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ORIGINAL ARTICLE

Correlation of anterior overbite with root position and buccal bone thickness of maxillary anterior teeth: a CBCT study

Rachana Shrestha[1,2] · Xin Liu[1,2] · Shoucheng Chen[1,2] · Zhipeng Li[1,2] · Zetao Chen[1,2] · Edmond H. N. Pow[3] · Zhuofan Chen[1,2] · Baoxin Huang[1,2]

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Abstract

Purpose To investigate the correlation of anterior overbite with the sagittal root position (SRP) and buccal bone thickness (BBT) of the maxillary anterior teeth.

Methods Cone-beam computed tomography (CBCT) data of southern Chinese patients who underwent CBCT examinations between November 2016 and December 2016 were collected. The anterior overbite was the predictor variable while the SRP and the BBT at 4 mm apical to the cementoenamel junction (CEJ-4) and midpoint of the root of the maxillary anterior teeth were set as the primary and secondary outcome variables, respectively. All measurements were done by two calibrated examiners. Correlations between variables were analyzed by the Spearman's correlation coefficient. The significance level was set at $P < 0.05$.

Results CBCT data of 146 patients (65 men and 81 women) with a mean age of 44.2 ± 13.4 years were analyzed, and of the 876 maxillary anterior teeth evaluated, 9.8% were presented with deep overbites. Most of roots of the anterior teeth (94.9%) were positioned against the buccal cortical plate, of which, in 63.8% of them the apex was not covered by bone along the long axis of the tooth. The mean BBT at CEJ-4 was 0.89 mm at the central incisor, 0.85 mm at the lateral incisor and 0.84 mm at the canine. The overbite was positively correlated with SRP Class I subtypes and the BBT at CEJ-4 ($P < 0.05$).

Conclusion Deep overbite was more frequently accompanied by bone fenestration in the anterior maxillary areas.

Keywords Occlusion · Overbite · Buccal bone thickness · Sagittal root position · CBCT · Maxillary anterior teeth

Introduction

Immediate implantation with immediate provisionalization has some advantages. For example, it prevents 3–6 months of edentulous waiting time, prevents a second surgery, reduces the patients' psychological pressure, and reduces the treatment time [10, 29]. Moreover, some studies have shown that immediate implantation with immediate provisionalization provides better esthetic outcomes [16, 20].

In a recent scenario of immediate implantation, achieving good esthetic results in esthetic areas seems to be a topic of interest due to the unpredictable outcomes associated with the implant position and soft tissue stability [7]. Therefore, several critical aspects should be taken into consideration when one is placing immediate implants, such as the determination of the SRP and the BBT [15].

It is generally considered that an intact buccal bone wall with a minimal thickness of 1 mm is a prerequisite for immediate implant success [24]. However, recent studies

Rachana Shrestha and Xin Liu contributed equally to this work and should be considered co-first authors.

Zhuofan Chen and Baoxin Huang contributed equally to this work and should be considered co-corresponding authors.

✉ Zhuofan Chen
dentistczf@163.com

✉ Baoxin Huang
dentisthbx@163.com

[1] Department of Oral Implantology, Guanghua School of Stomatology, Hospital of Stomatology, Sun Yat-Sen University, No. 56, Lingyuan west road, Guangzhou 510060, Guangdong, China

[2] Guangdong Provincial Key Laboratory of Stomatology, Guangzhou, Guangdong, China

[3] Department of Prosthodontics, Faculty of Dentistry, The University of Hong Kong, Hong Kong, Special Administrative Region, China

have shown that the BBT of anterior teeth is usually very thin (less than 1 mm) [9, 19, 21, 30]. Moreover, continuous resorption of the labial plate has been reported as an unavoidable consequence after extraction [2, 3], resulting in significant alveolar bone loss and fenestration, as well as increased risk of unsatisfactory esthetic results during immediate implant placement [4, 6]. Therefore, the presence of a thin labial plate and its pre-evaluation prior to immediate implantation should be considered.

The relationship between the BBT and the SRP in the upper anterior teeth has been studied using cone-beam computed tomography (CBCT), and it has been concluded that available labial bone varies according to the SRP [9, 19, 22]. Several methods have been introduced for classifying the SRP of maxillary anterior teeth [9, 19, 22, 27, 28].

