Original Article

Determination of genial tubercle position and dimensions using cone-beam computerised tomography

Shilpa Agarwal*, Isha Gaurav**, Rajesh Agarwal#, Karamdeep Singh Ahluwalia#

Abstract

Objective: To evaluate the position and dimensions of the genial tubercle.

Study Design: Cone-beam computed tomography (CT) records of 36 adult patients with Class I or Class II skeletal type were used to evaluate the position and dimensions of the genial tubercle and dimensions of the anterior mandible. Subjects were grouped by sex and skeletal type.

Results: In all groups, the genial tubercle width was close to the genial tubercle height. The distance from the inferior border of the genial tubercle to the inferior border of the mandible was greater in Class II male patients than in Class I female patients ($p < 0.05$). The anterior mandible in Class I male patients was thicker than in Class II female patients ($p < 0.05$).

Conclusions: The variable position and dimensions of this structure among patients suggest the need for cone-beam CT before attempting genioglossus advancement to treat obstructive sleep apnoea.

Key words: Cone-beam computed tomography; mandible; osteotomy; sleep apnea syndromes; tongue.

Introduction

Genioglossus advancement using box osteotomy was first described in 1984 for the treatment of obstructive sleep apnoea. The rationale for the procedure was to increase tension on the genioglossus muscle, preventing posterior collapse during sleep [1]. Subsequently, others reported similar procedures with modifications in osteotomy design, including circular osteotomy, box osteotomy with advancing genioplasty (2-piece), and reversed T osteotomy [2-5].

The effectiveness of these procedures has been validated repeatedly, although the degree of success has varied. In addition to careful case selection, the effectiveness of genioglossus advancement can be improved by accurately capturing the bone segment attached to the genioglossus muscle. The advancement is also challenged by the need to avoid mandible fracture and prevent dental root damage. These issues are determined by the anatomic structure of the anterior mandible, including the genial tubercle, an anatomic structure with most of the genioglossus muscle attachment, lower anterior teeth and symphysis region.

Thus, surgeons need accurate measurements of these structures to aid in preoperative planning. Many radiographic studies have been advocated, including panoramic radiographs, lateral cephalometric radiographs, periapical radiographs, and computed tomography. Cone-beam computed tomography (CBCT) is a relatively new radiology technology that offers significantly less radiation exposure than conventional computed tomography [6]. It has been used in the dental field to assess maxillofacial bone thickness and height in preparation for dental

*Department of Conservative Dentistry & Endodontics; **Department of Oral Diagnosis, Medicine and Oral Radiology; #Department of Orthodontics; Jaipur Dental College, Jaipur, India
Corresponding Author: Dr. Shilpa Agarwal, Professor, Department of Conservative Dentistry & Endodontics, Jaipur Dental College, Jaipur, India. Tel: +91-9314504846, E-mail: drrajeshagarwal@hotmail.com
Received: 15-10-2012 | **Accepted:** 24-10-2012 | **Published Online:** 30-10-2012

Conflict of interest: None declared | **Source of funding:** Nil | **DOI:** http://dx.doi.org/10.7713/ijms.2012.0064

implants [7,8].

Similarly, it is critical to accurately identify the genial tubercle, lower anterior teeth, and inferior border of the mandible in preparation for genioglossus advancement to manage obstructive sleep apnoea [9]. The purpose of this study was therefore to use CBCT to measure the position and dimensions of genial tubercles and dimensions of anterior mandibles as a reference to assist surgeons in designing an osteotomy.

Materials & methods

This study was approved by the Institutional Review Board. All measurements were taken from previously obtained cone-beam CT scans for evaluation of orthodontic or orthognathic treatment meeting the following selection criteria:

(1) Adult (>18 years) men and women

(2) Class I or Class II skeletal type

(3) No congenital craniofacial anomaly

(4) Intact anterior mandibular dentition

(5) No bone surgery on the anterior mandible.

All images were obtained from KODAK 3-D CBCT scan with 14-bit grayscale resolution and voxel size 0.4 mm^3. To standardise the measurements, scans were orientated so the bilateral zygomatic structures were at the same level in the axial view. The infraorbital foramen of right and left sides were parallel to the horizontal line in the coronal view. In the sagittal view, the Frankfort plane represented the true horizontal axis. Six variables were measured with KODAK software by one investigator (IG), including (1) genial tubercle height (GTH), (2) genial tubercle width (GTW), (3) distance from apices of lower incisors to superior border of genial tubercle (LI-SGT), (4) distance from inferior border of genial tubercle to inferior border of mandible (IGT-IBM), (5) thickness of anterior mandible (MT), and (6) Inter-canine distance at the level of 5 mm below the lower incisor apices (ICD) (Figure 1).

