Influence of Orthodontic Treatment with Premolar Extraction on the Spatial Position of Maxillary Third Molars in Adult Patients: A Retrospective Cohort Cone-bean Computed Tomography Study

Fangwei Pan
State Key Laboratory of Oral Diseases & National Clinical Research Center for Oral Diseases, West China School of Stomatology, Sichuan University
Zhentao Yang
State Key Laboratory of Oral Diseases & National Clinical Research Center for Oral Diseases, West China School of Stomatology, Sichuan University
Jian Wang
Sichuan University West China College of Stomatology
Ruilie Cai
University of South Carolina Arnold School of Public Health
Jialing Liu
Sichuan University West China College of Stomatology
Chenghao Zhang
Sichuan University West China Hospital of Stomatology
Wen Liao (liaowenssw@126.com)
Department of Orthodontics, West China Hospital of Stomatology, State Key Laboratory of Oral Diseases&National Clinical Research Center for Oral Diseases,Sichuan university, Chengdu, China
https://orcid.org/0000-0002-5737-9731

Research article

Keywords: Cone-bean computed tomography, Maxillary third molars, Premolar, Extraction, Spatial position, Adult

Posted Date: August 22nd, 2020

DOI: https://doi.org/10.21203/rs.3.rs-30799/v2

Version of Record: A version of this preprint was published on November 11th, 2020. See the published version at https://doi.org/10.1186/s12903-020-01314-0.

Abstract

Background: Based on low-dose radiation Cone-bean computed tomography (CBCT) images, ThisThe study aims of this study was to establish a space coordinate system, which offers more precise and comparable evaluation on changes of maxillary third molars influenced by orthodontic treatment with premolar extraction in adults. The system suggests promising application prospect in future studies related to CBCT superimposition and evaluation for its feasibility and efficiency.evaluate the changes in position, angulation, and rotation of maxillary third molars in adults after orthodontic treatment with premolar extraction using a space coordinate system based on Cone-bean computed tomography (CBCT) images.

Methods: Forty-nine maxillary third molars from 27 patients (mean age, 20.78 years) were included in the study. CBCT images were obtained before and after orthodontic treatment with premolars extracted (mean treatment duration, 31.47 months). The changes in the position, angulation, and rotation of the third molars were evaluated with a space coordinates system using four landmarks: anterior nasal spine (ANS), posterior nasal spine (PNS), left and right orbitales.

Results: After orthodontic treatment, the third molars moved forward (adjusted mean, 1.44 mm) ($p < 0.001$) and downward (adjusted mean, 2.87 mm) ($p < 0.001$) accompanied by outward rotation (mean, 5.38°) of the crowns (adjusted mean, 5.38°) ($p = 0.001$), whilebut the changes in angulation were insignificant.

Conclusions: This was the first study to systematically investigate the spatial position change of maxillary third molars in adult patients who received orthodontic treatment with premolar extraction. During the process, maxillary third molars moved downward and forward accompanied by outward rotation of the crowns. Orthodontists should take tooth movement potential into consideration when making extraction plans.

Background

Extractiocn of premolars, as a routine orthodontic treatment for reducing protrusion or crowding of dental arch, has been widely used in the correction of severe tooth-arch discrepancy and, in certain cases, of sagittal dysmorphosis(1). A previous study suggested that since 2006, 8.9–13.4% of orthodontic treatments included four first premolar extractions, with an overall extraction frequency fluctuating around 25% (third molars excluded)(2). In East Asia, the extraction rate is even higher, because the alveolar bone-dental arch discrepancy of Mongoloids is more severe than in Caucasians and Negroids(3).

Worldwide impaction prevalence is reported to be 18.97–30.80%[4], and third molars are the most frequently impacted teeth(5). Impacted third molars are closely related to complications, such as pericoronitis, caries, periodontal defects of adjacent second molar(6), possible late incisor crowding and post-orthodontic relapse(7). Therefore, many asymptomatic third molars are extracted for prophylactic purposes on dentists' personal values and empirical basis(8). However, considering the possibility of iatrogenic injury(9), economic burden(10), potential for auto-transplantation,(11) and psychological anticipation of patients, other orthodontists recommend a more conservative approach. Thus, the management of third molars, especially their extraction, has long been a matter of debate(12).

In theory, the extraction of premolars could relieve posterior space discrepancies. With mesial movement of the buccal segment, the position and angulation of third molars would change, which has the potential to ameliorate potential impacted situations and minimize possible risks. This has been partly confirmed in previous studies, especially in maxillary third molars. A systematic review published in 2017(13) reported a favorable change in the eruption rate, retromolar space, and angulation of third molars, especially in maxillary, although the level of evidence was relatively low.

Previous studies have all been based on two-dimensional images (lateral cephalogram or panoramic radiograph) with various reference lines and inconsistent measurement, and they have lacked adequate description of vital characteristics of selected cases, such as anchorage. Furthermore, previous studies have focused primarily on adolescents, such that the effect of therapeutic orthodontic intervention is difficult to distinguish from the effect of growth. Robust meta-analysis to guide clinical decisions is therefore lacking (10, 13).

It is widely agreed that measuring three-dimensional objects using two-dimensional images routinely leads to errors, such as projection, superimposition of anatomic structures, and magnification distortions(14, 15). CBCT is designed to overcome these issues, and it is widely applied in research and in the clinic. This technique is well suited to improve the reliability of measurements, including the spatial position change of third molars.

The purpose of this study was to precisely evaluate the influence of orthodontic treatment with premolar extraction on maxillary third molars in adult patients using an effective space coordinate system based on CBCT images. Position, angulation, and rotation of the maxillary third molars pre- and post-treatment were measured and compared.

Methods

Patients who received orthodontic treatment in the Department of Orthodontics, West China Hospital of Stomatology, Sichuan University (Chengdu, China) from March 2014 to January 2020 were filtered manually in a medical record database of the hospital.

