

Research Article

Ying Jia*, Hua Yang, Ping Li, Jiangyan Xiong, Bo Chen

Cone beam computed tomography analysis in 3D position of maxillary denture

<https://doi.org/10.1515/med-2017-0049>

received June 22, 2017; accepted August 29, 2017

Abstract: The dynamic correlation between teeth and denture morphology as well as the morphological positions needs to be explored.

Methodology: 63 adult patients with skeletal class III malocclusions that met the inclusion criteria were enrolled and imaged with Cone Beam Computed Tomography (CBCT), and Digital Imaging and Communications in Medicine (DICOM) data were collected. The torque angle and axial inclination were measured and analyzed for the corona, root, and entire body of every tooth on the maxilla.

Results: There is a statistically significant difference between the coronal axial inclination/coronal torque angle for the skeletal class III malocclusion cases and Andrew's six keys of occlusion. On the sagittal plane of the maxillary denture (except that the secondary molar is inclined medial-distally), the remaining teeth are inclined towards the labia with slightly larger angles compared to the normal occlusion. In the coronal direction, the maxillary anterior teeth tend to have a corona that inclines medial-distally, whereas the posterior teeth have a buccal inclination compared to the normal occlusion.

Conclusion: Sagittal and transversal compensations prevail in maxillary dentures; for the camouflaged treat-

ment design for skeletal class III, there is limited scope of sagittal and transversal movements on the maxillary denture.

Keywords: Skeletal Class III Malocclusion; Axial Inclination; Torque Angle; Cone Beam Computed Tomography

1 Introduction

Skeletal class III malocclusion is a severe malocclusion abnormality that results from sagittal and transversal malposition of the maxilla and mandible, which leads to denture compensation or decompensation [1]. The treatment for this abnormality primarily includes camouflage treatment [2] and/or orthodontic-occlusion treatment [3]. Both treatments involve compensation or decompensation of the tooth body and denture sites [4]. However, due to the biological limits of tooth movement, it is important and of practical significance to explore the 3D relationship of the tooth body and denture under this malocclusion abnormality to guide clinical establishments for tooth movement magnitude, thus avoiding iatrogenic damage in patients [5]. Currently, existing studies regarding the denture position characteristics for the skeletal class III malocclusion abnormality provide only a macro indication that is expressed by the length/width of the arch; however, the relation of the area in between each tooth site and the arch morphology is unclear. This experiment summarizes the measurement metrics and provides a quantification analysis of each tooth site characteristics on a maxillary denture that has skeletal class III malocclusion abnormality to provide experimental inputs and data reference for a clinical design and treatment plan for the skeletal class III malocclusion abnormality.

***Corresponding author: Ying Jia**, Department of Orthodontics, Guizhou Medical University School of Stomatology, No. 28 Beijing Road, Guiyang City, 550004, Guizhou Province. Tel: +86 851 8677 4434; E-mail: jiayingmed218@163.com

Hua Yang, Ping Li, Department of Orthodontics, Guizhou Medical University School of Stomatology, China

Jiangyan Xiong, College of Nursing, Guiyang College of Traditional Chinese Medicine, China

Bo Chen, College of Acupuncture and Massage, Guiyang College of Traditional Chinese Medicine

Ying Jia and Hua Yang contribute equally to this study

2 Methods

2.1 Subjects

A consecutive series of adult patients with a skeletal class III malocclusion abnormality that visited Department of Orthodontics, Guizhou Medical University School of Stomatology during March 2013 to March 2015 were enrolled (63 patients; 27 males and 36 females from 18 to 27 years of age with a mean age of 20 years). CBCT data were collected for retrospective investigation. Inclusion criteria: (1) both male and females were included from an age of > 18 yr; (2) molars were in medial relation without functional recession in the mandible; (3) wits < -1, ANB < 0°; (4) The number of teeth on the permanent dentition with an anterior crossbite was ≥ 3 ; and (5) no history of orthodontic treatment and no temporomandibular joint disease. Exclusion criteria: (1) patients with temporomandibular complaints or temporomandibular symptoms; (2) the degree of dentures crowded in the maxilla and mandible was > 4 mm and/or they had a significantly twisted tooth; (4) medium or above periodontal disease or I° or above alveolar bone absorption. Informed consent was obtained from all subjects; and the Guizhou Medical University School of Stomatology Ethics Committee approved the study.