When the canine roots were not shown at 5 mm below the lower incisor apices, these patients had no records of ICD. To reduce measurement error, all measurements were repeated on three separate occasions at weekly intervals and the average values were recorded.

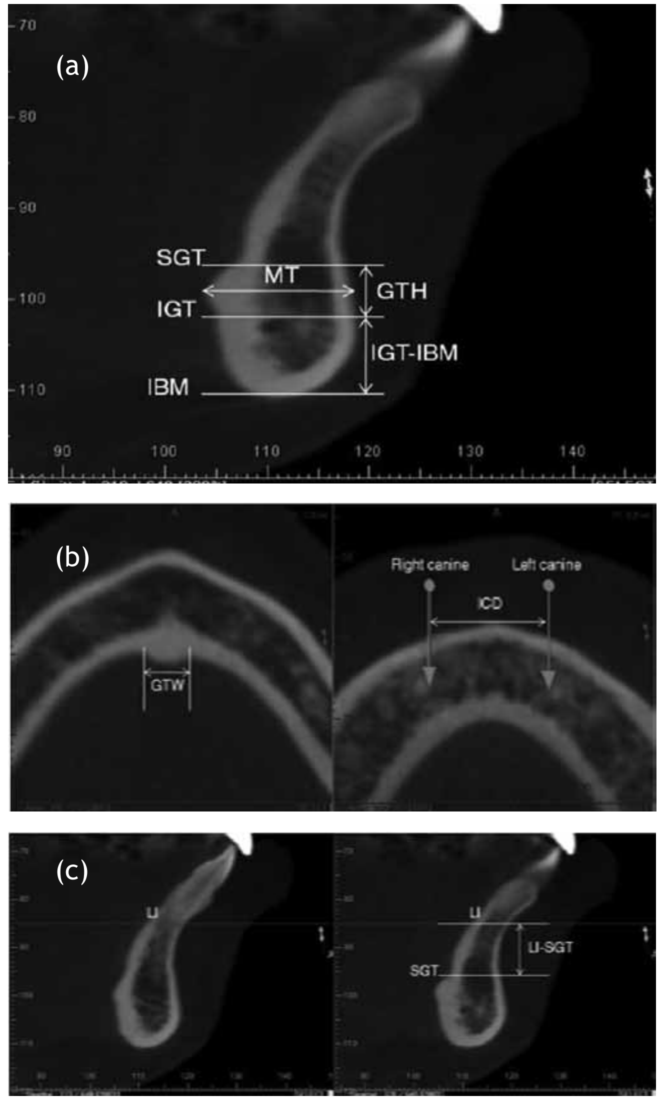

Figure 1- Cone-beam CT scan showing various measurements (a) MT, GTH and IGT-IBM, (b) LI-SGT (c) GTW and ICD

[MT = thickness of anterior mandible, SGT = superior border of genial tubercle, IGT = inferior border of genial tubercle, GTH = genial tubercle height (distance from SGT to IGT), IBM = inferior border of mandible, IGT-IBM = distance from IGT to IBM, LI = apices of lower incisors, LI-SGT = distance from LI to SGT, GTW = genial tubercle width; ICD = intercanine distance at 5 mm below the lower incisor apices.]

After measurements were taken, the subjects were divided into groups according to their sex and skeletal type: group 1 (n=9), skeletal Class I males;

group 2 (n=9), skeletal Class II males; group 3 (n=9), skeletal Class I females; and group 4 (n=9): skeletal Class II females. Skeletal type (Class I or Class II) was determined by measuring the ANB angle of Steiner's Analysis (point A-Nasion-point B) angle on lateral cephalograms created with KODAK software. Differences between various groups were analysed by ANOVA and Kruskal-Wallis tests respectively, for parametric (GTH, GTW, LI-SGT, IGT-IBM, MT) and non-parametric (ICD) variables. Statistical analyses were carried out using SPSS software version 17.0 (Chicago,IL, USA). The p-values were two-tailed and the level of significance was set at< 0.05.

Results

The average measurements of genial tubercle position and dimensions are summarised in Table 1. The ranges of measurements were GTH (6.3-7.2 mm), GTW (7.0-8.4 mm), LI-SGT (6.9-8.8 mm), IGT-IBM (6.2-8.4 mm), MT (12.3-14.2 mm), and ICD (17.2-18.8 mm). GTH, GTW, LI-SGT, and ICD did not differ significantly among groups (ANOVA, $p > 0.05$), but IGT-IBM and MT were significantly different (ANOVA, $p = 0.02$ for both). Individual group comparisons for these two parameters revealed that IGT-IBM was greater in Class II male patients than in Class I female patients ($p < 0.05$), while MT in Class I male patients was thicker than in Class II female patients ($p < 0.05$).