The inclusion criteria were: (1) patients with CBCT images taken before orthodontic treatment (T1) and after the treatment (T2) were available, (2) patient age at T1 from 18 to 30 years, (3) patients with one or two maxillary premolars extracted during the treatment, and (4) patients with third molar image in relevant tooth extraction site existed in both pretreatment and posttreatment CBCT. The exclusion criteria were: (1) patients with craniofacial syndrome and systemic disease, (2) patients with CBCT images were taken 2 weeks before the treatment began or 2 weeks after the treatment finish, and (3) patients with insufficient CBCT image quality, that is, critical landmarks were missing.

Orthodontic diagnosis and treatment characteristics of selected patients were recorded according to the medical records combined with pretreatment CBCT image.

All of the CBCT images were taken within 2 weeks before and after the orthodontic treatment. The standard of the end of orthodontic treatment is fully closed space and functional occlusal relationship. All of the CBCT images were taken using the same CBCT machine (3D Accuitomo, Morita Group, Japan), which was set according to the manufacturers' recommendations (10*10 cm FOV, 85 kV, 4 mA, and 360° rotation). During image acquisition, patients were seated statically with the Frankfort plane parallel to the ground. The CBCT data were exported in DICOM multifile format and imported into *Invivo* software (Version5.3.4; Anatomage, Inc., San Jose, CA, USA) with the plugin "3D analysis" for 3D volume rendering.

A space coordinate system was used with four landmarks as follows (Fig. 1). The horizontal plane (xOy) was defined as the plane passing through bilateral orbitales, while parallel to ANS-PNS. The sagittal plane (yOz) was defined as the plane passing through ANS and PNS while perpendicular to the horizontal plane. The frontal plane (xOz) was defined as the plane perpendicular to both horizontal plane and sagittal plane while passing through ANS. Landmark superimposition with the same four landmarks was performed to overlap three-dimensional reconstructed pre- and post- therapy images to evaluate the stability of the space coordinate system (Fig. 2).

Six other landmarks were located to define the spatial position of the third molar: mesiobuccal and distobuccal cusps of the third molar, root furcation and central pit of the third molar, root furcation, and central pit of the second molar. Software calculated the linear and angular dimensions between certain landmarks as follows. The forward, outward, and upward position were defined as positive directions (Fig. 3).

The distances from the mesiobuccal and distobuccal cusp of the third molar to the horizontal (xOy), frontal (xOz), and sagittal planes (yOz) were measured (Fig. 4A). The changes in vertical, transverse, and sagittal positions were calculated using the distance differences before and after orthodontic treatment.

The angles between the long axes of second and third molar (root furcation–central pit), and the angles between the long axes of third molar and the horizontal, frontal, and sagittal planes were measured (Fig. 4B). Changes of the angulation of third molars in all directions before and after orthodontic treatment were calculated.

The angles between the mesiobuccal–distobuccal cusp (crown axis) and the horizontal, frontal, and sagittal planes were measured (Fig. 4C). Changes of the angulation before and after orthodontic treatment were measured to evaluate the rotation of third molars.

All of the subjects were measured by two operators (Y. Z. and P. F.). The ICC values ranged from 0.78 to 0.96 for all of the angular variables, and from 0.96 to 0.97 for all of the positional values, showing the measurement's reliability.

Statistical evaluations were performed with software (Version 21.0; SPSS, Chicago, IL, USA). A paired *t*-test was used to evaluate the changes between CBCT images. Statistical significance was set at 0.05.

Results

Fourty-nine maxillary third molars from 27 patients were selected for analysis. About 22 patients had both maxillary third molars and 5 patients had unilateral maxillary third molars. Twenty-six patients received bilateral premolar extraction, and one received unilateral extraction. Table 1 shows the distributions of subjects, including demographic characteristics, orthodontic diagnosis, and treatment characteristics.

Table 1
Baseline characteristics of subjects

Patients (n)	**27**
Third molar (n)	49
Age at T1(y)	Mean 20.78 SD 2.78
Sex	
Male	2 (7.40%)
Female	25 (92.60%)
Treatment duration (mo)	Mean 31.47 SD 8.21
Malocclusion type	
Class I	7 (25.92%)
Class II	15 (55.56%)
Class III	5 (18.52%)
Median line (mm)	Mean 0.91 SD 0.77
Degree of crowding	
Mild	12 (44.44%)
Moderate	6 (22.22%)
Severe	9 (33.33%)
Degree of anchorage	
Maximum	21 (77.78%)
Moderate	6 (22.22%)
Tooth extracted	
First premolar	36 (73.47%)
Second premolar	13 (26.53%)
Orthodontic appliance	
Clear aligner	4 (14.81%)
Fixed appliance	23 (85.19%)

The position of maxillary third molars had significant differences after orthodontic treatment with premolar extraction ($P < 0.001$; Table 2). The third molars moved 2.87 mm downward and 1.44 mm forward respectively. On the transverse position, the mesial-buccal cusp of the third molars showed no significant difference; however, distal-buccal cusp of the third molars moved 0.69 mm outward ($P =$

0.007), which is in accordance with the result of third molars rotation (Table 2). Third molars were found to be rotated outward 5.38° ($P = 0.001$). However, the angulation of the third molars showed no difference between pre- and post- orthodontic treatment. The degree of landmark fit of the superimposed CBCT images of reconstructed pre- and post- therapy confirmed the stability of the space coordinate system.

