Journal of the Anatomical Society of India 65 (2016) 9–14

Contents lists available at ScienceDirect

Journal of the Anatomical Society of India

journal homepage: www.elsevier.com/locate/jasi

Original Article

A study on coronoid process of the dry adult human mandibles

PA Kasat *, PS Bhuiyan

Department of Anatomy, Seth G.S.M.C. & K.E.M. Hospital, Parel, Mumbai, Maharashtra 400012, India

ARTICLE INFO

Article history:
Received 17 January 2016
Accepted 26 July 2016
Available online 6 August 2016

Keywords:
Coronoid process
Variations
Reconstructive maxillofacial surgeries
Forensics
Anthropometry

ABSTRACT

Introduction: The coronoid process of mandible is of great clinical significance to maxillofacial surgeons for reconstructive purposes. Its variations can result in extremely narrow vestibular space, due to close proximity of the medial aspect of coronoid process to distal molar tooth. It is suitable for paranasal augmentation with the advantages of biocompatibility, availability and reduced operation time for harvesting. The knowledge of its variations is very helpful in anthropological and forensic practice. The present study was aimed to measure various dimensions of coronoid process and its variations in human mandible.

Method: The study was conducted on hundred dry human mandibles. Following parameters of coronoid process were studied: shape, width and height at its base and relation to the condylar process.

Results: Taking into consideration of both sides, the shape of coronoid process was hooked in 54.5%, triangular in 23.5% and rounded in 18.5% of the mandibles. Variant shapes were also observed like square (0.5%), hook & round (3%). The width of coronoid process on right side ranged from 13 to 28 mm with a mean of 19.30 ± 2.9 mm and on left side ranged from 10 to 28 mm with a mean of 19.1 ± 3.08 mm. The height of coronoid process on right side ranged from 11 to 27 mm with a mean of 18.2 ± 3.44 mm and on left side ranged from 11 to 27 mm with a mean of 18.0 ± 3.36 mm. Coronoid process was higher than condylar process bilaterally in 3 mandibles.

Conclusions: The morphologic and morphometric variations of coronoid process are clinically important for dental surgeons.

1. Introduction

The mandible is the largest, strongest and lowest bone of the face. This is the only bone in the skull, with the exception of tympanic ossicles, that is capable of separate movement. It is of special importance not only for chewing and speech but also in the esthetic appreciation of the face and its expressiveness.[1]

The mandible has a curved body that is convex forwards and two broad rami that ascend posteriorly. The rami has coronoid and condylar processes. The coronoid process is a thin, triangular eminence or a beak like projection, which is flattened from side to side, at the antero-superior aspect of the ramus. The largest portion of temporalis muscle is attached to the apex, whole of the medial surface and anterior part of lateral surface of the coronoid process. Rest of the lateral surface provides attachment to anterior fibers of masseter. These two are important muscles of mastication which show morpho-functional dependence.[1] The word coronoid process is derived from Greek "korone" means "like a crown". In lower animals separate coronoid bones are present which articulate with the splenial, angular, suprangular bones, etc. to form a common "dentary bone" which is homologous to mandible in humans. In humans, there is another "coronoid process" present in ulna and a "coronoid fossa" in humerus.[2]

The coronoid process is a membranous bone showing less resorption. A local bone graft from coronoid process of mandible can be harvested intraorally with minimal morbidity and without any cutaneous scarring. The coronoid process is of clinical significance to the maxillofacial surgeon for reconstructive purposes as it is used as grafts in reconstruction of osseous defects in oral and faciomaxillary region like alveolar defects, orbital floor repair, maxillary augmentation, correction of non-union fracture of mandible. No functional limitations are apparent after removing the coronoid process. The anatomical variations in coronoid process can result in extremely narrow vestibular space due to the close proximity of the medial aspect of the coronoid process to the distal molar. It seems to be suitable for paranasal

* Corresponding author at: c/o Dr. Gayatri Muthiyan, Flat No. 28, 4th Floor, Building No. 1, Government Colony, Near I.M.A. Hall, Haji Ali, Mumbai, Maharashtra 400034, India.
E-mail address: payalk554@yahoo.com (P.A. Kasat).