Discussion

This retrospective study using CBCT demonstrated that genial tubercles varied in position and dimensions among subjects. Subjects also differed in anterior mandible morphology by gender and skeletal type. This study, unlike previous studies [10-12] recruited only subjects with Class I or Class II skeletal type because these profiles are typical of patients with obstructive sleep apnoea.

Genioglossus advancement has four major requirements: (1) preventing dental root damage, (2) incorporating most of the genioglossus muscle, (3) avoiding mandible fracture, and (4) maximising the amount of genioglossus advancement. First, the upper horizontal cut of osteotomy should be at least 5 mm away from the lower incisor apices to avoid root damage and devitalisation of the teeth [10,13]. Although the mean LI-SGT ranged from 6.9 to 8.8 mm in this study, 12% of subjects had LI-SGT less than 5 mm. The mean measures for LI-SGT are lower than those reported by Mintz et al [11], who found the mean LI-SGT of 41 human skulls was 6.9±8.8 mm with a range of 1 to 14 mm. In their study, 35% of the genial tubercles were less than 5 mm from the lower incisors. Thus, measurements of LI-SGT seem to have been overestimated, resulting in fewer patients having greater risk of root damage. However, the mean LI-SGT reported for 10 Caucasian cadavers was 11.8 mm [10] and for 40 Chinese cadavers was 15.6 mm in males and 9.4 mm

Table 1- Comparison of genial tubercle position and dimensions (mm) among groups.

Various measurements	Group-1 (n=9)	Group-2 (n=9)	Group-3 (n=9)	Group-4 (n=9)	P value
GTH	7.3 ± 2.3	6.5 ± 1.7	7.9 ± 1.9	6.7 ± 1.9	0.83
GTW	8.2 ± 1.5	7.8 ± 1.6	7.4 ± 1.5	7.1 ± 1.6	0.74
LI-SGT	8.2 ± 2.9	9.1 ± 3.2	7.1 ± 3.0	8.0 ± 2.6	0.10
IGT-IBM	8.2 ± 2.3	8.4 ± 2.3	6.4 ± 2.3	7.9 ± 2.2	0.02
MT	14.6 ± 2.9	13.3 ± 1.7	13.1 ± 1.4	12.7 ± 2.1	0.02
ICD	19.1 ± 3.0	17.5 ± 3.4	17.6 ± 1.3	18.0 ± 2.0	0.50

GTH: genial tubercle height; GTW: genial tubercle width; LI-SGT: distance from apices of lower incisors to superior border of genial tubercle; IGT-IBM: distance from inferior border of genial tubercle to inferior border of mandible; MT: thickness of anterior mandible; ICD: intercanine distance at the level of 5 mm below the lower incisor apices.

in females [12]. Surgeons have to be very cautious with the upper horizontal cut of osteotomy in patients whose genial tubercles are located within the danger zone; however, violating the 5-mm safe zone is unavoidable for adequate performance of genioglossus advancement. Similarly, in reverse T osteotomy, the lower horizontal cuts should be at least 5 mm from the lower canine apices.

Second, the vertical cuts of osteotomy should be lateral to the genial tubercle and medial to bilateral canine roots. In this study, the mean GTW ranged from 7.0 to 8.4 mm. The mean ICD ranged from 17.2 to 18.8 mm. Almost half the subjects had canine roots that could not be seen at 5 mm below the lower incisor apices, which implies that the canine roots of these patients were at a relatively safe distance from damage. Although the mean GTW in this study was wider than the mean GTW (6.0 mm) reported by Mintz et al [11], the genial tubercles were still at considerably safe distances from the vertical cuts to the canine roots.

Third, the lower horizontal cut of box osteotomy should be at least 10 mm above the inferior border of the mandible to prevent mandible fracture [13]. This cut has been suggested by others to be approximately 5 to 6 mm above the inferior border of the mandible [14]. The mean IGT-IBM in this study was only 6.2 to 8.4 mm, suggesting a higher risk of mandible fracture due to lack of sufficient bone height. Indeed, the measurement is much less than the 11 mm reported by a Chinese cadaver study [12]. This discrepancy might be attributed to our study including only patients of skeletal Class I and Class II. It was also found that Class II males had greater IGT-IBM than Class I females (8.4 mm vs. 6.4 mm), suggesting that Class II males have an advantage in terms of avoiding mandible fracture.