Table 2
Position and angulation of third molar compared between pre- and post- therapy

	pretreatment		posttreatment		Treatment effect		*P* value
	Mean	SD	Mean	SD	Mean	SD	
Angulation (°)							
U7 axis with U8 axis	13.28	8.97	13.53	10.08	0.25	0.40	0.854
U8 axis with horiz	62.76	15.13	63.51	14.39	0.75	10.92	0.632
U8 axis with sagit	16.85	10.40	15.21	10.32	-1.63	10.27	0.272
U8 axis with front	20.13	15.24	19.90	15.22	-0.23	9.90	0.872
Rotation (°)							
U8 Cr with horiz	18.35	12.48	15.91	8.02	-2.45	10.76	0.118
U8 Cr with sagit	21.20	12.14	17.21	14.67	-3.98	10.35	0.01*
U8 Cr with front	59.24	10.70	64.62	11.64	5.38	10.43	0.001†
Position (mm)							
U8 MB cusp to front	-40.83	3.16	-39.39	3.67	1.44	1.83	< 0.001‡
U8 MB cusp to horiz	-36.49	6.51	-39.36	6.51	-2.87	2.26	< 0.001‡
U8 MB cusp to sagit	31.09	2.49	31.16	2.17	0.07	1.34	0.702
U8 DB cusp to front	-45.02	3.15	-43.52	3.56	1.50	1.71	< 0.001‡
U8 DB cusp to horiz	-35.50	6.49	-38.60	6.44	-3.10	2.00	< 0.001‡
U8 DB cusp to sagit	29.51	2.86	30.20	2.52	0.69	1.72	0.007†

U7, maxillary second molar; U8, maxillary third molar; Cr, crown; horiz, horizontal plane; front, frontal palne; sagit, sagittal plane; MB, mesial buccal; DB, distal buccal; *$p < 0.05$; †$p < 0.01$; ‡$p < 0.001$.

Discussion

Our study aimed to evaluate the effect of premolar extractions in orthodontics on the spatial position, rotation, and angulation of maxillary third molars. Three-dimensional CBCT images taken pre- and post-treatment were measured using space coordinates system to offer more precise measurements than 2D imaging systems. Measurements used in this study were based on previous work by Lee(16), who evaluated the change of maxillary third molars after total arch distalization with a space coordinates system re-orientated by six landmarks: bilateral porions, right orbitale, ANS, nasion, and PNS.

Considering the radiation dose and financial costs, CBCT images taken for clinical orthodontic needs generally do not include cranial anatomical structures, such as nasion and sella, which add challenges to the establishment of the space coordinate system by limited time-stable lower anatomical landmarks. To address this issue, our study innovatively used only four easily recognizable landmarks: left orbitale, right orbitale, ANS, and PNS. Their stability has been confirmed in previous studies(15–17). Superimposition according to these four landmarks was performed in this study pre- and post- treatment, confirming the stability of this space coordinate system and suggesting its reliability under low radiation dose. Moreover, given the widespread use of CBCT in clinics, the establishment of a space coordinate system based on CBCT images could make accurate and consistent comparisons between clinics easier.

The results in the current study revealed that the third molars moved downward, outward, and forward after orthodontic treatment with premolar extraction, while previous study indicates the maxillary third molars erupt downward, backward, and often outward(16), which moved in the same directions with the current study except in a sagittal direction. As previous studies suggested, the consistence renders the premolar extraction a positive influence on the eruption space of maxillary third molars in orthodontic treatment(13, 19–21). The sagittal difference can be explained by the subsequent mesial drift of third molars because of the increase of retromolar space during space closure caused by mesial drift of the molar segment(18). However, the amount of mesial movement was smaller than the 2.2 mm mesialization of third molars previously reported(20). The difference can be attributed to the greater potential of spontaneous tooth movement in adolescents and relatively high degree of anchorage.

Statistically significant improvement in the angulation of maxillary third molars was observed in previous studies(22, 23). However, no significant difference was found in this study. This may be due to the wide use of micro-implant anchorage in the current study, including 77.78% of selected cases having received maximum anchorage, such as mini-implant and Nance arch. It has been reported that the upright of third molars might be influenced by different anchorages used in orthodontic treatment and in cases with maximum anchorage, no upright of third molars was found(24). Besides, to reach a normal occlusal position, uprighting of maxillary third molars from initial distal inclination must be performed between the age of 10 and 21(25). However, the mean age of samples in the study was 20.78 years old, which may be reluctant to process the uprighting.

The major limitation of our study was the sex distribution in the samples. Only two males were selected, probably due to disparate willingness of adult males and females to undergo orthodontic treatment.

Our findings could be helpful in understanding the change of maxillary third molars after orthodontic treatment with premolar extracted. After premolar extracted and space closure, third molar movement was forward, downward, and outward, which is in favor of eruption and the alleviation of unfavorable impacted situations. This result may be clinically helpful when making a tooth extraction plan. Moreover, the successful practice of establishing a space coordinate system based on CBCT images using just four lower stable landmarks provides a new idea to describe the spatial location change of certain sclerous structures.

Conclusions

This was the first study to systematically examine the spatial position change of maxillary third molars in adult patients receiving orthodontic treatment with premolar extraction. During the process, maxillary third molars moved downward and forward accompanied by outward rotation of the crown. We also demonstrated the reliability and feasibility of a space coordinate system based on CBCT.

List of abbreviations

CBCT, cone-bean computed tomography; T1, before treatment; T2, after treatment; ANS, anterior nasal spine; PNS, posterior nasal spine; xOy, the horizontal plane; yOz, the sagittal plane; xOz, the frontal plane; U7, maxillary second molar; U8, maxillary third molar; Cr, crown; horiz, horizontal plane; front, frontal palne; sagit, sagittal plane; MB, mesial buccal; DB, distal buccal

Declarations

Declarations

Ethics approval and consent to participate

Approval was obtained from the Ethics Committee of West China Hospital of Stomatology, Sichuan University (WCHSIRB-D-2019-074), and informed consent was provided according to the Declaration of Helsinki. Written informed consent was provided by each participant.

Consent for publication

Not applicable.

Availability of data and material

The raw data is present in the CBCT software of our university clinic.

Competing interests

The authors declare that they have no competing interests.

Funding

This study was supported by the Science and Technology Department of Sichuan Province (20ZDYF2839). The funding body was not involved in the design of the study; collection, analysis or

interpretation of the data; or in writing the manuscript.

