of the alveolar bone, the position of the root in the alveolar bone should be determined. According to the literature, it can be divided roughly into three types: buccal, middle, and palatal.[8] In a previous study, we found that the buccal type accounted for more than 90%. Therefore, the buccal type was further classified into subtypes I, II, and III.[9]

Some authors choose the timing of implant placement based on the thickness of the BBW after extraction.[10] But so far, until now, the minimal BBW thickness required to avoid vertical crest resorption has not been established.[11] The distance from the cemento-enamel junction (CEJ) to the facial bone crest (FBC) may be a key factor to be considered. Some authors have found that the distance from the CEJ to the FBC was closely related to age factors.[12,13] This distance was also closely related to systemic diseases and smoking.[14] Many investigators have reported that periodontal disease leads to loss of adhesion, absorption of alveolar bone, and subsequent absorption of the BBW.[15,16] Alqahtani and co-workers considered that the level of cotinine in the peri-implant fluid (PISF) in smokers was significantly higher than that in non-smokers.[17] Some authors have found that smoking was an important factor in peri-implant diseases.[18,19]

At present, there are reports in the literature on the influence of smoking and age on the distance between the CEJ and the FBC and the thickness of the BBW.[20] However, differences in the thickness of the BBW and the distance between the CEJ and the FBC in the Chinese population due to differences in smoking, age, and root position in the alveolar bone have not been reported in the literature. The purpose of this study was to assess these differences. The effects of smoking, age, and gender on the distance from the CEJ to the FBC and the thickness of the BBW were further demonstrated, providing a theoretical basis for immediate implantation.

Materials and methods

Study design

In this retrospective study, 645 Cone beam CT (CBCT) images of maxillary central incisors from 645 patients were evaluated. All images were obtained at the Stomatological Hospital of Southern Medical University, between 1 Jan 2020 and 31 Mar 2020.The study was approved by the Ethics Committee of the Stomatological Hospital of Southern Medical University.

CBCT image analysis: measuring tools and methods

Patients seated in an upright position were scanned with CBCT (New Tom VGI, QR srl, Verona, Italy). The median sagittal plane of the face was perpendicular to the plane of the face, the orbital plane was parallel to the plane of the ground, the maxillary and maxillary teeth were in the intersection of the apex, the horizontal cursor overlapped with the orbital plane, and the vertical cursor overlapped with the midline of the patient's face. The scanning field was 16 cm × 7 cm, the voltage was 90 kVp, the current was 6.2 mA, the exposure time was 15 s, and the resolution was 0.2 mm.

Classification of sagittal root position

According to the literature,[8,21] the line connecting the most convex point of the incisal edge with the most convex point of the apex is defined as the longest axis of the tooth. A line was drawn passing through the most convex point of the apex and parallel to the CEJ line of the buccal side to the palatal side. The length of the line in the alveolar bone was defined as the width of the alveolar bone. The width of the alveolar bone at the apex was divided into three equal parts, defined as the buccal 1/3, middle 1/3, and palatal 1/3. The sagittal root position of the maxillary central incisor in alveolar bone can also be divided into three types: the buccal type, the middle type, and the palate type (Fig. 1).

The buccal type was further classified into three subtypes (Figs. 2 and 3): subtype I, subtype II, and subtype III.[9]

Measurements

(a) The distance from the CEJ to the FBC in the BBW.
(b) The 4 mm apical to the CEJ, the middle of the root, the apex in the BBW.

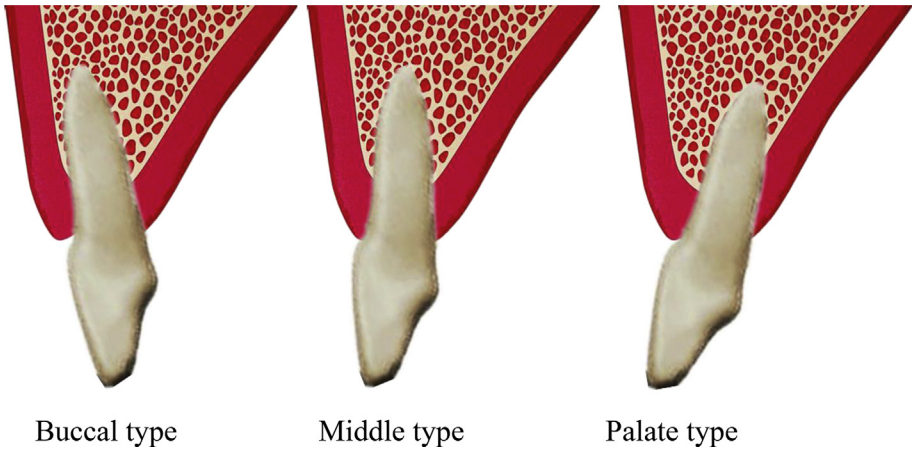

Figure 1 Schematic diagram of the general classification.