http://dx.doi.org/10.1016/j.jasi.2016.07.007
0003-2778/

augmentation. Its clinical application is also favorable because its size and morphology fits into the paranasal region, with the additional advantages of biocompatibility, availability and reduced operation time for harvesting.[3]

Literature search suggest varying form of coronoid process in adult human mandibles. Early back in 1915 Schafer[4,5] called it beak shaped process while Schulz in 1933[5] described it being S-shaped, undulant and low symmetrical. Sable like curvature of the process was interpreted as a manifestation of ageing.[5] Thereafter most authors like Hamilton,[6] Romanes,[7] Snell,[8] Basmajian and Slonecker,[9] have described it as triangular process. Presence of a double or second coronoid process has also been cited.[10] According to Isaac,[11] Prajapati et al.,[12] and Khan and Sharieff,[13] the process is triangular, hook and rounded. The coronoid process is large and project above the level of condyles at birth. Gradually with the growth of the neck of the mandible, condyles are at higher level in adulthood. Bilateral elongation of the coronoids of the mandible made of histologically normal bone goes more in favor of it being hyperplasic. This leads to a progressive, painless difficulty in opening the mouth; due to contact of coronoid process with the temporal surface of the zygomatic bone or medial surface of the zygomatic arch.

The shape and size of coronoid process is influenced by dietary habit, genetic constitution, hormonal activity and mainly by temporalis muscle activity.[14] Coronoid process enlargement may be seen in some pathological conditions like osteochondroma, exostosis, osteoma and other developmental anomalies.[14,15] Hernandez-Alfaro noticed a new joint between enlarged coronoid process and zygomatic bone (Jacob's disease) which causes restriction during mouth opening.[16] Though fracture of mandible is common, but coronoid fracture incidence is rare (2%) and requires no treatment unless impingement on the zygomatic arch is present.[2] The shape of coronoid process and lingula of mandible are very helpful in anthropological and forensic practice. This study was undertaken to note the forms of presentation and their prevalence in dry adult human mandibles. The variations of the coronoid process were observed and their photographs were taken for documentation.

The aim of this work was to study the morphology, morphometry and variations of the coronoid process in the dry adult human mandible.

The objectives of the study were:

1. To observe the shape of the coronoid process.
2. To measure the width of the coronoid process at its base.
3. To measure the height of the coronoid process from midbase to apex (tip).
4. To compare the results on the right and left sides.
5. To note any other variations if present.

2. Materials and methods

The study included 100 dry human mandibles of undetermined age and gender (as they were not recorded at the time of acquisition) procured from the Department of Anatomy, Seth G.S. Medical College, Parel, Mumbai, India from October 2012 to October 2014. They were kept free from any dust, moth or insect. Each mandible was assigned a serial number. The study was approved by the Institutional Ethics Committee. The results obtained were recorded and tabulated. The different parameters recorded were:

1. The shape of the coronoid process. It was classified into three types[2]:
   a) Triangular – tip pointing directly upwards (Fig. 1a).
   b) Rounded – tip rounded (Fig. 1b).
   c) Hook – tip pointing backwards (Fig. 1c).
2. The width of the coronoid process at its base (Fig. 2).