Authors' contributions

FP designed the study, carried out the data collection and drafted the manuscript; FP and ZY performed the measurements; JW gave statistical analysis guidance; JL and CZ gave procedure guidance; WL guided the whole process of the study. All persons listed as authors above have critically revised the manuscript, and have read and approved the final manuscript.

Acknowledgements

We acknowledge Accdon, LLC for their professional English calibration.

References

1. Keim RG, Gottlieb EL, Vogels DS 3rd, Vogels PB. 2014 JCO study of orthodontic diagnosis and treatment procedures, Part 1: results and trends. J Clin Orthod. 2014;48(10):607 – 30.
2. Jackson TH, Guez C, Lin FC, Proffit WR, Ko CC. Extraction frequencies at a university orthodontic clinic in the 21st century: Demographic and diagnostic factors affecting the likelihood of extraction. Am J Orthod Dentofacial Orthop. 2017;151(3):456–62.
3. Lavelle CL. A study of multiracial malocclusions. Community Dent Oral Epidemiol. 1976;4(1):38–41.
4. Carter K, Worthington S. Predictors of Third Molar Impaction: A Systematic Review and Meta-analysis. J Dent Res. 2016;95(3):267–76.
5. Badawi Fayad J, Levy JC, Yazbeck C, Cavezian R, Cabanis EA. Eruption of third molars: relationship to inclination of adjacent molars. Am J Orthod Dentofacial Orthop. 2004;125(2):200–2.
6. Smailiene D, Trakiniene G, Beinoriene A, Tutliene U. Relationship between the Position of Impacted Third Molars and External Root Resorption of Adjacent Second Molars: A Retrospective CBCT Study. Medicina. 2019;55(6):24.
7. Genest-Beucher S, Graillon N, Bruneau S, Benzaquen M, Guyot L. Does mandibular third molar have an impact on dental mandibular anterior crowding? A literature review. J Stomatol Oral Maxillofac Surg. 2018;119(3):204–7.
8. Bastos Ado C, de Oliveira JB, Mello KF, Leao PB, Artese F, Normando D. The ability of orthodontists and oral/maxillofacial surgeons to predict eruption of lower third molar. Prog Orthod. 2016;17(1):21.
9. Friedman JW. The prophylactic extraction of third molars: a public health hazard. Am J Public Health. 2007;97(9):1554–9.
10. Livas C, Delli K. Does Orthodontic Extraction Treatment Improve the Angular Position of Third Molars? A Systematic Review. J Oral Maxillofac Surg. 2017;75(3):475–83.
11. Bauss O, Kiliaridis S. Evaluation of tooth position, occlusion, and interproximal contacts after transplantation of immature third molars. Eur J Orthod. 2009;31(2):121–8.

12. Durgesh BH, Gowda KH, AlShahrani OA, Almalki AD, Almalki WD, Balharith MM, et al. Influence of premolar extraction or non-extraction orthodontic therapy on the angular changes of mandibular third molars. Saudi J Biol Sci. 2016;23(6):736–40.
13. Brezulier D, Fau V, Sorel O. Influence of orthodontic premolar extraction therapy on the eruption of the third molars: A systematic review of the literature. J Am Dent Assoc. 2017;148(12):903–12.
14. Heinz J, Stewart K, Ghoneima A. Evaluation of two-dimensional lateral cephalogram and three-dimensional cone beam computed tomography superimpositions: a comparative study. Int J Oral Maxillofac Surg. 2019;48(4):519–25.
15. Shahen S, Lagravere MO, Carrino G, Fahim F, Abdelsalam R, Flores-Mir C, et al. United Reference Method for three-dimensional treatment evaluation. Prog Orthod. 2018;19(1):47.
16. Lee YJ, Kook YA, Park JH, Park J, Bayome M, Vaid NR, et al. Short-term cone-beam computed tomography evaluation of maxillary third molar changes after total arch distalization in adolescents. Am J Orthod Dentofacial Orthop. 2019;155(2):191–7.
17. Ghoneima A, Cho H, Farouk K, Kula K. Accuracy and reliability of landmark-based, surface-based and voxel-based 3D cone-beam computed tomography superimposition methods. Orthod Craniofac Res. 2017;20(4):227–36.
18. Chipman MR. Second and Third Molars - Their Role in Orthodontic Therapy. Am J Orthod Dentofac Orthop. 1961;47(7):498-&.
19. Miclotte A, Grommen B, Cadenas de Llano-Perula M, Verdonck A, Jacobs R, Willems G. The effect of first and second premolar extractions on third molars: A retrospective longitudinal study. J Dent. 2017;61:55–66.
20. Kim TW, Artun J, Behbehani F, Artese F. Prevalence of third molar impaction in orthodontic patients treated nonextraction and with extraction of 4 premolars. Am J Orthod Dentofacial Orthop. 2003;123(2):138–45.
21. Turkoz C, Ulusoy C. Effect of premolar extraction on mandibular third molar impaction in young adults. Angle Orthod. 2013;83(4):572–7.
22. Janson G, Putrick LM, Henriques JFC, de Freitas MR, Henriques RP. Maxillary third molar position in Class II malocclusions: the effect of treatment with and without maxillary premolar extractions. Eur J Orthod. 2006;28(6):573–9.
23. Artun J, Thalib L, Little RM. Third molar angulation during and after treatment of adolescent orthodontic patients. Eur J Orthod. 2005;27(6):590–6.
24. Azizi F, Shahidi-Zandi V. Effect of different types of dental anchorage following first premolar extraction on mandibular third molar angulation. Int Orthod. 2018;16(1):82–90.
25. Silling G. Development and eruption of the mandibular third molar and its response to orthodontic therapy. Angle Orthod. 1973;43(3):271–8.