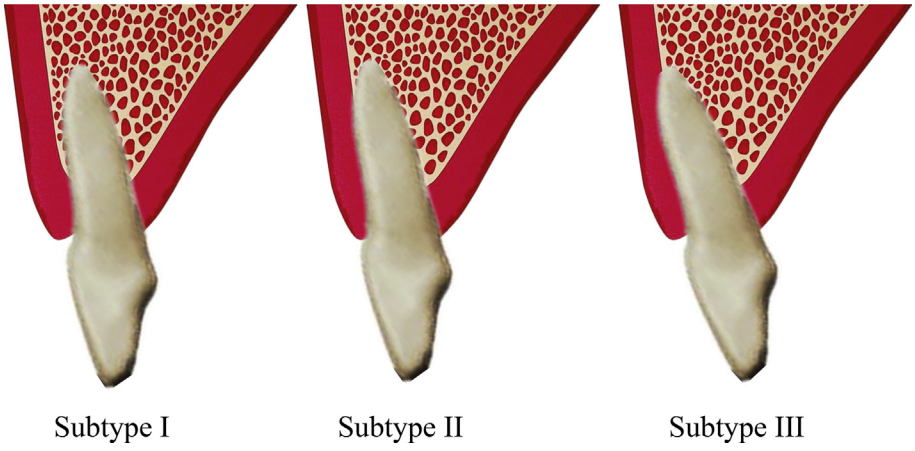

Figure 2 Schematic diagram of the subclassification.

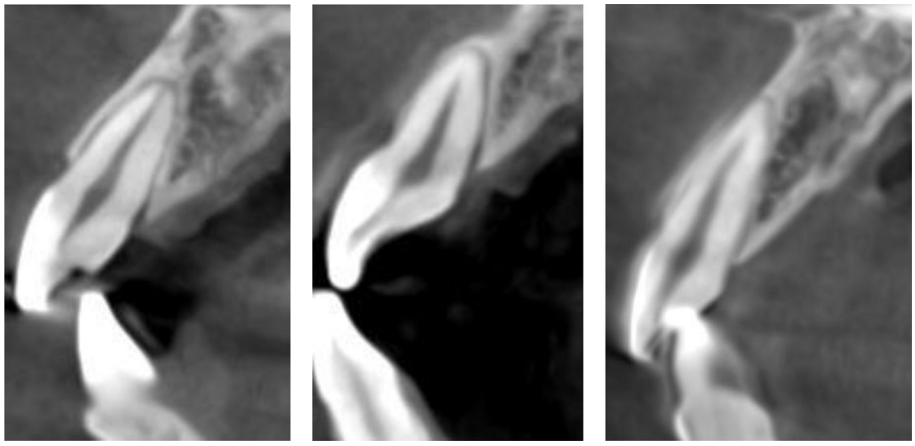

Figure 3 CBCT images showing the subtypes I, II, and III of the buccal type of the sagittal root position of the maxillary central incisors in the alveolar bone. B, buccal. In subtype I, the incisor root is covered by the BBW 4 mm apical to the CEJ, middle root, and apex, and the bone thickness increases toward the apex. In subtype II, the incisor root is covered by relatively thinner BBW in comparison with subtype I, and bone thickness does not increase noticeably toward the apex, which is covered by bone tissue in the long axis of the tooth. In subtype III, the apex is not covered by bone tissue in the long axis of the tooth, with or without BBW. BBW, buccal bone wall; CEJ, cemento-enamel junction.

Groups

1 Smoking: smokers and non-smokers
2 Gender: males and females
3 Age (years): <30, 30 to 40, 40 to 50, >50
4 Total types: buccal type, middle type, and palatal type
5 Subtypes: subtype I, subtype II, and subtype III

Statistical analysis

All statistical data were processed with SPSS 16.0 software for Windows (Chicago, IL, USA). Means and SD values were used for descriptional statistics for discrete and continuous numeric variables. Categorical variables were presented as numbers of events and percentages.

