ISSN 2347-5579

Unique Journal of Medical and Dental Sciences

Available online: www.ujconline.net

Research Article

# MORPHOMETRIC STUDY OF THE ARTICULAR FACETS OF ATLAS AND AXIS VERTEBRAE

Kaur Jasveen[1]*, Grewal Harsimran[2], Singh Poonam[3], Kumar Ajay[4]

Assistant Professor, Department of Anatomy, PIMS Jalandhar
Assistant Professor, Laxmi Bai College of Dental Sciences, Patiala
Professor and Head, Department of Anatomy, DMCH Ludhiana
Associate Professor, Department of Anatomy, DMCH Ludhiana

Received: 15-02-2014; Revised: 13-03-2014; Accepted: 11-04-2014

*Corresponding Author: **Dr Jasveen Kaur**
Assistant Professor, Department of Anatomy, PIMS, Garha Road, Jalandhar. Punjab, E-mail: jsvn.kr@gmail.com Mob: 9888911314

## ABSTRACT

**Introduction:** Atlantoaxial region shows variable anatomy and there are vital neurovascular structures in its proximity. Knowledge of this variability is important for neurosurgeons, orthopaedicians, etc, who in everyday practice are in contact with disorders of the spine and their consequences. Keeping this in mind a morphometric study was carried out on atlas and axis vertebrae.
**Methods:** Hundred dried human atlas and axis vertebrae (50 each) available in the Department of Anatomy, DMCH Ludhiana, were studied.
**Results:** Atlas vertebra: The mean of maximum anteroposterior diameter (max.APD) and maximum transverse diameter (max.TD) of superior articular facet (SAF) was measured bilaterally, as 21.52mm±2.36 and 11.21mm±1.47 on right side, 21.51mm± 2.07and 11.32mm±1.53 on left side. On right side, the mean of max.APD and max.TD of inferior articular facet(IAF) was measured as 17.54mm±1.50 and 14.99mm±1.65 and on left side as 17.70mm±1.60 and14.94mm±1.51,respectively.
Axis vertebra: The mean of max.APD and max.TD of SAF was measured as 17.42mm±1.73 and 15.31mm±1.44 on right side, 17.64mm±1.51 and 15.17mm±1.48 on left side. On right side the mean of max.APD and max.TD of IAF was measured as 11.54mm±1.66 and 9.23mm±1.70, and on left side as 12.14mm±1.58 and 9.41mm±1.61, respectively.
**Conclusion:** Transarticular screw fixation has become one of the primary treatment options for C1-C2 instability. The trajectory and angulation while screw placements is crucial because of the surrounding neurovascular structures. The knowledge of these dimensions can provide useful information for safe planning of osseous fixation.
**Keywords:** Atlantoaxial Joint, Atlas Vertebra, Axis Vertebra, Transarticular Screw.

## INTRODUCTION

The complex structure of the cranio-vertebral junction plays a significant role in global kinematics of the cervical spine to maintain head in upright posture[1] . The stability of the cervical spine is violated by various traumatic and non-traumatic causes.Trauma contributes to approximately 25% of all cervical spine injuries, mostly sustained in motor vehicle accidents and falls[2].
Instability at the atlas and axis requires internal fixation not only for immediate stability, but also to provide long-term immobility so as to attain a solid fusion[3].There are a wide variety of surgical techniques to achieve this. Recently transarticular and transpedicular screw fixation have been widely used[4]. As these surgical techniques and instruments continue to evolve, a detailed and precise knowledge about the cervical spine and surrounding anatomy is required.
The atlas (C1) is the first cervical vertebra which supports the globe of the head[5]. It is remarkable in that it lacks a body, rather being shaped like an irregular ring. Because it's a ring and a fracture results in disruption of this ring, more than one location is affected. It consists of two symmetrical lateral masses that are united by the anterior and posterior arches. These lateral masses are thick, supportive elements composed of both a superior and inferior articular surfaces[6]. This large size of lateral masses enables screw placement feasibility in almost all patients[7].
The axis (C2), also called the epistropheus, is the second vertebra of the cervical spine; it creates a pivot joint between the head and neck. Its strongest characteristic is the dens or the

odontoid process[8]. In the axis vertebra, two characteristics of superior articular facet differ from the facets of all other vertebrae. Firstly, its proximity to the corpus and the medial aspect of pedicle axis when compared to the other facets, which are located in proximity to the junction of the pedicle and lamina. Secondly, and more crucial is that vertebral artery foramen is present partially or completely in the undersurface of superior articular facet of axis while in other cervical vertebrae it is located entirely in relation to foramen transversarium[9].

Atlantoaxial region exhibits variable anatomy and there are vital neurovascular structures in its proximity.Knowledge of this variability is important for neurosurgeons, orthopaedicians, otorhynologists and other physicians who in everyday practice are in contact with disorders of the spine and their consequences[10].