2.2 Investigation method

2.2.1 Collection of information

All subjects were scanned using a cone beam CT machine (KaVo 3D eXam, Kavo America, USA) by the CT technician at the Department of Radiography in the affiliated hospital of Guizhou Medical University School of Stomatology. The images were reconstructed using KaVo 3D exam and integrated 3D software (KaVo 3D eXam vision). The created DICOM files were imported into Invivo5.1 (Ver. 5.1, Anatomage, USA) for measurement.

2.2.2 Indication definitions

Occlusal plane: the tangential plane between the incisive end of the maxillary incisors and the medial-distal buccal apex of the maxillary first molars.

Coronal long axis: the straight line connecting the middle point on the enamel-bone interfacing line and the middle point on the corona tangential end.

Root long axis: the straight line connecting the middle point on the enamel-bone interfacing line and the middle point on the dental root.

Tooth body long axis: the straight line connecting the middle point on the corona and the middle point on the dental root.

Axial inclination: the inclination of the tooth body's tangential occlusal gingiva towards the long axis that is mesiodistally positioned. The long axis root inclining medial-distally is expressed as positive, and the opposite inclination is negative.

Torque angle: the inclination of the tooth body's tangential occlusal gingiva towards the long axis in the labial (buccal) lingual direction. The long axis root inclining lingually is expressed as positive, and the opposite inclination is negative.

2.2.3 Measurement methodology

2.2.3.1 Determination of the base plane

Determination of the occlusal plane: We adjusted the head position on the sagittal plane, coronal plane, and axial plane, making tangential contact between the adjusted axial plane, the medial-distal buccal apex of the maxillary first molar, and the incisive end of the maxillary incisors. This axial plane is referred to as the occlusal plane (Fig. 1A-1C).

2.2.4 Measurement of the axial inclination

The tangential angle of the tooth position for measurement was set up on the determined occlusal plane, making a parallel tangential plane to the connecting line of the middle point on the mesiodistal marginal ridge of the same tooth. Slices were made along this direction with a slice thickness of 0.100 mm (Fig. 1D), and a full and complete image was acquired of the mesiodistal slice of this tooth position. With the coronal long axis located, the angle measurement option in the Invivo 5.1 software was used to measure the angle between the coronal long axis and the perpendicular plane (green line) of the occlusal plane (orange line). This intersection angle is the coronal axial inclination (Fig. 1E). The angle between the root long axis of this tangential plane and the perpendicular plane of the occlusal plane was measured in the same manner. This intersection angle is defined as the root axial inclination, whereas the angle between the tooth body long axis and the perpendicular line of the occlusal plane is defined as the entire tooth axial inclination.

2.2.5 Measurement of the torque angle

The slice angle of the tooth position that was measured was set up on the parallel plane of the determined occlusal plane, making the slice direction perpendicular to the connecting line of the middle point on the mesiodistal marginal ridge of the same tooth. Slices were made along this direction with a slice thickness of 0.100 mm (Fig. 1F), and we acquired a full and complete image of the labial (buccal) lingual slice of this tooth position. The angle measurement option in the Invivo 5.1 software was used to measure the angle between the coronal long axis and the perpendicular plane (green line) of the occlusal plane (orange line). This intersection angle is the coronal torque angle (Fig. 1G). The angle between the root long axis in this tangential plane and the perpendicular plane of the

occlusal plane was measured in the same manner. This angle is defined as the root torque angle, whereas the intersection in between the tooth body long axis and the perpendicular line of the occlusal plane is defined as the entire tooth torque angle.

2.3 Statistical handling

The analysis of the overall trends of the axial inclination and torque angle for the maxillary denture corona, root, and entire tooth that has skeletal class III malocclusion was performed via descriptive analysis.