Figures

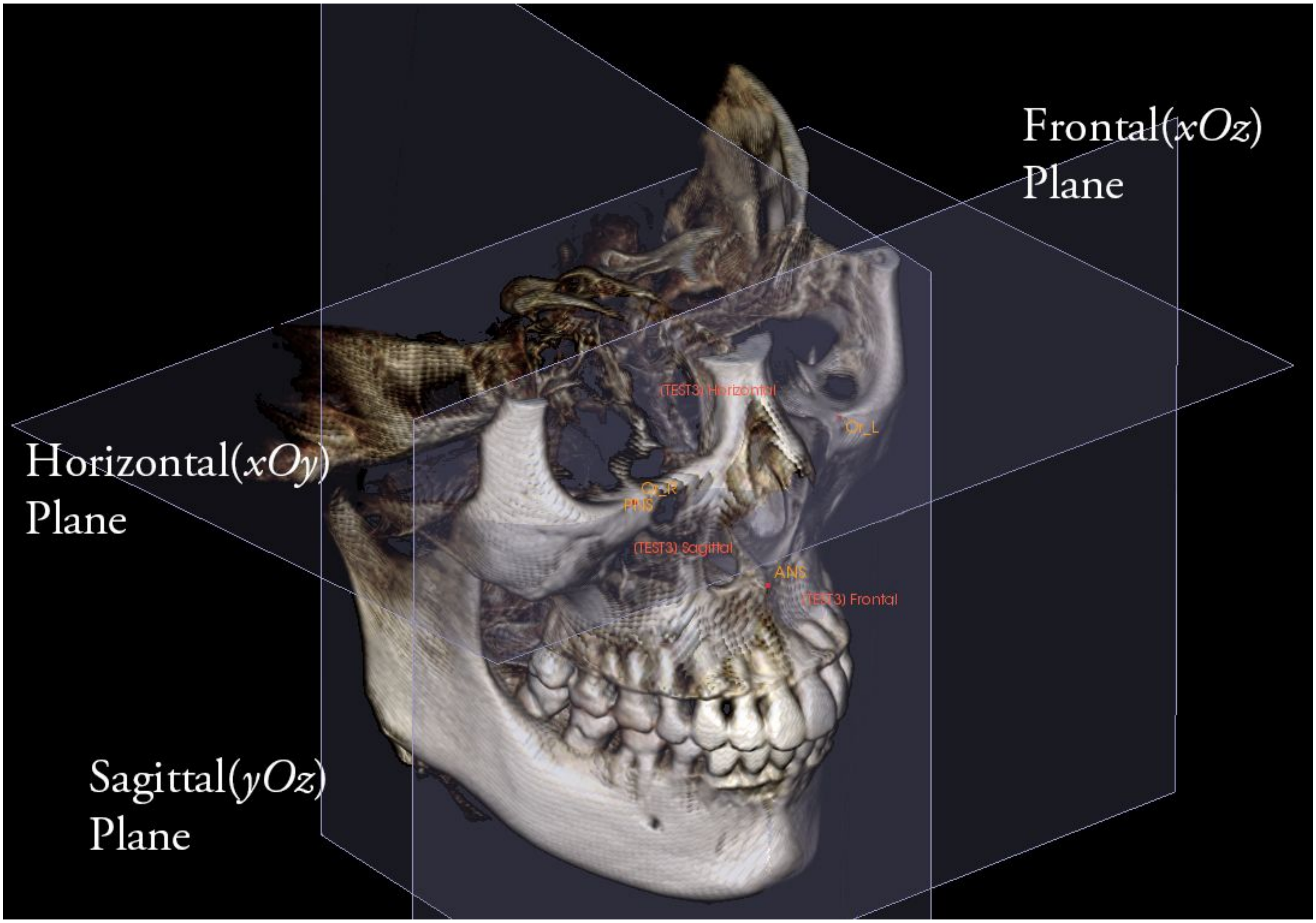

Figure 1

Maxillary coordinate system shown with 3 planes: horizontal(xOy), frontal(xOz) and sagittal(yOz) planes. 4 landmarks were used for setting up the system: ANS, anterior nasal spine; PNS, posterior nasal spine; Or_L, left orbitale; Or_R, right orbitale.