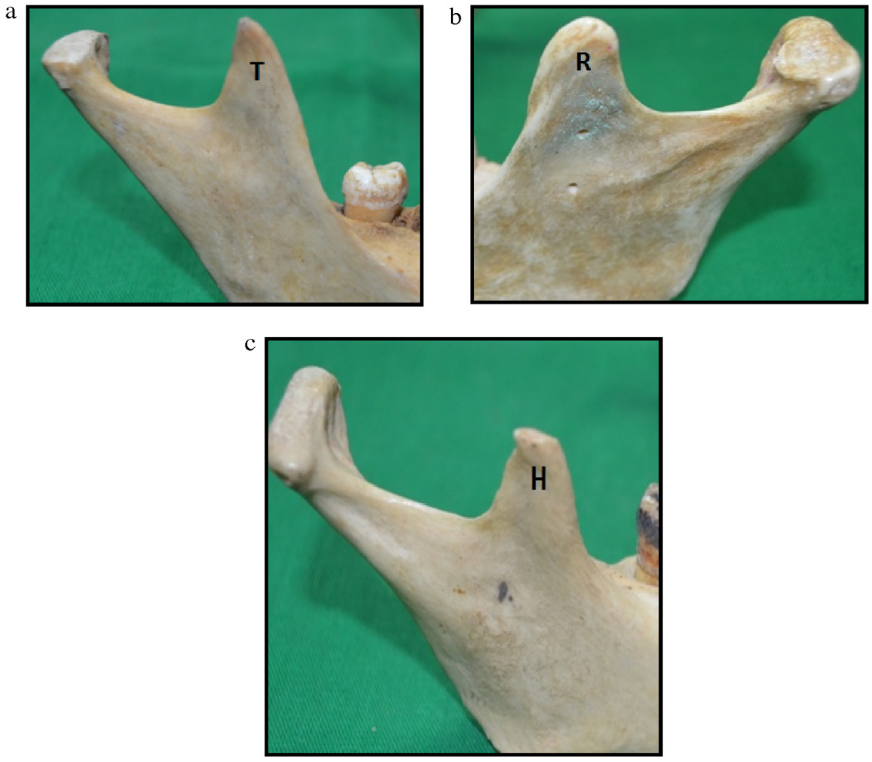

Fig. 1. (a) Illustration showing triangular coronoid process (T). (b) Illustration showing round shape coronoid process (R). (c) Illustration showing hook shaped coronoid process (H).

Fig. 2. Illustration showing measurement of width of coronoid process at its base.

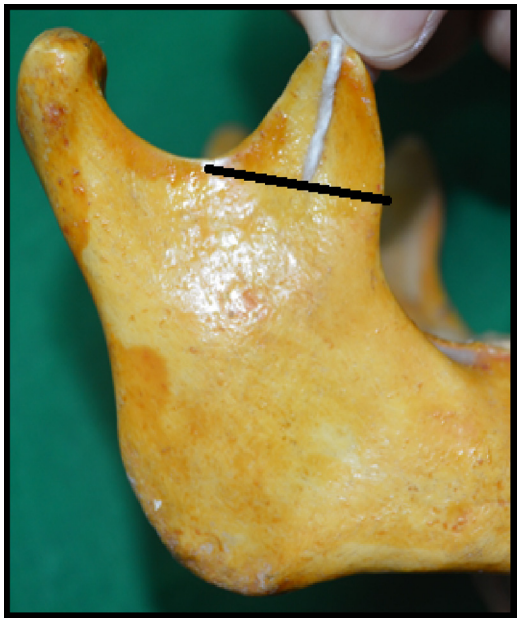

Fig. 3. Illustration showing measurement of height of coronoid process at its base (black line indicates base of the coronoid process).

