Classification of Sagittal Root Position and Angulation of Premolars for Immediate Implant Placement: A Cone Beam Computed Tomography Study

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Research article

Keywords: sagittal root position, angulation, buccal plate thickness, premolar, immediate implant placement

Posted Date: August 1st, 2020

DOI: <https://doi.org/10.21203/rs.3.rs-45863/v1>

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Abstract

Background: Sagittal root position (SRP) and thickness of buccal plate were of clinical guiding significance in implant treatment planning. The study was to classify the SRP and angulations of the maxillary and mandibular premolar to each osseous housing, and to measure the thickness of buccal plate by cone beam computed tomography (CBCT) in order to estimate the distributions and provide clinical decision support.

Methods: CBCT images was reviewed on 150 patients who fulfilled the inclusion criteria. The sagittal root position and angulations of the maxillary and mandibular premolars to their respective osseous housing were evaluated and classified using CBCT images. The thickness of buccal plate at 1 mm, 3 mm, 5 mm apical to the alveolar crest was also measured.

Results: The frequency distribution of SRP types indicated that, 41.67%, 51.83%, 3.67%, and 2.83% of maxillary premolars; 84.33%, 15%, 0%, and 0.67% of mandibular premolars were classified as type B, M, L, and N. The frequency distribution of angulation classifications indicated that, 20.83%, 46%, 32.17%, and 1% of maxillary premolars; 2%, 5.33%, 36.67%, and 56% of mandibular premolars were classified as class 1, 2, 3, and 4. The buccal bone thickness in most locations of premolar sites was less than 1 mm.

Conclusions: The classification of clinical relevance of SRP and angulation of the premolar root to osseous housing would help for treatment planning and improving interdisciplinary communication of immediate implant placement (IIP) in the premolar region.

Background

Previous studies have verified that the replacement of hopeless tooth by immediate implant placement (IIP) is a predictable procedure [1]. To ensure successful IIP, in addition to the absence of active infection and the presence of intact bony socket, the achievement of primary implant stability and the buccal plate thickness should be considered [2]. Sagittal root position (SRP) in related to osseous housing is also crucial in determining the feasibility of IIP and can be estimated by cone beam computed tomography (CBCT) [3].

It has been well known that after tooth extraction, significant alterations will occur. Not only the horizontal dimension (about 50%) but also the vertical buccal bone height will decrease following extraction [4, 5]. Previous evidence has verified that the alveolar ridge contraction could not be completely counteracted by IIP [6–10]. Therefore, the esthetic compromise that manifested in mid-buccal and interdental recession, loss of buccal contours remains one of the biggest challenges of IIP [11]. The successful IIP depends on several factors, including 3-D implant position, tissue dimension and morphology, and primary stability [2]. Proper preoperative assessment can avoid negatively influence of implant osseointegration and esthetic appearance in a certain degree.

Previous studies have classified the SRP of maxillary anterior teeth and measured the buccal plate thickness to aid in treatment planning for IIP [3, 12–20]. According to these studies, the root of maxillary central incisors is mainly located in buccal, furthermore the buccal plate thickness is thin. At present, the broader esthetic zone is consisted of premolar. To date, there are no data available in the premolar region for the root position and angulation to the alveolar bony housing.

Thus, the purpose of this study was to classify the relationship of SRP and angulation to respective osseous housing and to evaluate the buccal plate thickness of premolars using CBCT, in order to understand the distributions of these anatomic variables and discuss clinical implication.

Methods

The protocol was reviewed and approved by the ethics committee of Peking University School and Hospital of Stomatology (PKUSSIRB-202054033). This study was conducted in accordance with the Declaration of Helsinki. All subjects involved had provided their informed consent prior to inclusion in this study.

Subject Selection

CBCT scans taken by the Oral Radiology Clinic at First Clinical Division of the Peking University School and Hospital of Stomatology between January 2016 and November 2019 were reviewed. 69 male and 81 female subjects between the ages of 18 and 44 years were included according to following criteria: at least 18 years of age at the time of CBCT scan; all maxillary and mandibular premolar teeth were present; with two occluding molars in each quadrant. The exclusion criteria include: history of periodontitis, orthodontic therapy, and periodontal surgery; radiographic evidence of infection; history of trauma to maxillary and mandibular premolar dentition; obvious anatomic abnormalities including buccal ledging and exostoses; severe crowding; severe root resorption. The presence of existing implants or restorations with excessive scatter were also excluded.

CBCT scans were taken using the cs9300 (60-90kv, 2-15ma) (Carestream Health, NY, USA). Each scan was evaluated in X, Y, and Z planes at a 0.09 mm slice interval.