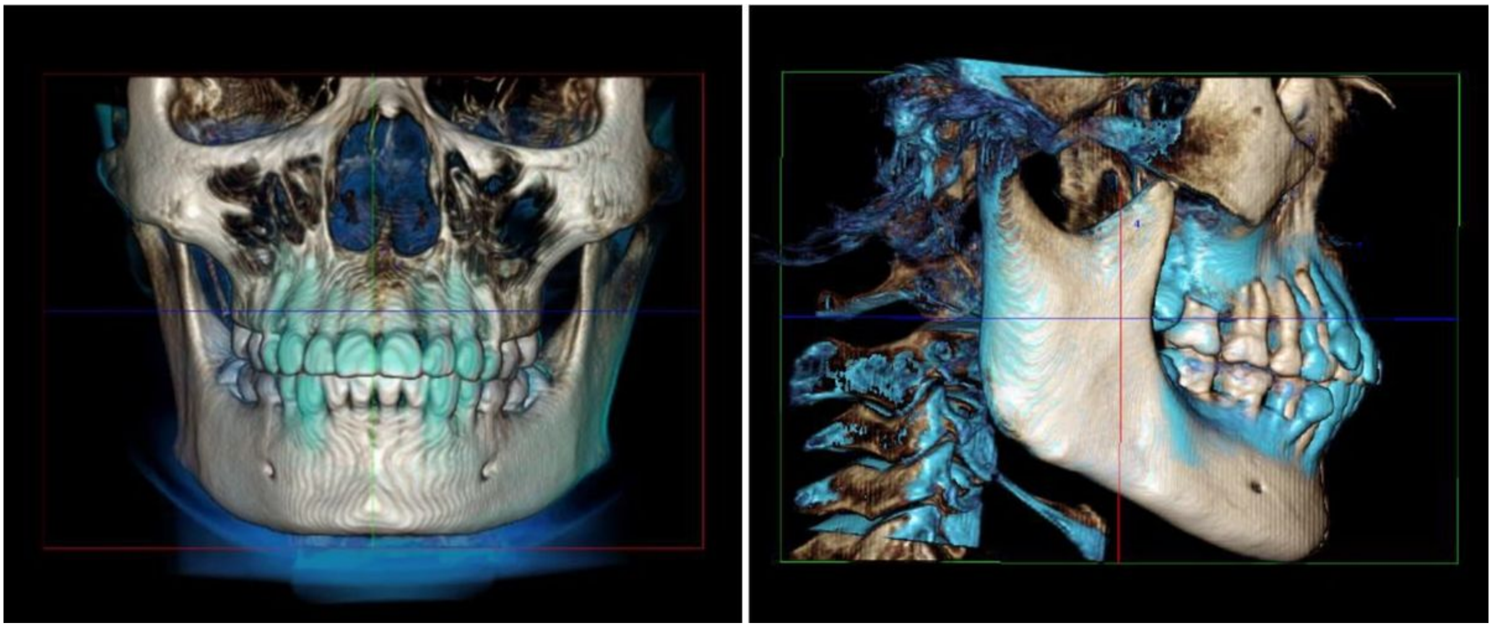

Figure 2

Landmark CBCT superimposition profiles. The same 4 landmark were included: ANS, PNS, bilateral orbitales.

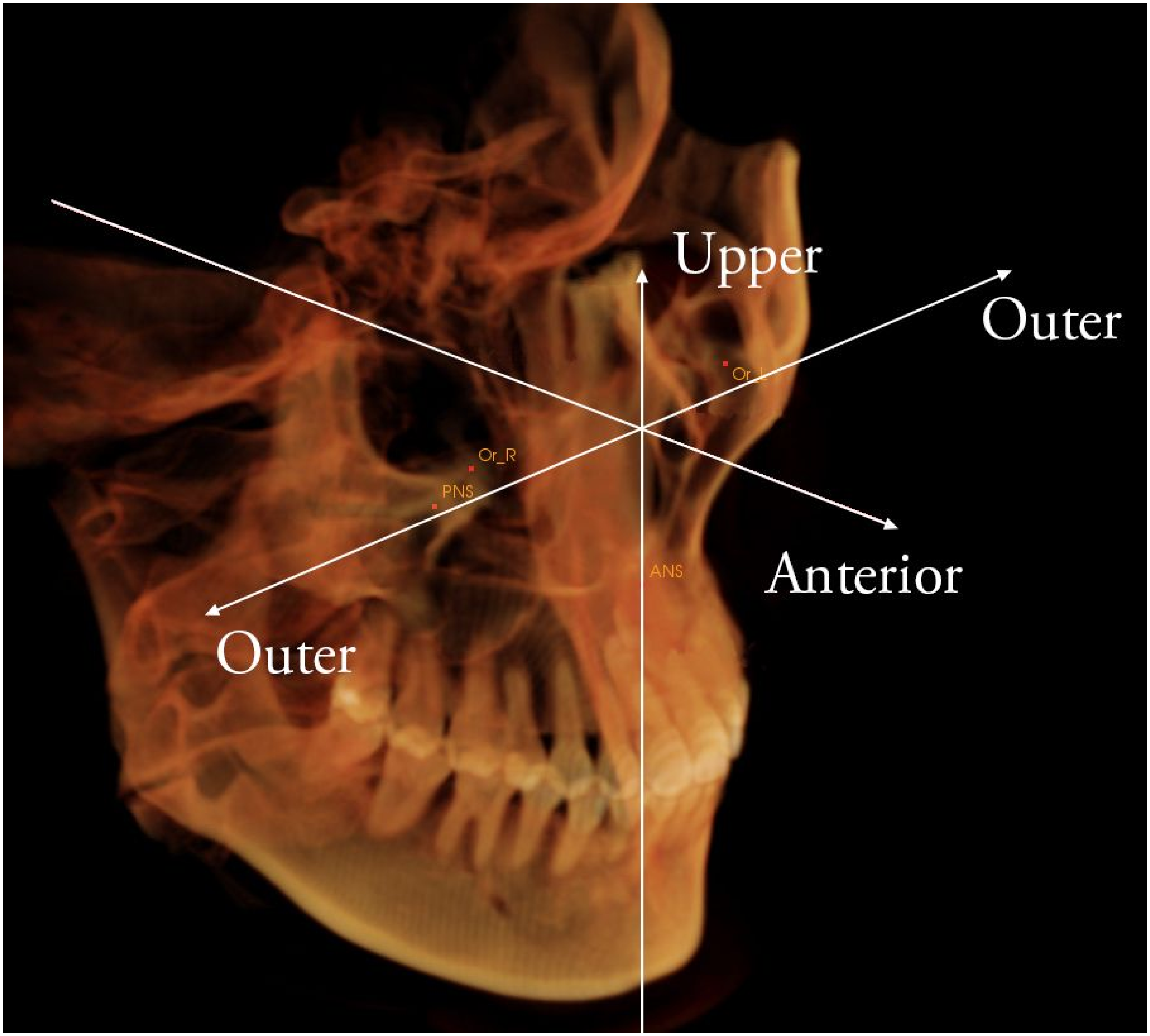

Figure 3

Upper, anterior, outer directions were defined as positive directions.