Although previous studies have focused on the BBT and the SRP of the anterior teeth, the analysis of anterior overbite, which is also considered to be one of the important factors affecting immediate implant restoration, is still lacking. The overbite and overjet may lead to unavoidable lateral loads of the teeth in the anterior maxilla. To avoid excessive lateral loads, good anterior guidance should be considered for favorable occlusal schemes [14]. Anterior overbite plays a vital role in immediate provisionalization. However, the correlation of anterior overbite with the SRP of the tooth and the BBT has not been reported yet. Therefore, the purpose of this study is to analyze the correlation of anterior overbite with the SRP and the BBT of the tooth.

Materials and methods

Study design

This study is a cross-sectional, retrospective study. All procedures performed in studies involving human participants were in accordance with the ethical standards of the Ethical Committee of Guanghua School of Stomatology, Hospital of Stomatology, Sun Yat-sen University (ERC-[2015]-32) and with the 1964 Helsinki declaration and its later amendments or comparable ethical standards.

Study sample

CBCT data from a total of 250 randomly selected patients who visited Guanghua School of Stomatology from November 2016 to December 2016 for CBCT evaluation were accessed. The images were carefully analyzed to select useful data so as to meet the defined inclusion and exclusion criteria. A total of 146 CBCT images of 146 patients (65 males and 81 females) were included in the final analysis. The age of the patients ranged from 19 to 82 years, with a mean age of 44.2 ± 13.4 years (males, 45.4 ± 13.4 years; females, 43.3 ± 13.4 years).

Inclusion criteria

The present study included CBCT images that meet the following inclusion criteria: subjects were aged more than 18 years, both maxillary and mandibular jaws were included in the images, images had complete dentition from canine to canine, and images were obtained by the same machine.

Exclusion criteria

The exclusion criteria were images of dentitions with severe alveolar bone resorption, severe periodontitis or severe crowding; CBCT with distorted images; pathologic finding in the anterior teeth.

Data collection methods

All three-dimensional images were obtained using a CBCT system (PaX Duo3D®; Vatech, Seoul, Korea). The image data were saved to DICOM (Digital Imaging and Communications in Medicine) files and then exported to EZ3D Plus professional software (version 1.2.1.0; Vatech). This software was used to analyze the CBCT images. For each single anterior tooth, the image display was standardized to adjust the tooth vertically and transversally to the alveolar bone in the multi-planar reconstruction (MPR) view at a slice thickness of 0.5 mm and at an image zoom of 300%. Following these standardized views were saved as "Captures" separately for each tooth. From 146 CBCT images of 146 patients, altogether, 876 teeth were measured (measurement of six anterior teeth in each CBCT image).

Two examiners participated in measurements of the SRP, the BBT and the anterior overbite. The central incisor (CI), the lateral incisor (LI), and the canine (C) were measured accordingly.

Anterior overbite

The classification of anterior overbite was modified according to Geiger's classification [12]. In the sagittal view of the maxillary anterior tooth, a line was drawn through the palatal surface of the tip of the crown to the CEJ. This line was then equally divided into three parts as the incisal 1/3rd, middle 1/3rd, and cervical 1/3rd (Fig. 1). The anterior overbite was then classified by viewing the position of the opposing lower anterior tooth that lies in these three segments as Class 1, 2, or 3 (Fig. 2).

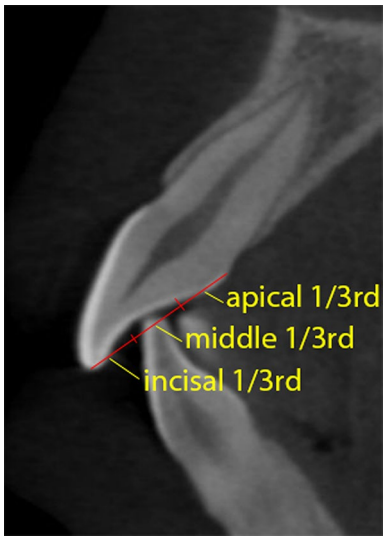

Fig. 1 Diagram showing a line drawn from the tip of the crown of palatal surface of maxillary anterior teeth to CEJ divided into three equal parts: incisal 1/3rd, middle 1/3rd, and cervical 1/3rd