Fourth, the amount of genioglossus advancement should be as great as possible and depends on the mandible thickness at the fixation point. In this study, the mean MT ranged from 12.3 to 14.2 mm, similar to previous reports of 12.6 mm [10] and 12.0 mm [12]. It was also found that Class I males had thicker anterior mandibles than Class II females (14.6 mm vs. 12.7 mm), suggesting that Class I males have an advantage in terms of maximal amount of genioglossus advancement.

To fulfill the major requirements for genioglossus advancement, surgeons should use very thin saws for osteotomy and stabilise the advanced segment with rigid internal fixation. To guide a precise osteotomy cut, patients should be prepared preoperatively by the cone-beam CT measurements, as have been analysed in this study.

However, direct observation of the range of muscle attachments near the genial tubercle is still required on the table during surgery because the genial tubercles in a study done on Chinese skulls showed that 8% of 40 skulls were shown to have 2-mm horizontal extensions of the genioglossus muscle attachments [12].

To conclude, CBCT is a non-invasive method to evaluate the position and dimensions of the genial tubercle. The variability in its position and dimensions among different types of patients emphasises the need for CBCT before attempting genioglossus advancement to treat Obstructive Sleep Apnoea. When performing this procedure, surgeons should also consider potential differences in anterior mandible morphology by gender and skeletal type.

Key Points

- It is critical to accurately identify the genial tubercle, lower anterior teeth, and inferior border of the mandible in preparation for genioglossus advancement to manage obstructive sleep apnoea.
- This study suggests that Cone-beam CT can be used as a non-invasive method to evaluate the position and dimensions of the genial tubercle.

References

1. Riley R, Guilleminault C, Powell N, Derman S. Mandibular osteotomy and hyoid bone advancement for obstructive sleep apnea: a case report. Sleep 1984;7:79-82.
2. Riley RW, Powell NB, Guilleminault C. Obstructive sleep apnea syndrome: a review of 306 consecutively treated surgical patients. Otolaryngol Head Neck Surg 1993;108:117-25.

3. Troell RJ, Riley RW, Powell NB, Li K. Surgical management of the hypopharyngeal airway in sleep disordered breathing. Otolaryngol Clin North Am 1998;31:979-1012.
4. Hendler B, Silverstein K, Giannakopoulos H, Costello BJ. Mortised genioplasty in the treatment of obstructive sleep apnea: an historical perspective and modification of design. Sleep Breath 2001;5:173-80.
5. Riley RW, Powell NB, Guilleminault C. Inferior sagittal osteotomy of the mandible with hyoid myotomy-suspension: a new procedure for obstructive sleep apnea. Otolaryngol Head Neck Surg 1986;94:589-93.
6. Loubele M, Bogaerts R, van Dijck E, Pauwels R, Vanheusden S, Suetens P, et al. Comparison between effective radiation dose of CBCT and MSCT scanners for dentomaxillofacial applications. Eur J Radiol 2009;71:461-8.
7. Fatemitabar SA, Nikgoo A. Multichannel computed tomography versus cone-beam computed tomography: linear accuracy of in vitro measurements of the maxilla for implant placement. Int J Oral Maxillofac Implants 2010;25:499-505.
8. Miller RJ, Edwards WC, Boudet C, Cohen JH. Maxillofacial anatomy: the manibular symphysis. J Oral Implantol 2011:37:745-53.
9. White DP. Pathogenesis of obstructive and central sleep apnea. Am J Respir Crit Care Med 2005;172:1363–70.
10. Silverstein K, Costello BJ, Giannakpoulos H, Hendler B. Genioglossus muscle attachments: an anatomic analysis and the implications for genioglossus advancement. Oral Surg Oral Med Oral Pathol Oral Radiol Endod 2000;90:686-8.
11. Mintz SM, Ettinger AC, Geist JR, Geist RY. Anatomic relationship of the genial tubercles to the dentition as determined by cross-sectional tomography. J Oral Maxillofac Surg 1995;53:1324-6.
12. Yin SK, Yi HL, Lu WY, Guan J, Wu HM, Cao ZY, et al. Anatomic and spiral computed tomographic study of the genial tubercles for genioglossus advancement. Otolaryngol Head Neck Surg 2007;136:632-7.
13. Li KK, Riley RW, Powell NB, Troell RJ. Obstructive sleep apnea surgery: genioglossus advancement revisited. J Oral Maxillofac Surg 2001;59:1181-4.
14. Dattilo DJ, Aynechi M. Modification of the anterior mandibular osteotomy for genioglossus advancement with hyoid suspension for obstructive sleep apnea. J Oral Maxillofac Surg 2007;65:1876-9.
15. Hueman EM, Noujeim ME, Langlais RP, Prihoda TJ, Miller FR. Accuracy of cone beam computed tomography in determining the location of the genial tubercle. Otolaryngol Head Neck Surg 2007;137:115-8.