Quantitative variables were normalized by the Shapiro–Wilk test. Parametric variables were compared by means of two-tailed analysis of variance (ANOVA); if this proved significant, a post hoc Bonferroni test was performed to define differences between groups. The $p < 0.05$ level was used to determine statistical significance.

Results

General characteristics

Maxillary central incisors were measured in 645 patients (323 males and 322 females). The average age of the patients was 38.09 ± 11.78 years (males, 39.47 ± 12.80 years; females, 36.70 ± 10.51 years). The average age of male subjects was significantly higher than that of female subjects ($p = 0.03$).

Differences in smoking

The numbers of smoking and non-smoking patients were roughly the same (Fig. 4). The CEJ-FBC distance of patients who smoked (2.79 ± 0.78 mm) was significantly longer than that of non-smokers (2.54 ± 0.69 mm), with a statistically significant difference ($p < 0.05$).

Gender differences

Measurements at four sites (Fig. 5) revealed that male patients had longer CEJ-FBC distances (2.71 ± 0.77 mm) than did female patients (2.61 ± 0.72 mm), but there was no statistically significant difference ($p > 0.05$). The thickness of the males' BBW at 4 mm apical to the CEJ (0.77 ± 0.34 mm) was thinner than that of the females (0.80 ± 0.33 mm), but no statistically significant difference was found ($p > 0.05$).

Age differences

Patients were compared by age (Fig. 6). The distance between the CEJ and the FBC gradually increased with age, and there were statistically significant differences among the four age groups ($p < 0.05$). The BBW at 4 mm apical to the CEJ was thinner in the 50-year-old groups (0.68 ± 0.42 mm) than in the other groups, with a statistically significant difference ($p < 0.05$).

Differences in the general classification of the position of the tooth root in the alveolar bone

Because there were only three cases of the palatal type, it was impossible to calculate whether there was a statistically significant difference after data comparison and analysis. From the measurement results of the CEJ-FBC (Fig. 7), the distance of the buccal type was the longest (2.71 ± 0.75 mm), and that of the middle type was the shortest (2.07 ± 0.39 mm).

Differences in the subclassification of the position of the tooth root in the alveolar bone

The distances between the CEJ and the FBC in the three subtypes were approximately the same (Fig. 8), and no statistically significant difference was found ($p > 0.05$). The thickness of the BBW of subtype III (0.74 ± 0.43 mm, 0.81 ± 0.36 mm) was thinner than that of subtypes I and II

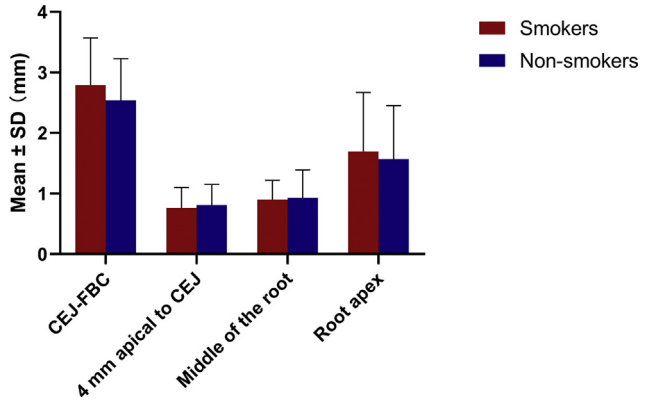

Figure 4 Measurement of patients who smoked and those who did not at four measurement sites (*$p < 0.05$). FBC, facial bone crest; CEJ, cemento-enamel junction.

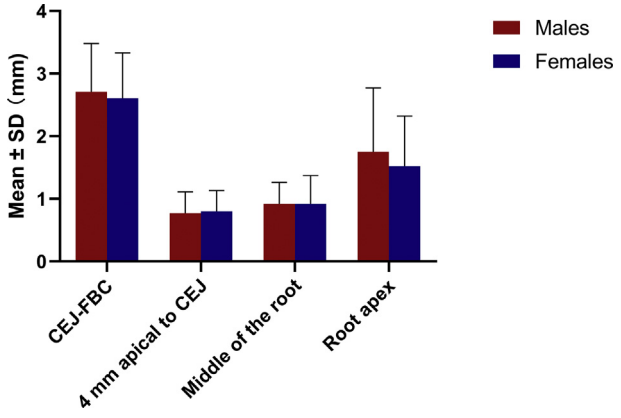

Figure 5 Measurement of male and female patients at four measurement sites. FBC, facial bone crest; CEJ, cemento-enamel junction.