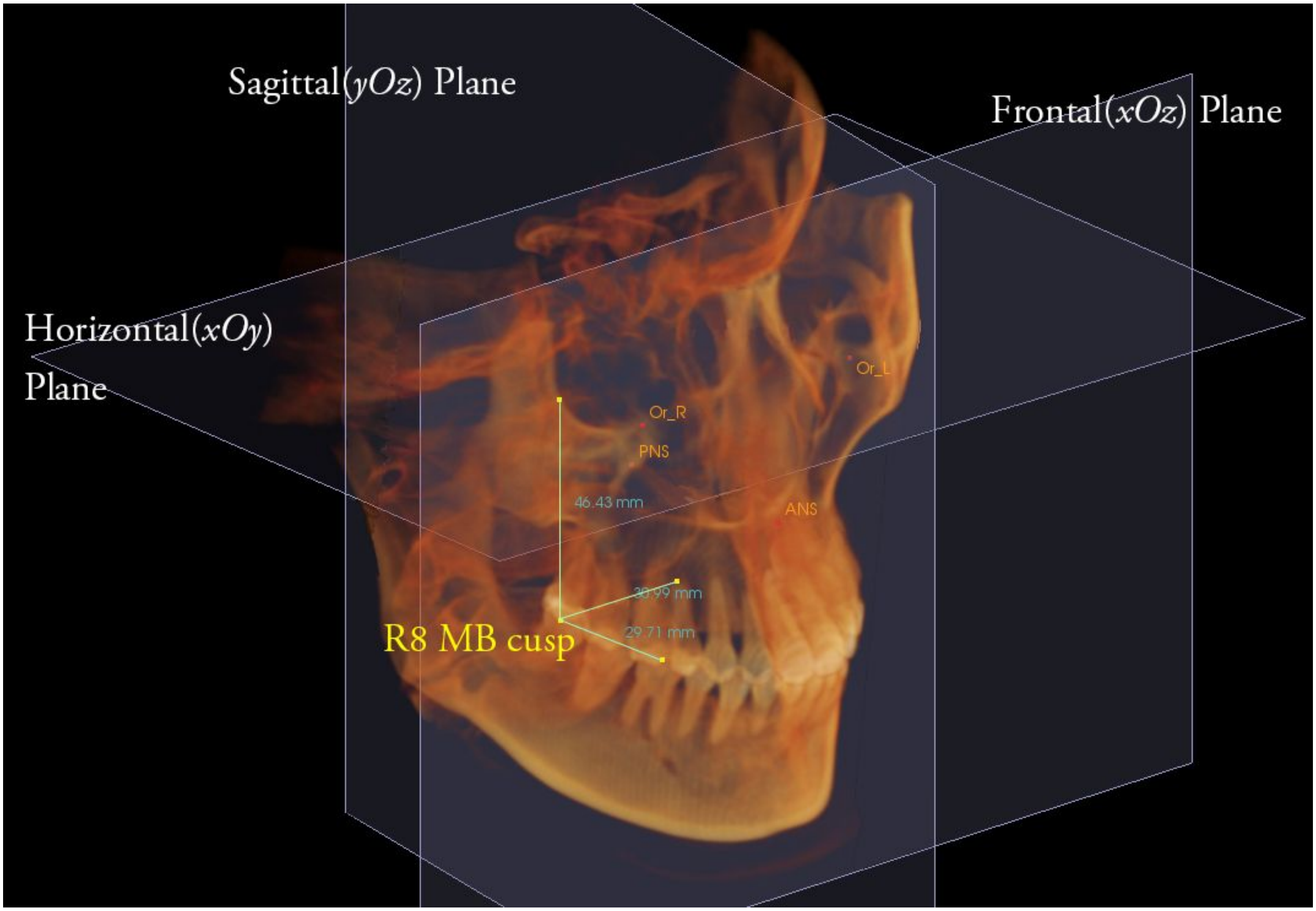

Figure 4

Determination of the position of right third molar. The distance from the mesiobuccal cusp to sagittal, frontal and horizontal planes were measured. R8, right third molar; MB, mesiobuccal.