The differences between the mean value and Andrew's normal values of the coronal axial inclination and coronal torque angle on each tooth position of the patients with

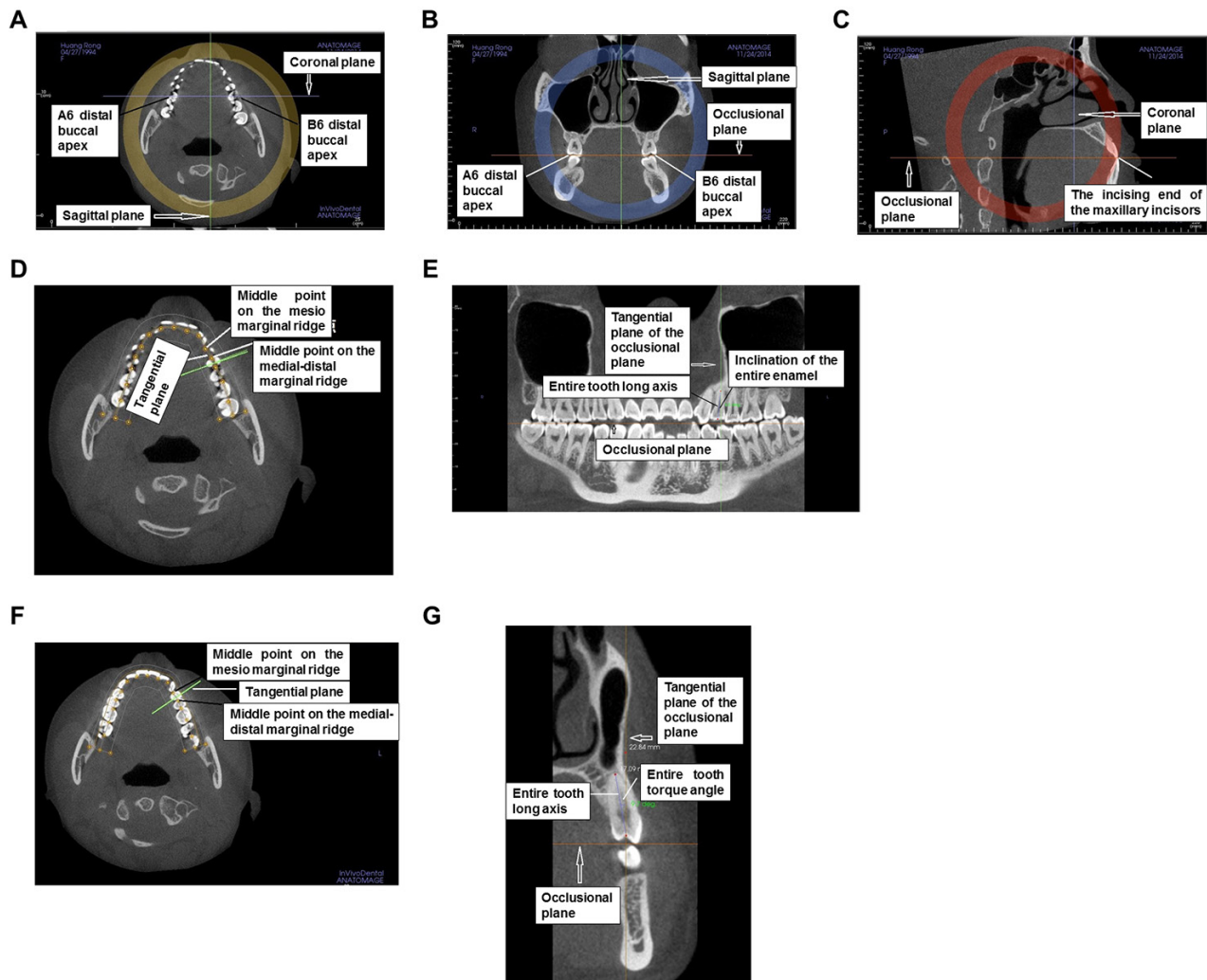


Figure 1: Adjustment of the base position for the craniofacial metrics plane. (A) Axial plane. (B) Coronal plane. (C) Sagittal plane. (D) Determination of the tangential plane on the measured tooth. (E) Measurement of the coronal axial inclination in the entire tooth mesiodistal transverse plane. (F) Determination of the tangential plane on the measured tooth. (G) Measurement of the coronal torque angle in the entire tooth buccal (labial) lingual transversal plane.

skeletal class III malocclusion were compared using individual sample t-tests.