## MATERIALS AND METHODS

Fifty atlas and fifty axis vertebrae, available in the Department of Anatomy, Dayanand Medical College and Hospital, Ludhiana were studied. The specimens selected were dry, complete, human cadaveric vertebrae of Indian origin. Vertebrae with gross vertebral pathology were excluded.

Surgically important measurements were taken on the articular facets of both atlas and axis vertebrae as shown in figures1,2,3,4.

Various dimensions were taken with the help of Vernier Calipers. All the measurements were recorded bilaterally, in millimetres. The measured data was statistically analysed including test of significance (paired t-test). Comparison was done with existing studies.

**Figure 1: Atlas Vertebra- Superior View**

**a – b: Maximum Antero-Posterior Diameter of Superior Articular Facet – maximum antero-posterior dimension of superior articular surface along its principal axis directed anteromedially.**

**c - d: Maximum Transverse Diameter of Superior Articular Facet – the maximum transverse dimension of superior articular surface perpendicular to the antero-posterior dimension.**

**Figure 2: Atlas Vertebra – Inferior View**

**e - f: Maximum Antero-Posterior Diameter of Inferior Articular Facet – the maximum antero-posterior dimension of inferior articular surface along its principal axis directed anteromedially.**

**g - h: Maximum Transverse Diameter of Inferior Articular Facet – maximum transverse dimension of inferior articular surface perpendicular to the antero-posterior dimension**


**Figure 3: Axis – Superior View**

**i - j : Maximum Antero-Posterior Diameter of Superior Articular Facet– the maximum antero-posterior dimension of the superior articular surface along its principal axis directed anteromedially**

**k - l : Maximum Transverse Diameter of Superior Articular Facet– the maximum transverse dimension of the superior articular surface perpendicular to the antero-posterior dimension.**

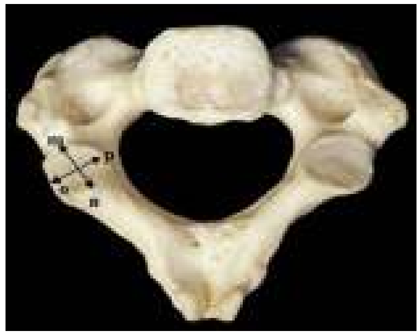


**Figure 4: Axis – Inferior View**

**m - n : Maximum Antero-Posterior Diameter of Inferior Articular Facet – maximum antero-posterior dimension of the inferior articular surface along its principal axis.**

**o - p : Maximum Transverse Diameter of Inferior Articular Facet – the maximum transverse dimension of the inferior articular surface perpendicular to the antero-posterior dimension.**

## RESULTS AND DISCUSSION

The results obtained on atlas and axis are shown in tables 1and 2, respectively.

Observations were recorded and tabulated. Standard statistical analysis was done. Test of significance (paired t-test) was carried out for comparison of right and left sides. The p value $< 0.05$ was considered to be significant and $> 0.05$ was considered to be insignificant. For all parameters, this was insignificant showing bilateral symmetry.

**Table 1: Dimensions on Atlas**

| Dimension | Range (mm) | Mean |
|---|---|---|
| Maximum Antero-Posterior Diameter of Superior Articular Facet | R- 17.00 – 27.00<br>L- 16.74 – 26.48 | 21.52±2.36<br>21.51±2.07 |
| Maximum Transverse Diameter of Superior Articular Facet | R- 8.42 – 15.10<br>L- 9.22 – 16.42 | 11.21± 1.47<br>11.32± 1.53 |
| Maximum Antero-Posterior Diameter of Inferior Articular Facet | R -14.28 – 21.24<br>L -12.24 – 21.30 | 17.54±1.50<br>17.70±1.60 |
| Maximum Transverse Diameter of Inferior Articular Facet | R-12.70 – 19.84<br>L-12.80 – 19.98 | 14.99±1.65<br>14.94±1.51 |

**Table 2: Dimensions on Axis**

| Dimension | Range (mm) | Mean |
|---|---|---|
| Maximum Antero-Posterior Diameter of Superior Articular Facet | R - 13.20 – 23.54<br>L - 13.52 – 22.44 | 17.42±1.73<br>17.64+1.51 |
| Maximum Transverse Diameter of Superior Articular Facet | R- 12.20 – 18.34<br>L- 12.78 – 19.22 | 15.31±1.44<br>15.17±1.48 |
| Maximum Antero-Posterior Diameter of Inferior Articular Facet | R -8.36 – 15.72<br>L -9.42 – 16.68 | 11.54±1.66<br>12.14±1.58 |
| Maximum Transverse Diameter of Inferior Articular Facet | R-5.74 – 14.20<br>L-6.22 – 13.84 | 9.23± 1.70<br>9.41 ±1.61 |

The first cervical vertebra is formed by the caudal half of occipital somite 4 and the cranial half of cervical somite1[11]. It is commonly ossified from three centres. One appears in each lateral mass at about the seventh week, gradually extending into the posterior arch where they unite between the third and fourth years, usually directly but occasionally through a separate centre.Occasionally the anterior arch is formed by the extension and ultimate union of centres in the lateral masses and sometimes from two lateral centres in the arch itself[12]. The posterior part of superior articular facet is developed by the posterior arch. This different embryological development of the two parts of the superior articular facets explains their partial or complete dissociation[13]. In the present study, atlas specimens with gross anomalies were excluded but partial dissociation was noticed in some.