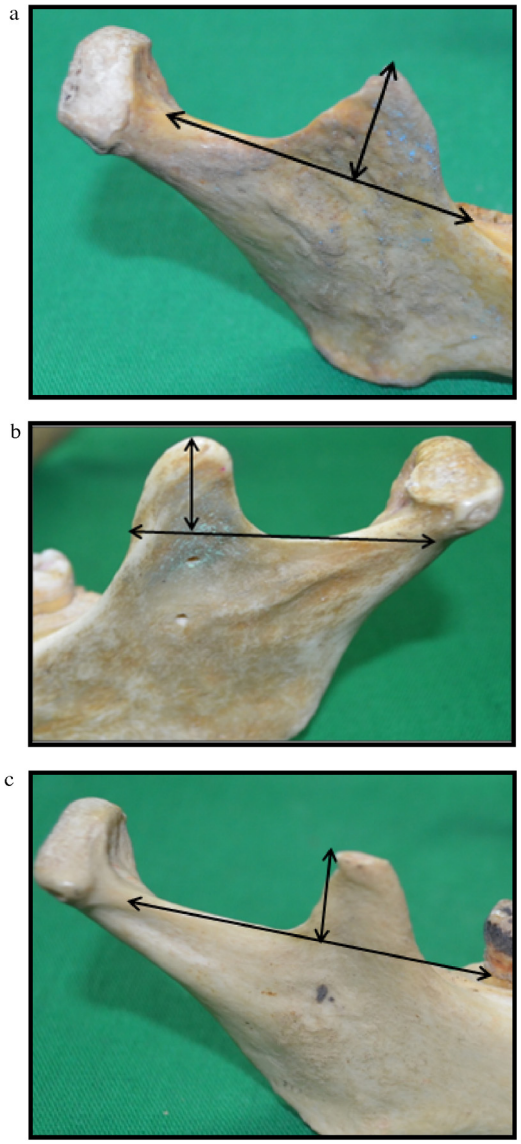

Fig. 4. (a) Illustration showing measurement of height of triangular coronoid process at its base (horizontal black line indicates base of the coronoid process and black line perpendicular to it is the height of coronoid process). (b) Illustration showing measurement of height of round coronoid process at its base (horizontal black line indicates base of the coronoid process and black line perpendicular to it is the height of coronoid process). (c) Illustration showing measurement of height of hook shaped coronoid process at its base (horizontal black line indicates base of the coronoid process and black line perpendicular to it is the height of coronoid process).

3. The height of the coronoid process from its midbase to its apex (Figs. 3 and 4a–c).
4. Any other variations.

For measurement of its width and height, the base of coronoid process was taken as the line tangential to the deepest part of mandibular notch.[2] The width and the height of coronoid process were measured using thread and then the thread was measured using a scale (Figs. 2 and 3). The height of the different shapes of coronoid process was measured as shown in Fig. 4a–c.

Inclusion criteria: All the mandibles available during the study period.

Exclusion criteria: Damaged mandibles, mandibles of pediatric age group and mandibles affected by pathology.

The data was statistically analyzed for the purpose of comparison and correlation by calculating the mean, range and standard deviation of width and height of coronoid process. Student's paired *t*-test with two-tailed distribution was applied for comparison of right and left values of different parameters. *p-value* < 0.05 was considered as statistically significant.

3. Results

The width of coronoid process on the right side ranged from 13 to 28 mm with a mean of 19.30 ± 2.9 mm. The width of coronoid process on the left side ranged from 10 to 28 mm with a mean of 19.1 ± 3.08 mm. There was statistically no significant difference

Fig. 5. Illustration showing square shaped coronoid process (S).

between right and left values of width of coronoid process. *p-value being 0.401* (*p*-value >0.05).

The height of coronoid process on the right side ranged from 11 to 27 mm with a mean of 18.2 ± 3.44 mm. The height of coronoid process on the left side ranged from 11 to 27 mm with a mean of 18.0 ± 3.36 mm. There was statistically no significant difference between right and left values of height of coronoid process. *p-value being 0.663* (*p*-value >0.05).

The shape of coronoid process was hook shaped in 54.5% (Fig. 1c), triangular in 23.5% (Fig. 1a) and round in 18.5% (Fig. 1b) of the mandibles considering both sides. Variant shapes like square in 0.5% (Fig. 5) and hook and round in 3% of the mandibles (Fig. 6) were also observed (Table 1).

Coronoid process was higher than the condylar process (Fig. 7a and b) bilaterally in three mandibles.

Table 1
Shape of the coronoid process

Side	Hook	Triangular	Round	Hook and round	Square
Right	53	22	22	2	1
Left	56	25	15	4	0
Total	109	47	37	6	1

4. Discussion

In the present study, hook shaped (54.5%) coronoid process is most prevalent followed by triangular (23.5%) and rounded (17.0%). This is in accordance with findings of Subbaramaiah et al.[5] and Hossain et al.[17] However, this differed from other studies which were notably from different parts of India. Apart from different shapes described in literature, variant shapes like square (0.5%), hooked and round (3%) are also observed in the present study. This data will be valuable for maxillofacial surgeons (Tables 1 and 2). In studies by Isaac et al.,[11] Khan and Sharieff,[13] Nirmale et al.,[18] Sudha et al.,[19] Tapas[20] and Desai et al.,[3] triangular shape of coronoid process was most prevalent followed by hook shaped and rounded. According to Prajapati et al.[12] and Pradhan et al.[21] hook shaped was the least prevalent shape of coronoid process. Isaac et al.[11] reported in a study of 157 mandibles incidence of hook shaped was 27.4%, triangular 49% and rounded type 23.6%. The author found the incidence of the rounded type almost equal in male and female mandibles, triangular type slightly more in the females, while hook type more in the male mandibles. Prajapati et al.[12] noted prevalence of rounded shape more in females compared to males while hook shape was similar in both genders. Khan and Sharieff[13] reported triangular process more commonly present in males while females presented with rounded type. In present study, gender differences were not taken into consideration. Diet has a vital role in affecting the muscular pull on the bony process and can alter the shape of coronoid process markedly. Occupation and hormones also has its effect. For example, basket makers who often use their mouth for weaving, tend to have a bigger coronoid process due to functional over