Data Collection

For each subject, CBCT was processed to ensure the best geometric presentation for measurement with high accuracy. In the axial plane, the arch form selector tool was centered through the middle of arch. In the sagittal plane, the volume was oriented to enable visualization of the entire root. The individual reference line of each tooth was created to generate the ideal coronal slice at the mid-root level apicocoronally.

The SRP and angulation of root to osseous housing were evaluated in the cross-sectional image, which made at the midpoint of each tooth parallel to each long axis. A classification system was used and recorded during image assessment.

The thickness of buccal plate was evaluated at three locations perpendicularly to PDL space of each tooth: 1 mm (Measure I), 3 mm (Measure II), and 5 mm (Measure III) apical to the alveolar crest (Fig. 1). In the case of dehiscence (DEH) defect, a line was drawn from the most coronal level of the palatal/lingual plate perpendicular to its long axis and defined as the presumptive zero point for buccal plate measurement. The location with detectable DEH and fenestration (FEN) defects of buccal plate was record. The apical bone height of maxillary premolar was also measured along the root long axis from root apex toward superior bone surface.

The classification and measurement were accomplished by a single calibrated examiner (ZYL). Intra-examiner reliability was determined by repeating 10% of these classifications and measurements. 10% of these measurements and classifications were independently repeated by a second examiner (WMZ) to assess the inter-examiner reliability.

SRP and Angulation Classification

The root position and angulation were classified with reference to the osseous housing. The relationship of SRP to respective osseous housing was categorized as follows (Fig. 2): type B (closer to the buccal cortical plate); type M (in the middle of alveolar housing without engaging either the buccal or palatal/lingual cortical plate); type L (closer to the palatal/lingual cortical plate); and type N (At least two thirds of the root is engaging both the buccal and palatal/lingual cortical plate). The angulation of root long axis to the alveolar process was classified as follows (Fig. 2): class 1 (the root axis angulated toward buccal side with the long axis passing anterior to point A); class 2 (the root axis angulated toward buccal side with the long axis passing posterior to point A); class 3 (the root axis angulated parallel to the alveolus); and class 4 (the root axis angulated toward palatal/lingual side).

Statistical analysis

The maxillary and mandibular premolars were analyzed separately. Statistical analysis was performed by SPSS (Chicago, IL, USA). The frequency of classification and the thickness of buccal plate were reported by descriptive statistics. The comparisons of buccal plate thickness among three measure locations in each tooth and in different teeth were made. The thickness of buccal plate was approximately lognormal distribution and therefore measures were log-transformed for repeated measures ANOVAs followed by Bonferroni correction for post hoc multiple comparisons.

Results

The reliability test was done to estimate the accuracy of classifications and measurements between intra- and inter-examiners. In 55% of repeated measurement between intra-examiner, the differences were < 0.1 mm, and 96% were < 0.2 mm. In 45% of repeat measurements between inter-examiner, the differences were < 0.1 mm, and 90% were < 0.2 mm. All repeated classifications were consistent.

The Frequency Distribution of SRP Types and Angulation Classifications

The frequency distribution was categorized according to SRP (type B, M, L, and N) (Fig. 3). The maxillary first premolars presented with 63.67%, 31%, 0%, and 5.33%, respectively, of type B, M, L, and N. The maxillary second premolars presented with 19.67%, 72.67%, 7.33%, and 0.33%, respectively. The mandibular first premolars presented with 90.67%, 8%, 0%, and 1.33%, respectively. The mandibular second premolars presented with 78%, 22%, 0%, and 0%, respectively.

The frequency distribution of angulations (class 1, 2, 3, and 4) showed that in the maxillary first premolars, 35%, 46.67%, 18.33%, and 0% were class 1, 2, 3, and 4 respectively. 6.67%, 45.33%, 46%, and 2% of maxillary second premolars were class 1, 2, 3, and 4 respectively. The frequency of class 1, 2, 3, and 4 was 1.67%, 5.33%, 33.33%, and 59.67% in the mandibular first premolars; 2.33%, 5.33%, 40%, and 52.34% in the mandibular second premolars, respectively (Fig. 4).