3 Results

The overall trends of the axial inclination and torque angle on the maxillary denture corona, root, and entire tooth that has a skeletal class III malocclusion abnormality.

For the skeletal class III malocclusion abnormality, the torque angle and axial inclination of the corona, root, and entire body on the left and right maxillary with the same dental notation are principally symmetric. Except for the negative axial inclination on the secondary molar, the remaining maxillary tooth positions are positive in axial inclination, i.e., the roots incline medial-distally (Fig 2A).

The torque angle and axial inclination of the corona, root, and entire body on all teeth conform well in terms of magnitude and direction, and the paired comparison exhibits no statistical difference ($P > 0.05$). Therefore, the coronal angle, which is representative of the tooth inclination and direction, is used for the following statistical analysis (Fig 2B).

Comparison of the skeletal class III malocclusion cases with the Andrew's ideal occlusion cases for the maxillary coronal axial inclination and torque angle on each position.

There is a statistically significant difference ($P < 0.05$) in the measurements of the coronal axial inclination/coronal torque angle of each tooth position for the skeletal class III malocclusion cases compared with Andrew's occlusion cases. Compared with Andrew's measurements, the axial inclination of the secondary molar is negative with the axial inclination of the anterior molar increased, and the axial inclination of the anterior teeth and canines decreased (Fig 2C). The torque angles of all teeth are positive, and the torque angle of the incisors increased. The torque direction is consistent with the same dental notation for normal occlusion. The torque angles of the canines and posterior teeth are positive, whereas the corresponding tooth position on the normal occlusion is reversed (Fig 2D).

Comparison of the skeletal class III malocclusion cases with Andrew's ideal occlusion cases for the inclination along the sagittal and coronal directions

The sagittal inclination on the maxillary denture for the skeletal class III malocclusion cases is polarized. The corona of the secondary molar inclined medial-distally, but the remaining sit on the maxilla inclined to the mesio and labial directions with an inclination magnitude that is significantly greater than that of Andrew's normal value (Fig 2E). (This is due to the morphologic characteristics of the arch; the sagittal inclination is expressed using the torque on the maxillary anterior tooth and the axial inclination of the maxillary posterior tooth.)

Upon comparing the skeletal class III malocclusion cases with Andrew's normal value for the maxillary denture in the coronal direction, we found that the maxillary denture trends in a symmetric direction that distributes along the midmost sagittal plane as an axis. The anterior tooth may still incline to the mesio direction, yet the inclination is significantly less, whereas the posterior tooth significantly inclines to the buccal direction (Fig 2F). (The coronal inclination in the coronal direction is expressed using the reverse axis of the maxillary anterior tooth and the torque of the maxillary posterior tooth.)

Schematic of the changes on the class III denture: the maxillary arch changes to a squarely round arch. From an aesthetics aspect, the coordination of the anterior tooth's torque with the axial inclination is the key factor that requires attention.

4 Discussion

Skeletal class III malocclusion is a dentognathic deformity in the form of jaw bone dysplasia, whereas its pathogenesis is the displacement of the jaw from all 3 dimensions, including the sagittal plane, axial plane, and perpendicular plane [6]. With the development of clinical investigation approaches, the requirement for 3D knowledge of the pathogenesis of skeletal class III malocclusion has been generally recognized, which is a hotspot in this research field.