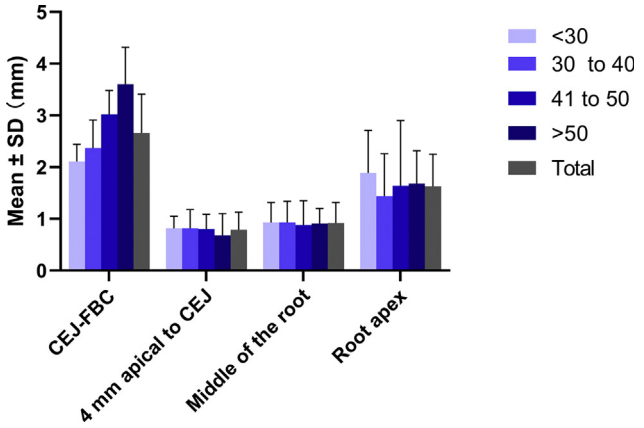

Figure 6 Measurement of different age groups at four measurement sites (*$p < 0.05$). FBC, facial bone crest; CEJ, cemento-enamel junction.

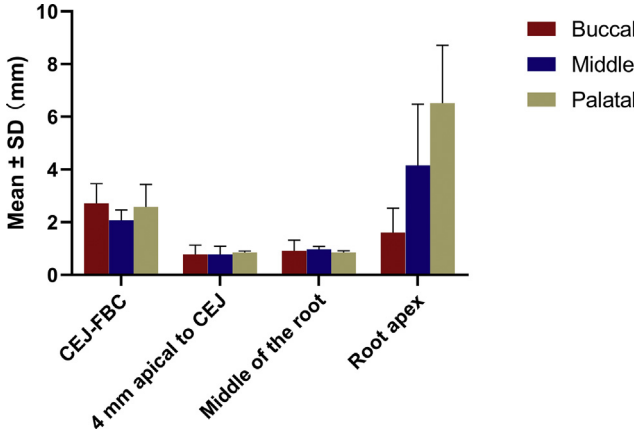

Figure 7 Measurement of total types at four measurement sites. FBC, facial bone crest; CEJ, cemento-enamel junction.

at 4 mm apical to the CEJ and in the middle of the root, with a statistically significant difference ($p < 0.05$).

Discussion

In this study, in terms of smoking (Fig. 4), the CEJ-FBC distance of patients who smoked (2.79 ± 0.78 mm) was significantly greater than that of non-smoking patients (2.54 ± 0.69 mm), with statistically significant differences ($p < 0.05$). Ghassemian et al. found that the mean values of CEJ-FBC of the maxillary central incisors in patients who smoked were 3.60 ± 1.30 mm and 3.48 ± 1.06 mm, and that those in non-smoking patients were 2.56 ± 1.05 mm and 2.37 ± 0.83 mm.[12] In the results of this study, the CEJ-FBC of non-smokers was roughly the same as that found by Ghassemian, but the CEJ-FBC of patients who smoked was small. The reason may be that Ghassemian selected a smaller number of older patients who smoked. The majority of smokers selected in this study were young and middle-aged, and the number of people selected was also large. In terms of the three measurement sites of the thickness of the BBW, the thickness of the non-smoking patients' BBW

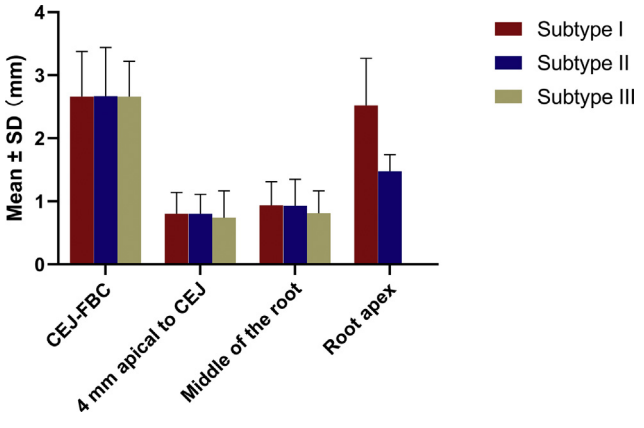

Figure 8 Measurement of subtypes at four measurement sites. FBC, facial bone crest; CEJ, cemento-enamel junction.

was slightly larger than that of the patients who smoked, but there was no statistically significant difference, which was also consistent with the research results of Ghassemian and Bergström, indicating that smoking can reduce the height of the alveolar bone but not cause the significant absorption of the BBW.[12,22]