The analyses that combined both the SRP type and angulation classification showed as follows (Fig. 5): In the maxillary first premolars, the incidence of type B1 (22.67%) was only slightly less than that of type B2 (36%), followed by type M3 (12.33%), type M2 (9.67%), type M1 (9%), type B3 (5%), type N1 (3%), type N2 (1.67%), and type N3 (0.66%). No type B4, M4, L1, L2, L3, L4, or N4 was found in the maxillary first premolars of our subject series. In the maxillary second premolars, the incidence of type M3 was 40.67% followed by type M2 (27%), type B2 (15%), type M1 (3.67%), type L2 (3.33%), type L3 (3%), type B1 (2.67%), type B3 (2%), type M4 (1.33%), type L4 (0.67%), type L1 (0.33%), and type N3 (0.33%). No type B4, N4, N1, or N2 was found in the maxillary second premolars. In the mandibular first premolars, the incidence of type B4 was 57% followed by type B3 (27%), type M3 (5.67%), type B2 (5.34%), type M4 (2.33%), type B1 (1.33%), type N3 (0.67%), type N4 (0.33%), and type N1 (0.33%). No type M1, M2, L1, L2, L3, L4, or N2 was found in the mandibular first premolars. In the mandibular second premolars, the incidence of type B3 (29%) was less than that of type B4 (42.34%), followed by type M3 (11%), type M4 (10%), type B2 (4.33%), type B1 (2.33%), and type M2 (1%). No type M1, L1, L2, L3, L4, N1, N2, N3, or N4 was found in the mandibular second premolars.

The Thickness of Buccal Plate

The buccal plate thickness at different locations was presented as median (P25, P75) in Fig. 6. In the maxillary first premolars, the buccal plate thickness at the 1 mm, 3 mm, and 5 mm apical to the alveolar crest (measurement I, II, III) were 0.90 (0.60, 1.20) mm, 0.70 (0.40, 1.20) mm, and 0.50 (0.20, 1.00) mm. The thickness at the measurement I, II, III level was 1.60 (1.00, 2.30) mm, 1.70 (1.10, 2.50) mm, and 1.60 (0.90, 2.40) mm in maxillary second premolars; 0.30 (0.10, 0.60) mm, 0.30 (0.10, 0.60) mm, and 0.50 (0.20, 0.80) mm in mandibular first premolars; 0.70 (0.50, 0.90) mm, 0.80 (0.50, 1.18) mm, and 1.10 (0.70, 1.70) mm in mandibular second premolars, respectively.

The frequency distribution of sites with various thickness of buccal plate showed in Fig. 7. The buccal plate thickness at the 1 mm apical to the alveolar crest level was less than 1 mm in 55%, 21%, 95%, and 75.33% of the maxillary first, second premolars, and the mandibular first, second premolars, respectively. Only 8%, 0.33%, and 2.33% displayed a width of 2 mm or more of the buccal plate, in the maxillary first, mandibular first and second premolars, respectively (Fig. 7).

In the maxillary first premolars, there was a significant decrease in thickness of buccal plate from coronal to apical along the root ($P < 0.05$, Fig. 6). Conversely, the mandible demonstrated significant increase in thickness from coronal to apical ($P < 0.05$, Fig. 6). In either maxilla or mandible at all measurement points, the first premolars were significantly thinner than the second premolars ($P < 0.001$, Fig. 6). In the second premolars, the mandible was significantly thinner than the maxilla ($P < 0.001$, Fig. 6). Thus, the position was a significant determinant in the thickness of buccal plate, with both arches demonstrating an increase in thickness from first premolar to second premolar ($P < 0.001$, Fig. 6).

Regarding the apical bone height, 33.33% of the maxillary first premolars and 36% of the maxillary second premolars had less than 4 mm of bone height (Fig. 8). In addition, 12.67% and 41.67% showed the root apex close to the sinus floor in the maxillary first and second premolars (Fig. 8). The incidence of DEH was 1%, 0%, 23%, and 3.33%, and the incidence of FEN was 23%, 4%, 7.67%, and 2% of the maxillary first and second premolars, mandibular first and second premolars, respectively (Fig. 9). No double-root was found in the mandibular premolars of our subject series. The incidence of double-root was 19.33% in maxillary first premolars, and was 2% in maxillary second premolars. The double-root located in buccal and palatal respectively.

Discussion

This study analyzed the CBCT data to aid decision making in implant replacement of premolars. CBCT imaging has become routine used technique for diagnosis and implant planning, due to the advantages of accuracy, relatively low radiation dosage, and convenience [21–24].

In previous study, the root position was only evaluated in the maxillary anterior teeth [3, 12, 13]. In this study, SRP and angulation of premolars in relation to their osseous housing were evaluated and classified. Both the SRP and angulation were categorized in the present study for giving recommendations according to their difficulty for achieving ideal results in IIP. The clinical implications of each classification were discussed.