SRP measurement

The SRP of the teeth was evaluated and classified as Class I, II, III, or IV according to Kan's classification [19]. Briefly, Class I, Class II, or Class III was classified according to the root against the labial bone wall, centered in the middle of the alveolar, or positioned against the palatal bone wall. When at least 2/3 of the root was engaging both the labial and palatal cortical plates, it was Class IV. The buccal type (Class I) was further classified into three subtypes as I, II, and III (Fig. 3), according to Xu's classification [28].

BBT measurement

The thickness of the BBT at 4 mm apical to the CEJ (CEJ-4) and at the midpoint of the root (MR) was measured as reported previously [5] (Fig. 4).

This retrospective analysis did not alter the management of the patients; thus, no specific consent was required. The institutional review board waived the need for consent.

Statistical analysis

Statistical analysis was performed using SPSS (software version 20.0). To rule out the intra-examiner variation, each

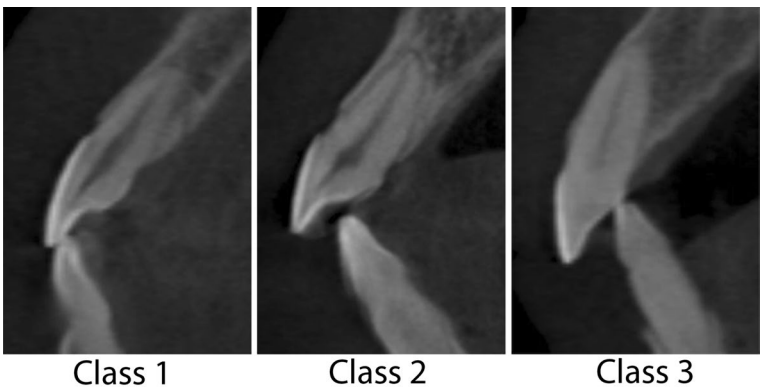

Fig. 2 Classification of anterior overbite Class 1, Class 2, and Class 3. In Class 1, lower anterior tooth that lies in incisal 1/3rd. In Class 2, lower anterior tooth that lies in middle 1/3rd. In Class 3, lower anterior tooth that lies in cervical 1/3rd

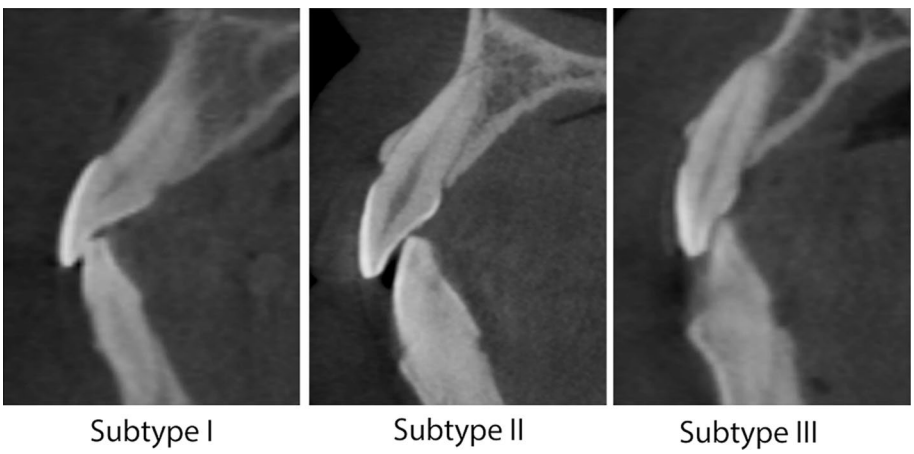

Fig. 3 SRP Class I is classified as follows: subtype I: the incisor root is covered by the labial bone wall, and the bone thickness increases toward the apex. Subtype II: the incisor root is covered by a relatively thinner labial bone wall than in subtype I, and the bone thickness does not increase noticeably toward the apex, which is covered by bone tissue in the long axis of the tooth. Subtype III: the apex is not covered by bone tissue in the long axis of the tooth