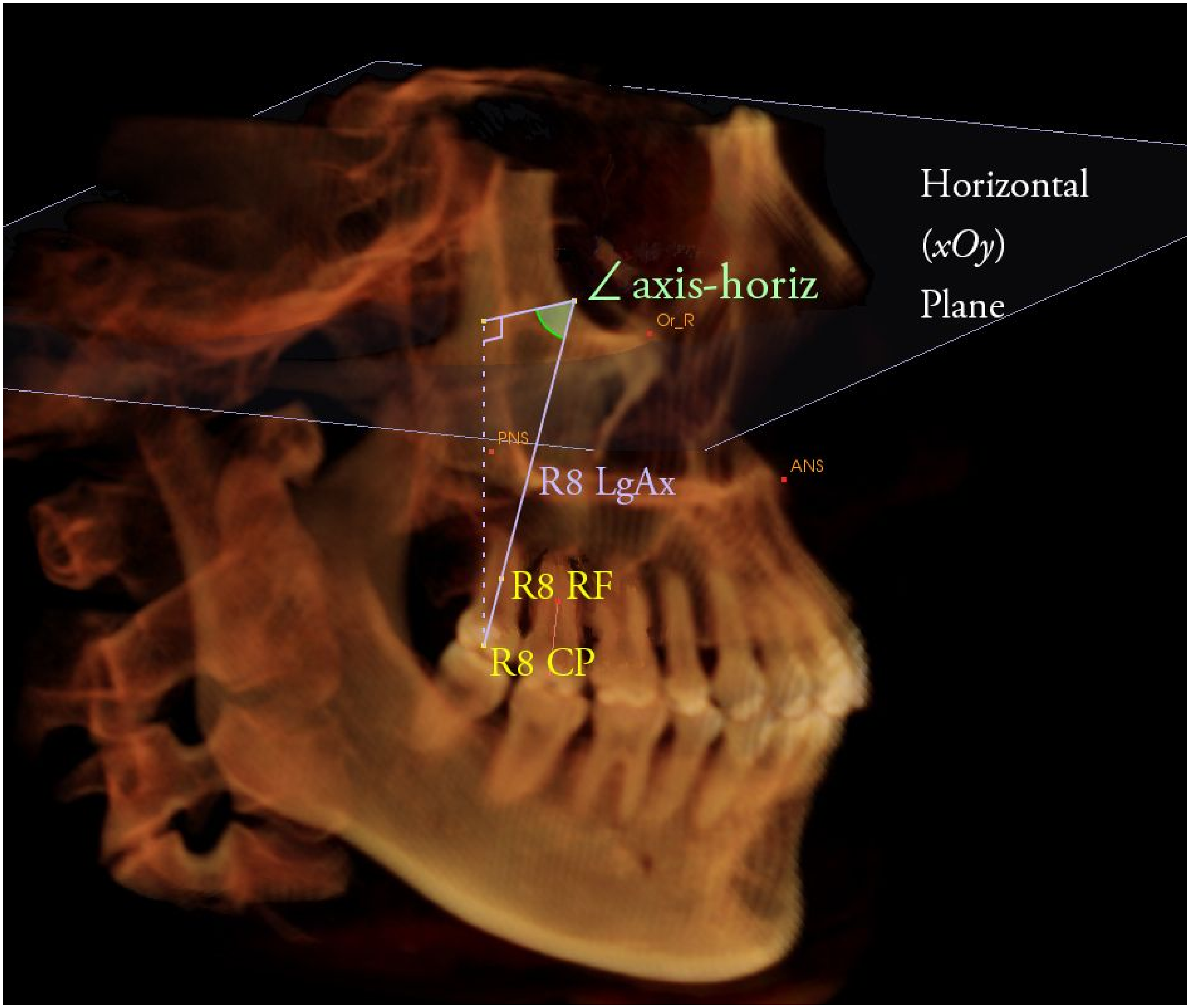

Figure 5

Determination of the angulation of right third molar. The angle between the long axis and the horizontal plane were measured. R8, right third molar; CP, central pit; RF, root furcation; LgAx, long axis; horiz, horizontal plane.

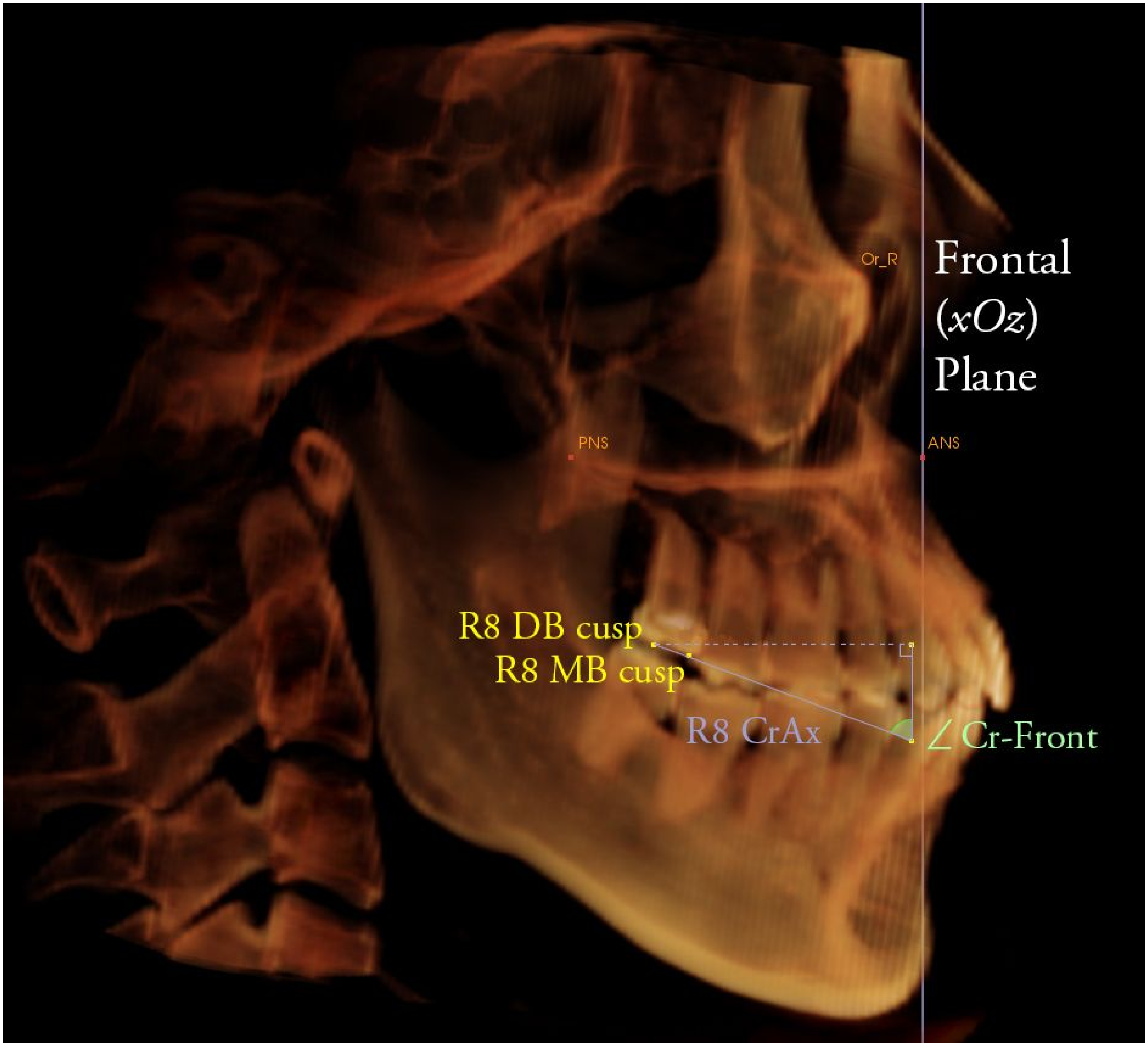

Figure 6

Determination of the rotation of right third molar. The angle between the mesiobuccal-distobuccal cusp (crown axis) and the frontal plane were measured. R8, right third molar; MB, mesiobuccal; DB, distobuccal; Cr, crown; Ax, axis; Front, frontal plane.

Supplementary Files

This is a list of supplementary files associated with this preprint. Click to download.

- STROBEchecklistcohort.doc