In the type B SRP, in which the root was closer to or contact with the buccal cortical plate, a certain amount of bone was usually present on the palatal/lingual aspect for implant placement to attain primary stability during IIP. The implant should be placed palatal/lingual to avoid drilling or compressing buccal plate, minimizing the chance of thinning, fenestration, or perforation of buccal bone. In general, the palatal implant engagement leaves the buccal bone intact and results in a gap between implant and buccal bone [25]. The implant-socket gap is usually filled with bone grafting materials [26]. In this study, 63.67% of the maxillary first premolars, 90.67% of the mandibular first premolars, and 78% of the

mandibular second premolars had type B SRP. This suggested that majority of the maxillary first premolars, mandibular first premolars, and mandibular second premolars in this study was favorable for IIP according to guidelines that have been established in the literature [27–29]. Most of the mandibular premolars were type B4, which the long axis of the root apex was angulated lingual, enough bone should be present at the lingual and apical aspect in order to obtain appropriate implant stability.

The frequency of type L SRP in this study was only in maxillary second premolars (7.33%), showing the rarity of this root position. In the type L4 SRP (0.67%), the most length of the root engages the palatal cortical plate; therefore, the stability that achieving depended on the implant engagement in the available bone on palatal aspect is impossible. The implant position need to be compromised, which a bone-driven protocol is taken for achieving good primary stability. Thus, there is a higher tendency for buccal bone resorption as a result of peri-implant bone remodeling, and potentially leading to fenestration/perforation when buccal implant engagement in thin buccal bone (more than half of the cases less than 2 mm) is attempted [30].

In the type M SRP, the root was centered at the middle of alveolar housing. Generally, the volume of bone available surrounding the extraction socket on both the palatal and buccal aspects was less than what is encountered in type B or type L SRPs, respectively. Therefore, when a clinician is considering IIP procedures in a site with type M SRP, the amount of available bone beyond the apex of extraction socket must be critically evaluated, particularly in type M3, M4 (nearly half the maxillary second premolar), as the stability of the implant relies primarily on it. Nevertheless, the apical bone height in 36% maxillary second premolars was less than 4 mm. IIP combined with maxillary sinus floor elevation was need in part of these cases [31]. In addition, the apex of root in 41.67% maxillary second premolars were close to the sinus floor. This suggests that majority of the maxillary second premolars in the present study was unfavorable for IIP. Delayed implant placement was recommended in these cases.

In the type N SRP, which comprised 5.33% of maxillary first premolars, 0.33% of maxillary second premolars, and 1.33% of mandibular first premolars, the tooth root occupied the majority of the alveolar volume. Following extraction, there is a limited amount of bone with which appropriate implant stability can be obtained [32]. Therefore, a type N SRP is considered to be the contraindication for IIP. The minimal buccal plate thickness required to avoid vertical alveolar bone resorption after tooth extraction has been explored. The critical buccal plate thickness to reduce the loss of buccal bone was around 2 mm [33–35]. In majority of maxilla first premolars and mandibular premolars, the thickness of buccal plate was less than 2 mm. Significantly alterations of alveolar bone dimension would occur in these sites. So as to increase the predictability of implant treatment, bone grafting procedures would be necessary at the corresponding period of tooth extraction, prior to or at the corresponding period of implant placement in this type [36–39]. As such, the long-term tissue stability would be more predictable. These results emphasized the importance of CBCT during diagnosis and treatment planning for IIP.

As previously mentioned, the major disadvantage of IIP is lack of the predictability of long-term tissue profile, especially on buccal aspect [25, 40]. Irrespective of IIP, it has been clearly established that bone

resorption after extraction will still take place, resulting in dimensional changes of the alveolar ridge [6–9], which more obvious in the buccal bone [41]. In this respect, the buccal plate thickness gains significance. Except for the position of implant placement, the thickness of buccal plate is worthwhile information. In general, a minimal width of 2 mm of buccal plate is a prerequisite to maintain the vertical dimension of alveolar crest [33–35]. While the evaluation of the buccal bone thickness was lack in premolars.

The result of this study demonstrated that significant effect of buccal plate thickness in premolars. The buccal plate thickness increased from first premolar to second premolar. This trend was found both in the maxilla and mandible. Anatomically, the buccal plate behaved differently in the upper and lower jaws. The maxillary premolars tend to decrease in thickness coronal-apically. Whereas, the mandibular premolars tend to increase in thickness coronal-apically.