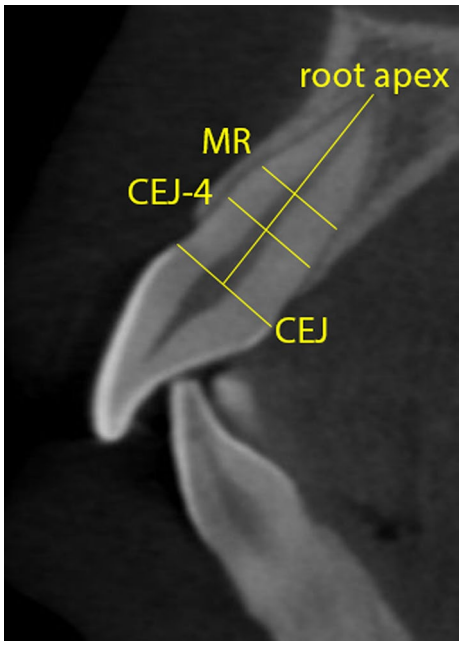

Fig. 4 Measurement of the buccal bone thickness (BBT). *CEJ* estimated position of the CEJ, *CEJ-4* 4 mm apical to the CEJ, *MR* middle of the root

investigator repeated the measurements of 30 randomly selected CBCT images twice. Another 30 CBCT images that were randomly selected were measured to determine inter-examiner variability using an inter-class correlation coefficient (ICC). The inter-observer and intra-observer reproducibility of BBT were excellent (ICC = 0.93 and 0.97, respectively). Spearman's correlation coefficient was used to find a correlation between overbite with the SRP and BBT at CEJ-4 and the MR. $P < 0.05$ was considered to be statistically significant.

Results

The frequency distribution of the overbite of the anterior teeth is shown in Table 1. The overall percentage is highest in Class 1 [Class 1 (61.4%) > Class 2 (28.8%) > Class 3 (9.8%)], which is the predominant class among the three classes.

Of the total 876 SRP images evaluated, 94.9% of the anterior teeth have SRP Class I, 2.4% have Class II, 0% has Class III, and 2.7% have Class IV (Table 2). Among the subtypes of SRP Class I, subtype III was the most prevalent (63.8%), followed by subtype II (27.1%) and subtype I (9.1%) (Table 2). This means that in 63.8% of teeth with SRP Class I, there was fenestration in the apex of the tooth.

The mean BBT at CEJ-4 was 0.89 ± 0.51 mm at the central incisor, 0.85 ± 1.12 mm at the lateral incisor and 0.84 ± 0.68 mm at the canine (Table 3). Only 43.7% and 4.0% of the anterior teeth showed a BBT at CEJ-4 of more than 1 mm and 2 mm, respectively. Similarly, the mean BBT at the MR was 0.77 ± 0.44 mm at the central incisor, 0.59 ± 0.55 mm at the lateral incisor and 0.43 ± 0.83 mm at the canine. Only 24.7% and 1.6% of the anterior teeth showed a BBT at the MR of more than 1 mm and 2 mm, respectively.

The frequency distribution of the overbite classification and SRP is shown in Table 4. The BBT (mm) according to the anterior overbite classification is presented in Table 5. Overbite is positively correlated with SRP Class I subtypes ($P < 0.05$) and BBT at CEJ-4 ($P < 0.05$) (Table 6). A deep overbite (Class 3) was more frequent with subtypes III of SRP Class I, which has a higher tendency of fenestration in the anterior maxillary teeth.