Orthodontic treatment is a correction for the malocclusion that ultimately utilizes teeth movements, whereas malocclusion correction may involve iatrogenic risks, such as bone fenestration, fracture, etc. that are closely related to poor control of teeth movements. Currently, the most common diagnostic approaches for the malocclusion abnormality focus primarily on the malposition of the inter-jaw bone and arch, which is deemed a macro level diagnostic. For 3D position characteristics of an individual tooth within a denture, it is called micro level diagnostics, and relevant research results will improve

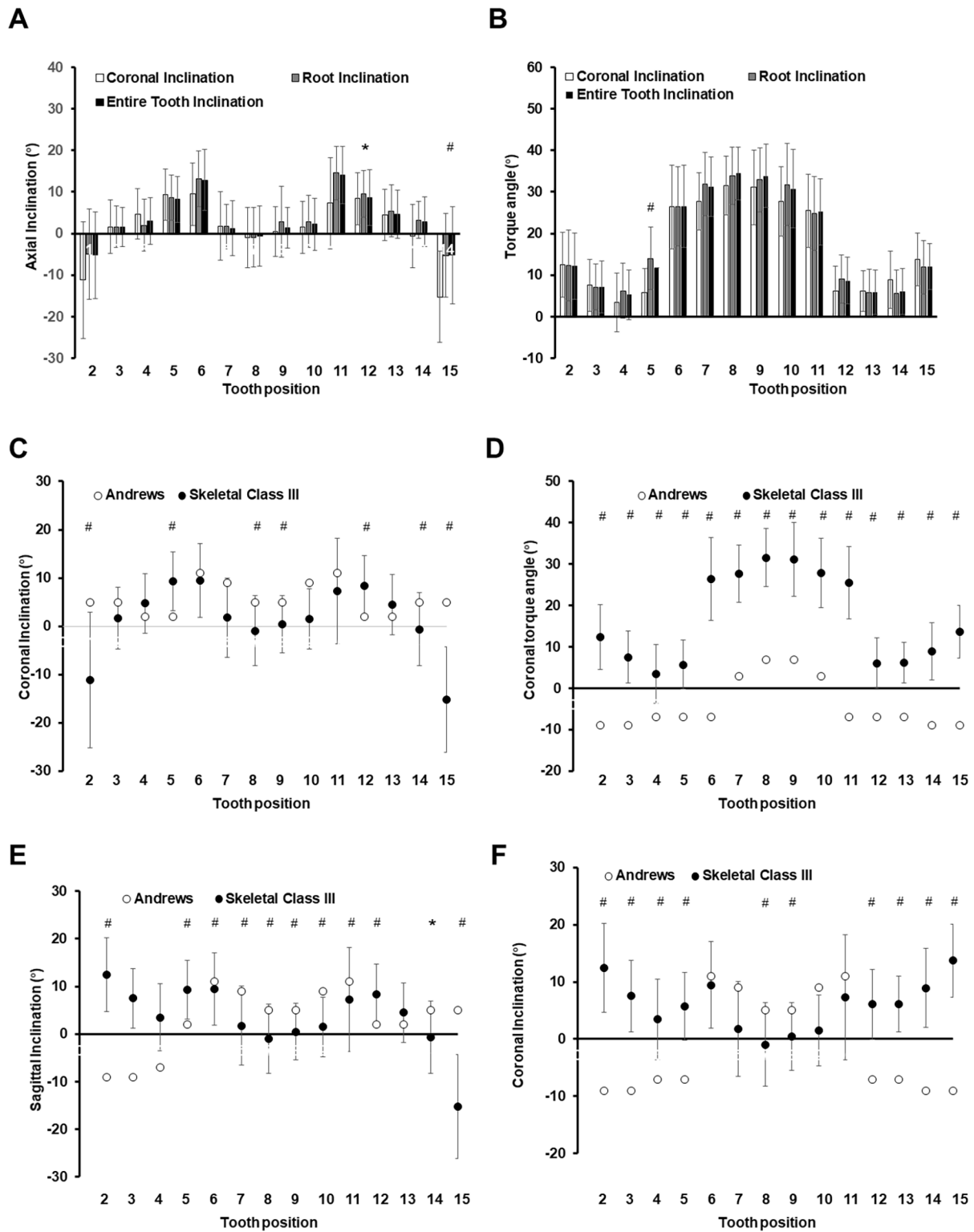


Figure 2: (A) Change in axial inclination of the maxillary tooth position for the skeletal class III malocclusion abnormality. (B) Change in torque angle of the maxillary tooth position for the skeletal class III malocclusion abnormality. (C) Comparison of the skeletal class III malocclusion with Andrew’s measurements for the maxillary coronal axial inclination. (D) Comparison of the skeletal class III malocclusion with Andrew’s measurements for the maxillary coronal torque angle. (E) Comparison between the skeletal class III malocclusion cases and the normal occlusion cases for sagittal inclination on the maxillary teeth. (F) Comparison between the skeletal class III malocclusion cases and the normal occlusion cases for the coronal inclination on the maxillary teeth.

the accuracy of the orthodontic treatment. In recent years, many authors have found that the bony cortex on the upper anterior labial side is thinner [1, 7]; thus, during the adduction of the orthodontic treatment, if the thickness of the bony cortex is breached, there are frequent occurrences of bone fenestrations and dehiscence [8]. Therefore, a pre-alert has been raised due to the medical risks. This phenomenon is related to the 3D diagnostics of the root position; therefore, it is of practical and clinical significance to accumulate data and establish, supplement, and complete the spatial coordinate system for malocclusion diagnosis. Currently, there are few reports in this field. This study was performed based on an earlier thematic group who provided an inclination conformity assessment of the coronal and root long axis of skeletal class III malocclusion cases [9]. Further investigations and analyses should be performed on the direction and magnitude of the sagittal and coronal inclination to determine the possible relation between the inclination of the teeth and the changes of the arch length/width [10]. Additionally, investigations to preliminarily explain the micro mechanism for the maxilla changes in skeletal class III malocclusion cases should be performed.