Fig. 6. Illustration showing hook and round shaped coronoid process (HR) of left side. *Note*: Coronoid process is higher than the condylar process and the width of the ramus of the mandible is more superiorly because of hook and round shaped coronoid process.

Fig. 7. (a) Illustration showing coronoid process being higher than the condylar process on the right side. *Note*: Bilaterally narrowed mandibular body in the region of premolars and anteroinferiorly rounded oblique lines bounding bilateral retromolar fossae. (b) Illustration showing coronoid process being higher than the condylar process on the left side. *Note*: Bilaterally narrowed mandibular body in the region of premolars and anteroinferiorly rounded oblique lines bounding bilateral retromolar fossae.

activity of the temporalis. The sample type chosen in different studies could be another reason for the varied results.[5] The inclusion of the other variant shapes in the present study is another possibility for altered results. However, such an inclusion was essential to segregate those mandibles with indistinct features which would otherwise increase the percentage of observer bias. In the present study such grouping and repeated reconfirmation of results has minimized the observation bias to a large extent.

In the present study, the mean width of the coronoid process on the right side is 19.3 mm and on the left side is 19.1 mm. This finding is similar to the value found by Lang.[22] They found that the mean width of the coronoid process on the right side was 20.4 mm and on the left side was 20.3 mm (Table 3).

In the present study, the mean height of the coronoid process on the right side is 18.2 mm and on the left side is 18.0 mm. Also, coronoid process was higher to condylar process in 3 mandibles. Chauhan and Dixit[14] reported coronoid process projecting much above the level of condyles on both sides in a mandible of late adulthood. They found that the height of the coronoid process on the right side was 24.0 mm and on the left side was 26.0 mm (Table 4).

At the time of birth, coronoid process projects above the level of condylar process. With growth, it comes to lie at lower level in adults. Bilateral hyperplasia of the coronoid processes of the mandible is less frequent mostly affecting males between the ages of 14 and 16 with male and female ratio of 5:1. Craniofacial development is a complex process. This requires the integration of multiple specialized tissues, such as the surface ectoderm, neural crest, mesoderm, and pharyngeal endoderm. Development of the lower jaw occurs mainly between the fourth and eighth weeks of gestation, from the paired mandibular prominences. All of these prominences are produced by the proliferation of the neural crest cells that migrate into the arches from the neural crest during the fourth week of gestation. Neural crest cells of the mandibular primordia come mainly from the region of the anterior rhombencephalon and give rise to the connective tissue components, including cartilage, bone and ligaments in the facial and oral regions.[14]

Factors causing disturbance in formation of lower jaw can lead to modification in morphology of mandible. For example, hyperactivity of the temporalis muscle causes reactive elongation of the coronoid process. Also, dysfunction of the temporomandibular joint caused by chronic disc displacement is related with cases of unilateral hyperplasia. It is mentioned as one of the causes of Jacob's disease. Other causes may include trauma, genetic and family factors. In one of the studies ankylosing spondylosis has

Table 2
Comparison of shape of the coronoid process with other studies

Study	Year	Country	Sample size	Types of coronoid process (%)		
				Triangular	Hook shaped	Rounded
Isaac et al.[11]	2001	India (Tamil Nadu)	157	49.0	27.4	23.6
Khan and Sharieff[13]	2011	South India	200	67.0	30.0	3.0
Hossain et al.[17]	2011 July	Bangladesh	140	29.7	45.0	25.4
Prajapati et al.[12]	2011 October	India (Gujarat)	120	54.2	21.3	24.6
Nirmale et al.[18]	2012	India (Maharashtra)	84	65.0	28.0	7.0
Sudha et al.[19]	2013	South India	125	60.8	25.6	14.0
Tapas[20]	2014 March	India (New Delhi)	50	60.0	22.0	18.0
Desai et al.[3]	2014	India (Karnataka)	100	68.0	24.0	16.0
Pradhan et al.[21]	2014 August	India (Orissa)	92	46.7	17.9	35.3
Subbaramaiah et al.[5]	2015	India (Bangalore)	100	14.0	61.5	12.5
Present study		India	100	23.5	54.5	17.0