In most maxillary first premolars and mandibular premolars examined, the thickness of buccal plate at 1 mm apical to alveolar crest was ≤ 1 mm. This finding was in agreement with previous published data of maxillary posterior sites [14]. The data of this study suggested that the buccal plate thickness of premolars was thin on average. Only a minority of premolars have a buccal bone plate width of 2 mm or more. Thus, if the criterion of minimal width to maintain stable buccal bony plate is 2 mm, only a limited number of premolars represent such a clinical situation. In turn, this mean that in most cases, when IIP is considered, placing the implant palatal may be needed to achieve at least 2 mm gap between internal buccal socket wall and implant shoulder, which should be filled with graft materials, so as to maintain the alveolar bone around the implant [42–44]. In addition, it is important not to cut buccal plate during osteotomy, especially for type B, due to the buccal plate is expected to be thinner than other types. Or else, the risk of thinning down the already thin buccal bone or perforation will be high.

The general recommendation in the apical dimension for the IIP is to engage the implant 3 to 5 mm beyond the socket apex to achieve good primary stability [45]. 46% of the maxillary first premolars and 77.67% of the maxillary second premolars had less than 4 mm of bone height. In addition, 12.67% and 41.67% showed the apex of root close to the sinus floor in maxillary first and second premolars. The result of this study showed inadequate apical bone in most cases that might be have influence on primary stability of implant.

Conclusions

As the concept of IIP has become more widely accepted, the SRP and angulation in relation to osseous housing, and the buccal plate thickness are vital adjunct to treatment planning of IIP. Furthermore, both the SRP types and the angulation classifications of premolars were categorized in this study based on the data of Chinese population, in order to give general recommendations and caution for IIP in premolar region in Asian populations.

Declarations

Ethics approval and consent to participate

The protocol was reviewed and approved by the ethics committee of Peking University School and Hospital of Stomatology (PKUSSIRB-202054033). This study was conducted in accordance with the Declaration of Helsinki.

Consent for publication

All subjects involved had provided their informed consent prior to inclusion in this study.

Availability of data and materials

The datasets used in current study are available from the corresponding author on reasonable request.

Competing interests

The authors declare that they have no competing interests.

Funding

This study was supported by research funds from the National Natural Science Foundation of China (NSFC): 81800976.

Authors' contributions

ZY, WM, and LF were responsible for conceptualization. CX was responsible for data collection. ZY and WM measured and analyzed data. ZY and LF wrote the original draft. WM and CX were involved in the critical review of the manuscript. All authors read and approved the final manuscript.

Acknowledgements

The authors thank the faculty of the Oral Radiology Clinic for help with the execution of this project.

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Figures

Figure 1

The thickness of the buccal plate at three locations for each tooth: 1 mm (Measure I), 3 mm (Measure II), and 5 mm (Measure III) apical to the alveolar crest.

Figure 2

Classification according to root position and angulation. The relationship of each SRP to respective osseous housing was categorized as the type B, M, L, and N; and the angulation was classified as the class 1, 2, 3, and 4 in the (a) maxilla and (b) mandible. Solid line: root axis; dashed line: center line of the alveolar process.

Figure 3

Frequency distribution of SRP types in the (a) maxillary first premolar, (b) maxillary second premolar, (c) mandibular first premolar, (d) mandibular second premolar. 1st: first; 2nd: second.

Figure 4

Frequency distribution of angulation classifications in the (a) maxillary first premolar, (b) maxillary second premolar, (c) mandibular first premolar, (d) mandibular second premolar. 1st: first; 2nd: second.

Figure 5

Frequency distribution of combine the SRP types with the angulation classifications in the (a) maxillary first premolar, (b) maxillary second premolar, (c) mandibular first premolar, (d) mandibular second premolar. 1st: first; 2nd: second.

Figure 6

Buccal plate thickness of the (a) maxillary and (b) mandibular premolars at three locations for each tooth: 1 mm, 3 mm, and 5 mm apical to the alveolar crest. Data were presented as median (P25, P75). Data were log-transformed for repeated measures ANOVAs. Overall p-values of the comparisons among different locations of maxillary 1st premolar, mandibular 1st premolar and mandibular 2nd premolar were <.001; *p <.05 after Bonferroni correction in post hoc testing. Overall p-values of the comparisons between different teeth at each location were <.001; #p <.001 after Bonferroni correction in post hoc testing. 1st: first; 2nd: second.

Figure 7

Frequency distribution of the buccal bone thickness at (a) 1, (b) 3, (c) 5mm apical to the bone crest.

Figure 8

Frequency distribution of the apical bone height of maxillary premolars.

Figure 9

Incidences of the DEH and FEN in premolars.