In terms of gender differences (Fig. 5), there were no statistically significant differences between males and females at the 4 measurement sites. However, the CEJ-FBC distances in males were greater than those in females. The reason may be that, among the patients selected in this study, the majority of those who smoked were male patients, and smoking may cause a decrease in the height of alveolar bone. At three measurement sites where the thickness of the BBW was measured, there was no statistically significant difference in the thickness of the BBW in men compared with women. However, in previous studies, some scholars concluded that the thickness of the BBW in males was thicker than that in females, and there were statistically significant differences.[23] At 4 mm apical to the CEJ and at the middle of the root, the thickness of the male BBW was 0.77 ± 0.34 mm and 0.92 ± 0.34 mm, both of which were less than 1 mm, indicating that, in Chinese, the BBW was thin. Lee et al. determined that the thickness of the maxillary central incisor was 3 mm apical to the CEJ and 5 mm apical to the CEJ.[24] The thickness of the male BBW was thicker than that in females. The thickness of the BBW measured by Lee was thicker than in this study, but overall, the BBW in Asians was relatively thin, making it difficult for immediate implant surgery to be performed.

However, from the perspective of age groups (Fig. 6), the distance between the CEJ and the FBC gradually increased with age, and there was a statistically significant difference among the four age groups ($p < 0.05$). This may illustrate that alveolar bone resorption with age leads to an increased risk during implantation. This study was conducted from the CBCT image distance of the CEJ to the FBC to verify this view. At present, many scholars have demonstrated this hypothesis in terms of biological width, plaque index, and gingival thickness.[25] In this study, the shortest distance between the CEJ and the FBC was in the <30-year-old age group, where the distance was 1.49 mm shorter than in the >50-year-old age group. This was also

roughly the same as the results obtained by Ghassemian and other studies. Ghassemian measured statistics showing that the CEJ-FBC distances in patients aged >50 years were 1.04 mm−1.34 mm greater than those in patients aged <30 years. The thickness of the buccal bone wall at 4 mm apical to the CEJ was thinner in the >50-year-old age group (0.68 ± 0.42 mm) than in the other three groups, with statistically significant differences ($p < 0.05$). It has been shown that with increased age, especially after the age of 50, the height and width of the BBW would obviously be lost, and the risk during implant surgery would thereby be significantly increased. This was basically consistent with the conclusions drawn by Gakonyo et al.[23]

In the general classification, the distance between the CEJ and the FBC in the buccal type was the greatest (2.71 ± 0.75 mm), and the distance in the middle type was the shortest (2.07 ± 0.39 mm). The thickness of the apex BBW of the buccal type (1.60 ± 0.93 mm) was smaller than that of the other two types. It was shown that patients with the buccal type have lower alveolar bone height and a thinner BBW, and the risk of immediate implantation was greater than in the other two types. This was basically consistent with previous reports in the literature.[8,21]

In this study, the buccal type was further divided into 3 subtypes. After measurement and statistical analysis, the thickness of the BBW of subtype III (0.74 ± 0.43 mm, 0.81 ± 0.36 mm) was thinner than that of subclasses I and II at 4 mm apical to the CEJ and in the middle of the root, with a statistically significant difference ($p < 0.05$). Most of the long axis of teeth in subtype III was too incline to the buccal side, and the bone wall on that side was very thin. This study determined that the thickness of the BBW was 0 mm, or extremely thin, which was difficult to measure. After tooth extraction, the bone wall on the buccal side is especially atrophic and absorbed, which may easily lead to bone defects. If this type of tooth is extracted, with the implant inserted along the long axis of the tooth, bone fracture is prone to occur, which affects the initial stability of the implant and eventually leads to implant failure. Therefore, patients with subtype III have the highest implant risk. When implant surgery is planned, the palatal bone wall needs to be fully utilized, and bone grafting should be performed if necessary. At the apex, the thickness of the BBW of subtype I (2.52 ± 0.75 mm) was thicker than in subgroup II (1.48 ± 0.26 mm), with a statistically significant difference ($p < 0.05$). The results showed that the implantation conditions of subclass I were the most ideal among the three subclasses, and it was more suitable for immediate implantation.

In most Chinese people, the BBW of the maxillary central incisor is relatively thin, so the height of the alveolar crest and the thickness of the BBW should be accurately measured by CBCT before immediate implantation. Smoking, gender, age, and the position of the root in alveolar bone are all important factors that need to be considered before immediate implantation.

Declaration of Competing Interest

The authors have no conflicts of interest relevant to this article.

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Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.jds.2020.05.021.

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