Table 3
Comparison of width of the coronoid process with other studies

Study	Year	Country	Materials for study	Mean width of the coronoid process (in mm)
Lang[22]	1984	New York	Dry bones	R: 20.4 (range 14.5–25.5) L: 20.3 (range 14.0–26.0)
Present study		India	Dry bones	R: 19.3 (range 13.0–28.0) L: 19.1 (range 10.0-28.0)

Note: R, right side; L, left side.

Table 4
Comparison of height of the coronoid process with other studies

Study	Year	Country	Materials for study	Height of the coronoid process (in mm)
Chauhan and Dixit[14]	2011	India	Dry bone (Case report)	R: 24.0 L: 26.0
Present study		India	Dry bones ($n = 100$)	R: 18.2 L: 18.0

Note: R, right side; L, left side.

also been said to cause mandibular elongation (Bechterew disease).[14]

The excess growth of the coronoid processes results in impingement on the zygomatic processes leading to mandibular hypo mobility. The treatment is surgery by intraoral approach with removal of coronoid process on both sides. This gives access to the coronoid process, decreases morbidity to the facial nerve and avoids unsightly scarring. In case of zygomatic-coronoid ankylosis, submandibular approach is preferred. The coronal approach has also been described in cases of very elongated coronoid processes or associated lesions, such as osteochondroma. In each case the right surgical approach should be established.[14] Early post-operative rehabilitation has to be done with physiotherapeutic techniques.[14,15] Fernandez et al. recommend the constant use of TheraBite® over 3–6 months. It is a simple manual physiotherapy device, with two padded, horseshoe shaped contact surfaces, which distribute the stress evenly over the 10 front teeth of each jaw. This exerts less pressure on the incisors and decreases the risk of damage to the teeth. The action works through a combination of stretching and passive movements, increasing mandibular opening and mobility and avoiding overloading the joint.[15]

Autologous, allograft or synthetic bone grafts can be obtained by different approaches. An autologous bone graft is taken from a part of the patient's body and can be used in another part of same person. In this way, complications such as infection, bleeding, and tissue damage is lower than allografts and so this method is preferred by surgeons. Graft bone is usually harvested from iliac crest, rib or calvarium. If injured area is small, the coronoid process can be used as a graft material. The coronoid process graft has some advantages as discussed earlier. It is valuable to know that available dimensions of issued bone are adequate before the grafting operations.[23]

5. Conclusions

The variations in the shape of coronoid process are clinically important for dental surgeons. Coronoid process hyperplasia as the cause of mandibular hypo mobility is largely under diagnosed as it is a very rare entity, but a thorough clinical and radiological examination can help to rationalize the line of management and the ultimate clinical outcome. Knowledge of the morphological shapes of the coronoid process is useful for the maxillofacial surgeon. It makes an excellent donor graft site for reconstruction of orbital floor deformities.[24] Clauser et al.[25] reported the use of a temporalis myofascial flap both as a single and as composite flap with cranial bone, coronoid process or skin island in all aspects of reconstructive craniomaxillofacial surgery including trauma, deformities, tumors, temporomandibular joint ankylosis and facial paralysis.[25] It is hoped that the findings of the study will be of great help to dental surgeons, anthropologists and forensic practitioners.

Conflicts of interest

The authors have none to declare.