Earlier researchers found that there is good conformity for the long axis inclination/torque between the corona, root, and tooth body for skeletal class III malocclusion cases [9]. Therefore, this study utilized the coronal direction to represent the trend in both the root and tooth body direction (thus, the results omitted the segmental measurements and added curvature measurements of the compensational curve and the deepest point).

Our results revealed that in the skeletal class III cases, the axial inclination on the maxillary molars decrease, even with secondary molars in the negative direction. The axial inclination of the anterior molar increased, and the axial inclination of the anterior teeth decreased, but in the positive direction. This change is caused by the length dysplasia on the maxillary jaw bone and positional recession in skeletal class III malocclusion, leading to denture compensation, i.e., the anterior molar and anterior teeth “follow” the relatively forwarded mandibular denture to the mesio by “trying hard” to establish a normal occlusion. However, the molar compensation decreased in axial inclination even in the negative direction, implying the posterior maxillary base bone is crowded, and the distal drift of the molar is conservative.

Both the maxillary molar and anterior molar belong to the posterior tooth region, and they are important scaffolding units. In the skeletal class III case, the change of the axial inclination for the above two teeth is reversed, making the straight wire arch correction unfavorable for

scaffold protection. In addition, the increased positive torque of the anterior teeth tends to consume the biological molar scaffolding. The biological scaffolding concept was raised in the XU Tianmin’s PASS correction technique [11], and it may support the results of this study. The sequential scaffolding preparation concept in the TWEED technique also showed that the scaffolding preparation is conservative and is performed step-by-step [12]. The drive straight wire arch correction technique of Lin Jiuxiang also recommends not including the anterior molar in the correction regimen during the alignment phase, which substantiates the importance of protecting the biological scaffolding of the molar. Our results may serve as experimental evidence for the above correction technique.

From the coronal direction, all coronas in the skeletal class III cases occur in a distributing fashion relative to the frontal sagittal plane, i.e., the torque angle of the posterior teeth increases as the axial inclination of the anterior teeth decreases. This change is the expression of the width dysplasia on the maxillary jaw bone in skeletal class III malocclusion cases that leads to the denture compensation, implying that the transverse design of the arch in skeletal class III cases must be conservative. Otherwise, the vertical control and post-extension stability will be compromised.