Table 1 Frequency distribution of anterior overbite classification ($n = 146$)

Anterior overbite	Central incisor		Lateral incisor		Canine		Overall	
	No	%	No	%	No	%	No	%
Class 1	157	53.8	176	60.3	205	70.2	538	61.4
Class 2	104	35.6	85	29.1	63	21.6	252	28.8
Class 3	31	10.6	31	10.6	24	8.2	86	9.8

Table 2 Frequency distribution [% (number)] of SRP classification ($n = 146$)

Tooth	Class I	Class I subtypes			Class II	Class III	Class IV
		I	II	III			
Central incisor	95.5 (279)	17.9 (50)	45.9 (128)	36.2 (101)	3.4 (10)	0	1.0 (3)
Lateral incisor	93.5 (273)	3.7 (10)	19.0 (52)	77.3 (211)	3.1 (9)	0	3.4 (10)
Canine	95.5 (279)	5.7 (16)	16.1 (45)	78.1 (218)	0.7 (2)	0	3.8 (11)
Overall	94.9 (831)	9.1 (76)	27.1 (225)	63.8 (530)	2.4 (21)	0	2.7 (24)

Table 3 Descriptive statistics for BBT (mm) and frequency distribution [% (number)] at CEJ-4 and MR ($n=146$)

Reference point	Central incisor	Lateral incisor	Canine	Overall
CEJ-4	0.89 ± 0.51	0.85 ± 1.12	0.84 ± 0.68	0.88 ± 0.81
< 0.5 mm	18.5 (54)	28.4 (83)	30.5 (89)	25.8 (226)
≥ 0.5 < 1 mm	35.6 (104)	30.5 (89)	24.3 (74)	30.6 (267)
≥ 1 < 2 mm	43.2 (126)	36.3 (107)	39.4 (115)	39.7 (348)
≥ 2 mm	2.7 (8)	4.5 (13)	4.8 (14)	4.0 (35)
MR	0.77 ± 0.44	0.59 ± 0.55	0.43 ± 0.83	0.61 ± 0.64
< 0.5 mm	22.9 (67)	47.9 (140)	59.6 (174)	43.5 (381)
≥ 0.5 < 1 mm	42.5 (124)	28.4 (83)	24.7 (72)	31.8 (279)
≥ 1 < 2 mm	33.9 (99)	20.5 (60)	14.7 (43)	23.1 (202)
≥ 2 mm	0.7 (2)	3.1 (9)	1.0 (3)	1.6 (14)

Discussion

The present study was aimed at analyzing the correlation of anterior overbite with SRP and the BBT of the tooth. The results of this study showed that anterior overbite is positively correlated with SRP Class I subtypes ($P<0.05$) and BBT at CEJ-4 ($P<0.05$), which indicates that the deep overbite (Class 3) was more frequently accompanied by bone fenestration (SRP Class I subtype III) in the anterior region.

Several considerations should be made when one is planning for immediate implantation with immediate provisionalization. As for the alveolar socket bone, intact socket walls with at least 1 mm in thickness should be satisfied for predictable esthetic outcomes [24]. It was demonstrated that thin facial bone wall thickness (≤ 1 mm) displayed the pronounced vertical bone resorption of the midfacial bone wall, with a median bone loss of 7.5 mm, 8 weeks after the extraction of a maxillary anterior tooth [8]. Therefore, a precise preoperative evaluation of the facial bone wall is crucial for a satisfactory esthetic result.

The results from the present study showed that the mean BBT was lower than 1.0 mm for all of the teeth (0.89 mm, 0.85 mm and 0.84 mm at the central incisor, the lateral incisor, and the canine, respectively) at CEJ-4, and it decreased apically (at MR point). Our results are in agreement with several previous studies. Januario et al. [17] measured the BBT of 250 subjects at distances of 1, 3, and 5 mm from the bone crest. The mean overall wall thickness varied within 0.5–0.7 mm. Likewise, in the study of Wang et al. [27] involving 300 participants, the BBT was measured via CBCT at distances of 4 mm apical to the CEJ and the MR. The mean bone thickness was 0.8 mm for the central incisors and 0.7 mm for the lateral incisors and the canines. A recent study that Gluckman et al. [13] conducted also reported that

Table 5 Descriptive statistics for BBT (mm) according to anterior overbite classification