References

1. Collins P. Infratemporal and Pterygopalatine Fossae and Temporomandibular Joint. In: Standring S, ed. In: *Gray's Anatomy: The Anatomical Basis of Clinical Practice* 40th ed. New York: Elsevier Churchill Livingstone; 2008:527–560.
2. Nayak S, Patra S, Singh G. Study of the size of the coronoid process of mandible. *IOSR J Dent Med Sci.* 2015;14(6):66–69.
3. Desai VC, Desai SD, Shaik HS. Morphological Study of Mandible. *J Pharm Sci Res.* 2014;6(4):175–177.
4. Schafer EA, Thane GD. *Quain's Elements of Anatomy*. 10th ed. London: Longmans, Green & Co.; 1980:60.
5. Subbaramaiah M, Bajpe R, Jagannatha SR, Jayanthi KS. A study of various forms of mandibular coronoid process in determination of sex. *Indian J Clin Anat Physiol.* 2015;2(4):199–203.
6. Hamilton WJ. *Textbook of Human Anatomy*. 2nd ed. London: Macmillan; 1976:80.
7. Romanes GJ. Head and neck.In: *Cunningham's Manual of Practical Anatomy*. 15th ed. Singapore: Oxford University Press; 1986:12.
8. Snell RS. Head and neck.In: *Clinical Anatomy for Medical Students*. 3rd ed. Boston: Little Brown and Company; 1986:773.
9. Basmajian JV, Slonecker CE. *Grant's Method of Anatomy*. 11th ed. Baltimore, London: Williams & Wilkins; 1989:516.
10. Kansu H, Kansu O, Akgunlu F. Bifid coronoid process. *Oral Surg Oral Med Oral Pathol.* 1994;78(2):136.
11. Isaac B, Holla SJ. Variations in the shape of the coronoid process in the adult human mandible. *J Anat Soc India.* 2001;50(2):137–139.
12. Prajapati VP, Ojaswini Malukar O, Nagar SK. Variations in the Morphological Appearance of the Coronoid Process of Human Mandible. *Nat J Med Res.* 2011;1:64–66.
13. Khan TA, Sharieff JH. Observation on morphological features of human mandibles in 200 south Indian subjects. *Anat Karnataka.* 2011;5(1):44–49.
14. Chauhan P, Dixit SG. Bilateral elongated coronoid processes of mandible: a case report. *Int J Anat Var.* 2011;4:25–27.
15. Fernandez FM, Fernandez SJ, Sandoval GJ, Costas LA, Lopez de SA, Etayo PA. Treatment of Bilateral Hyperplasia of the Coronoid Process. *Med Oral Patol Oral Cir Bucal.* 2008;13:595–598.
16. Hernández-Alfaro F, Escuder O, Marco V. Joint formation between an osteochondroma of the coronoid process and the zygomatic arch (Jacob disease): report of case and review of literature. *J Oral Maxillofac Surg.* 2000;58(February (2)):227–232.
17. Hossain SMA, Hossain SMM, Banna FAMH. Variations in the Shape of the Coronoid Process in the Adult Human Mandible. *Bangladesh J Anat.* 2011;9(July (2)):75–78.
18. Nirmale VK, Mane UW, Sukre SB, Diwan CV. Morphological features of human mandible. *Int J Recent Trends Sci Technol.* 2012;3(2):38–43.
19. Sudha R, Chandrasekaran S, Aruna N. Study of Morphological Variations in the Shape of Coronoid Process of Mandible in South Indian Population. *Int J Curr Res Rev.* 2013;5(May (10)):84–92.
20. Tapas S. Morphological Variations of Coronoid Process in Dry Adult Human Mandibles. *Indian J Basic Appl Med Res.* 2014;3(March (2)):401–405.
21. Pradhan S, Bara DP, Patra S, Nayak S, Mohapatra C. Anatomical study of various shapes of mandibular coronoid process in relation to gender & age. *IOSR J Dent Med Sci.* 2014;13(August (8)):9–14.
22. Lang J. *Clinical Anatomy of the Masticatory Apparatus and Peripharyngeal Spaces*. New York: Thieme Medical Publishers, Inc.; 1995:19–39.
23. Bakirci S, Ari I, Kafa IM. Morphometric characteristics and typology of the coronoid process of the mandible. *Acta Med Mediter.* 2013;29:683–686.
24. Mintz SM, Ettinger A, Schmakel T, Gleason MJ. Contralateral coronoid process bone grafts for orbital floor reconstruction: an anatomic and clinical study. *J Oral Maxillofac Surg.* 1998;56(10):1140–1145.
25. Clauser L, Curioni C, Spanio S. The use of the temporalis muscle flap in facial and craniofacial reconstructive surgery. A review of 182 cases. *J Craniomaxillofac Surg.* 1995;23(4):203–214.