5 Conclusion

To summarize, the characteristics of the maxillary denture in skeletal class III cases include the following: all coronas incline to the mesio/labial except for the molar, and all coronas disperse/incline away from the frontal sagittal plane. Therefore, the following clinical speculations can be made. 1) Sagittal and axial compensations prevail in the maxillary denture. 2) In the camouflaged treatment design for skeletal class III cases, the maxillary denture may have a limited the scope of movement, and the clinically popular compensational treatments, such as arch transversal extension, distal drift of the molar, and incisor labial extension, may influence the post-corrective stability. Thus, an orthodontic-occlusion integrated treatment may be a better fit for dental biology. 3) In the orthodontic treatment for skeletal class III cases, the protection of the biological scaffolding of the maxillary molar should be emphasized.

Acknowledgements: This work was supported by the Education and Teaching Reform Project of Guizhou Provincial Department of Education (No. 080701806).

Conflict of interest statement: Authors state no conflict of interest

References

- [1] Cappelozza JA, Guedes FP, Nary Filho H, Capelozza Filho L, Cardoso Mde A. Orthodontic decompensation in skeletal Class III malocclusion: redefining the amount of movement assessed by Cone-Beam Computed Tomography. *Dental press journal of orthodontics*. 2015;20(5):28-34
- [2] Sangcharearn Y, Ho C. Effect of Incisor Angulation on Overjet and Overbite in Class II Camouflage Treatment. A typodont study. *The Angle orthodontist*. 2007;77(6):1011-1018
- [3] McNamara JA, Jr., Seligman DA, Okeson JP. Occlusion, Orthodontic treatment, and temporomandibular disorders: a review. *Journal of orofacial pain*. 1995;9(1):73-90
- [4] Choi BH, Jin LH, Kim KH, Kang SA, Kang JH, Yoon SM, et al. Cystometric parameters and the activity of signaling proteins in association with the compensation or decompensation of bladder function in an animal experimental model of partial bladder outlet obstruction. *International journal of molecular medicine*. 2013;32(6):1435-1441
- [5] Shibata M, Nawa H, Kise Y, Fuyamada M, Yoshida K, Katsumata A, et al. Reproducibility of three-dimensional coordinate systems based on craniofacial landmarks: a tentative evaluation of four systems created on images obtained by cone-beam computed tomography with a large field of view. *The Angle orthodontist*. 2012;82(5):776-784
- [6] Park HS, Lee JH. A comparative study on the location of the mandibular foramen in CBCT of normal occlusion and skeletal class II and III malocclusion. *Maxillofacial plastic and reconstructive surgery*. 2015;37(1):25
- [7] Sun B, Tang J, Xiao P, Ding Y. Presurgical orthodontic decompensation alters alveolar bone condition around mandibular incisors in adults with skeletal Class III malocclusion. *International journal of clinical and experimental medicine*. 2015;8(8):12866-12873
- [8] Azamian Z, Shirban F. Treatment Options for Class III Malocclusion in Growing Patients with Emphasis on Maxillary Protraction. *Scientifica*. 2016;2016:8105163
- [9] Shen JW, He FM, Jiang QH, Shan HQ. [Measurement of facial bone wall thickness of maxillary anterior teeth and premolars on cone beam computed tomography images]. *Zhejiang da xue xue bao Yi xue ban = Journal of Zhejiang University Medical sciences*. 2012;41(3):234-238
- [10] Kim YI, Choi YK, Park SB, Son WS, Kim SS. Three-dimensional analysis of dental decompensation for skeletal Class III malocclusion on the basis of vertical skeletal patterns obtained using cone-beam computed tomography. *Korean journal of orthodontics*. 2012;42(5):227-234
- [11] Xu TM, Zhang X, Oh HS, Boyd RL, Korn EL, Baumrind S. Randomized clinical trial comparing control of maxillary anchorage with 2 retraction techniques. *American journal of orthodontics and dentofacial orthopedics : official publication of the American Association of Orthodontists, its constituent societies, and the American Board of Orthodontics*. 2010;138(5):544 e1-9; discussion -5
- [12] Klontz HA. Tweed-Merrifield sequential directional force treatment. *Seminars in orthodontics*. 1996;2(4):254-267