Anterior overbite	Tooth	CEJ-4	MR
Class 1	Central incisor	0.89 ± 0.51	0.80 ± 0.42
	Lateral incisor	0.94 ± 1.33	0.63 ± 0.59
	Canine	0.78 ± 0.63	0.48 ± 0.93
	Overall	0.82 ± 0.59	0.60 ± 0.52
Class 2	Central incisor	0.88 ± 0.52	0.73 ± 0.47
	Lateral incisor	0.82 ± 0.68	0.55 ± 0.48
	Canine	1.00 ± 0.79	0.43 ± 0.54
	Overall	0.89 ± 0.64	0.59 ± 0.50
Class 3	Central incisor	0.94 ± 0.55	0.74 ± 0.43
	Lateral incisor	1.04 ± 0.67	0.52 ± 0.53
	Canine	0.92 ± 0.71	0.42 ± 0.48
	Overall	0.96 ± 0.63	0.56 ± 0.49

Table 4 Frequency distribution [% (number)] of anterior overbite classification and SRP ($n=146$)

Anterior overbite	Tooth	SRP I	SRP I subtypes			SRP II	SRP III	SRP IV	Overall
			I	II	III				
Class 1	CI	94.3 (148)	20.9 (31)	48.6 (72)	30.4 (45)	5.1 (8)	0	0.6 (1)	53.8 (157)
	LI	94.3 (166)	3.6 (6)	23.5 (39)	72.9 (121)	3.4 (6)	0	2.3 (4)	60.3 (176)
	C	95.1 (195)	6.7 (13)	20.5 (40)	72.8 (142)	1.0 (2)	0	3.9 (8)	70.2 (205)
Class 2	CI	98.1 (102)	10.8 (11)	50.0 (51)	39.2 (40)	0	0	1.9 (2)	35.6 (104)
	LI	94.1 (80)	5.0 (4)	12.5 (10)	82.5 (66)	2.4 (2)	0	3.5 (3)	29.1 (85)
	C	98.4 (62)	4.8 (3)	8.1 (5)	87.1 (54)	0	0	1.6 (1)	21.6 (63)
Class 3	CI	93.5 (29)	27.6 (8)	17.2 (5)	55.2 (16)	6.5 (2)	0	0	10.6 (31)
	LI	87.1 (27)	0	11.1 (3)	88.9 (24)	3.2 (1)	0	9.7 (3)	10.6 (31)
	C	91.7 (22)	0	0	100 (22)	0	0	8.3 (2)	8.2 (24)
Overall		94.9 (831)	9.1 (76)	27.1 (225)	63.8 (530)	2.4 (21)	0	2.7 (24)	100 (876)

CI central incisor, *LI* lateral incisor, *C* canine

Table 6 Correlations between anterior overbite with SRP and BBT at CEJ-4 and MR ($n = 146$)

	SRP		SRP I subtypes		BBT (CEJ-4)		BBT (MR)	
	Correlation coefficient	*P*	Correlation coefficient	*P*	Correlation coefficient	*P*	Correlation coefficient	*P*
Anterior overbite	0.003	0.931	0.094*	0.007	0.078*	0.021	− 0.006	0.859

*Spearman's coefficient was used. $P < 0.05$

the majority of maxillary anterior teeth had thin facial bone at the crest (83%) and at the MR point (92%). In other words, BBT is inadequate for immediate implant placement in the esthetic zone in most cases.

The SRP was also reported in the present study. Previous studies have shown the prevalence of Class I type SRP ranging from 78.8 to 95.4% [9, 18, 19, 22, 28], which is similar to our finding of 94.9%. These results suggest that Class I type is the most frequent type of SRP. Patients with the buccal-type root position have relatively thick palatal bone wall. It can be utilized during implant site preparation so as to preserve the labial bone wall and provide implant primary stability in immediate implant placement. For knowing that whether apex is covered by bone tissue in the long axis of the tooth or not, the SRP Class I was further classified into three sub-types such as subtypes I, II and III according to Xu's classification [28]. The percentage of Class I subtype II and III for central incisor in our study was 45.9%, and 36.2%, respectively. The lateral incisor and the canine have predominantly the SRP Class I subtype III. In the SRP Class I subtype III, the long axis of the tooth is steeped towards the buccal wall, resulting in an extremely thin labial bone wall or fenestration. It was partly in accordance with the finding by Lin et al. [23], who reported that canines have a high incidence of fenestration. Our finding suggests that CBCT is often necessary to recognize the need to perform guide bone regeneration when an immediate implant without a flap elevation in the lateral incisor and the canine is being planned.

Although occlusion is one of the key factors for decision-making and planning for immediate implant placement with immediate provisionalization, scarce information exists in the current literature on the classifications of the anterior overbite [1, 12, 25]. The results from the present study revealed that 9.8% of the maxillary anterior teeth in the sample were deep overbites (Class 3). Data from the present study concurred with a previous study by Geiger et al. [12], who determined the overbite relationship of the area of contact of the incisal edge of the mandibular incisor with the lingual surface of the maxillary incisor. They reported that the point of contact was apical to the crest of the cingulum in 15.5% of patients.

The effects of anterior overbite on the SRP of the maxillary teeth in the anterior section were evaluated in the current study. The results from present study showed that overbite was positively correlated with SRP Class I subtypes ($P < 0.05$). In a maxillary anterior tooth with a deep overbite (Class 3), subtype III of SRP Class I was the most prevalent. It means that an anterior tooth with deep overbite (Class 3) was much more easily associated with the fenestration of the labial bone than an anterior tooth with a light overbite when immediate implant placement was performed. Recently, Farahamnd et al. [11] reported that the frequency of fenestrations and the dehiscence of the facial bone in the anterior maxillary region was considered to be related to the class of occlusion. Patients with Class II malocclusion showed a higher prevalence of fenestrations while patients with Class III malocclusion had a greater prevalence of dehiscence. However, it is difficult to compare the finding of Farahamnd et al. with the result of the present study due to the fact that the classification of occlusion was different. To the best of the authors' knowledge, this is the first study to report a relationship between anterior overbite and SRP of the maxillary anterior teeth.

The relation between overbite and BBT of the maxillary teeth in the anterior section was also examined in this study. Overbite was positively correlated with the BBT at CEJ-4 ($P < 0.05$). This means that an anterior tooth with a deep overbite (Class 3) may have much thicker bone thickness at CEJ-4. Although thick BBT at CEJ-4 in a tooth with a deep overbite is beneficial for immediate implant placement, it may mislead the clinician, who might ignore the high prevalence of fenestrations at the root position. A recent study by Lin et al. [23] also showed that a thicker facial bone thickness would result in a more apical position fenestration in maxillary anterior areas. With this in mind, and based on the fact that a tooth with a deep overbite is more vulnerable to excessive lateral loads, we propose that a tooth with a deep overbite (Class 3) should be treated with caution during immediate implant placement with immediate provisionalization. CBCT analyses of BBT and SRP are recommended to dental implant treatment approach in this area. In addition, the result of present study could be further broadened to other clinical applications such as planning of orthodontic treatment and assessment for maxillomandibular osteotomies.

Recent literature has shown that CBCT has relatively lower positive predictive values in thin bone [26]. This may be seen as a limitation of this study. However, CBCT is a common tool used for pre-surgery assessment, although

some of the inherited problems are unavoidable. Second, the clinical information of patients' general condition was unknown in the present study. Another limitation was the lack of clinical documentation to support the current findings. Therefore, further research is necessary to verify the present results.

Conclusions

Within the limitations of our study, the following conclusions can be drawn. The majority of the maxillary anterior teeth were positioned in close proximity to the buccal plate, which is very thin. Hence, a deep overbite (Class 3) was more frequent accompanied by bone fenestration in the maxillary anterior areas.

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Author contributions RS: data collection and data analysis, and manuscript writing; XL: data collection and data analysis and literature research; SC: data collection and data analysis; ZL: literature research and manuscript editing; ZTC: literature research and manuscript editing; EHNP: manuscript editing; ZFC: project development, data collection and data analysis, manuscript writing, and editing; BH: project development, data collection and data analysis, manuscript writing, and editing.

Compliance with ethical standards

Conflict of interest The authors declare that they have no conflict of interest.

Ethical standards All procedures performed in studies involving human participants were in accordance with the ethical standards of the Ethical Committee of Guanghua School of Stomatology, Hospital of Stomatology, Sun Yat-sen University (ERC-[2015]-32) and with the 1964 Helsinki declaration and its later amendments or comparable ethical standards.

Informed consent This study was retrospective, and it did not alter the management of the patients; thus, no specific consent was required.

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