The axis is formed from the anterior halves of the first and second spinal sclerotomes and the posterior dense half of the first spinal sclerotome. It is ossified from five primary and two secondary centres. The vertebral arch has two primary centres and the centrum has one, as in a typical vertebra[14].

There is known sexual dimorphism in atlas and axis vertebrae[15, 16]. Racial variations have also been observed.Wood-jones F[17]observed that dimensions of Europeons are larger in comparison to other races. In the present study most of the parameters observed on Indian subjects are shorter than that of the Europeon studies.

**Table 3: Comparison of Maximum Antero-Posterior Diameter of Superior Articular Facet of atlas**

| Author | Origin | Dimension (mm) | |
|---|---|---|---|
| | | Right | Left |
| Gupta et al | Indian | 19.73 | |
| Kandziora et al | European | 25.3 ± 2.22 | |
| Naderi et al | Turkish | 19.9355 ± 2.4212 | |
| Konig et al | German | 22.7 ± 3.0 | 22.8 ± 4.2 |
| Sengul et al | Turkish | 19.9 ± 3.4 | 18.6 ± 3.2 |
| Gomez-Olivencia et al | Spanish | 23.7 ± 1.8 | 23.5 ± 1.7 |
| Rocha et al | American | 23.9 ± 2.5 | 23.6 ± 2.5 |
| Present study | Indian | 21.52 ± 2.36 | 21.51 ± 2.07 |

The table 3 shows that there is dimensional equivalence amongst the present study and most of the previous studies. While Gupta et al[18], Naderi et al [19], Sengul et al[10], have lower value, Kandziora et a1[20], Gomez-Olivencia et al[21] and Rocha et al[22] have higher value.. Hence the variation in the values can be as a result of differences in sampling and methodology adopted by these studies. Racial variations can be attributed to the difference between the previous foreign studies.

**Table 4: Comparison of Maximum Transverse Diameter of Superior Articular Facet of Atlas**

| Author | Origin | Dimension (mm) | |
|---|---|---|---|
| | | Right | Left |
| Gupta et al | Indian | 11.12 | |
| Konig et al | German | 11.6 ± 2.0 | 11.2 ± 1.5 |
| Sengul et al | Turkish | 9.6 ± 1.9 | 9.8 ± 1.5 |
| Gomez-Olivencia et al | Spanish | 10.4 ± 1.2 | 10.5 ± 1.0 |
| Present study | Indian | 11.21 ±1.47 | 11.32 ± 1.53 |

According to the table 4 present study has similar values with most of the previous studies. The observations made by Sengul et al[10] and Gomez-Olivencia et al[21] are lower than our study.

**Table 5: Comparison of Maximum Antero-Posterior Diameter of Inferior Articular Facet of Atlas**

| Author | Origin | Dimension (mm) | |
|---|---|---|---|
| | | Right | Left |
| Gupta et al | Indian | 15.76 | |
| Konig et al | German | 18.5 ± 3.2 | 19.0 ± 2.5 |
| Sengul et al | Turkish | 17.1 ± 2.6 | 17.5 ± 2.4 |
| Rocha et al | American | 18.8 ± 1.7 | 18.7 ± 1.6 |
| Gomez-Olivencia et al | Spanish | 16.3 ± 1.3 | 16.2 ± 1.2 |
| Cattrysse et al | Belgian | 17.0 ± 1.8 | 16.6 ± 1.6 |
| Present study | Indian | 17.54 ± 1.50 | 17.70 ± 1.60 |

The table 5 depicts that there are similarities between our study and previous studies. In comparison to Indian studies by Gupta et al[18]our study has higher values. This is may be either due to varying sample size or unknown ratio of sexes.

**Table 6: Comparison of Maximum Transverse Diameter of Inferior Articular Facet of Atlas**

| Author | Origin | Dimension (mm) | |
|---|---|---|---|
| | | Right | Left |
| Gupta et al | Indian | 15.22 | |
| Konig et al | German | 15.9 ± 1.1 | 16.2 ± 1.0 |
| Sengul et al | Turkish | 14.6 ± 2.5 | 14.6 ± 2.5 |
| Rocha et al | American | 16.6 ± 2.0 | 16.4 ± 2.0 |
| Gomez Olivencia et al | Spanish | 15.5 ± 1.0 | 15.8 ± 1.2 |
| Cattrysse et al | Belgian | 16.9 ± 1.6 | 17.2 ± 2.0 |
| Present study | Indian | 14.99 ± 1.65 | 14.94 ± 1.51 |

The table 6 shows that the observations of present study are lower than most of the previous studies. Gupta et al[18] have given an average value whereas our study has values of both the sides, which can attribute to slight variation in values. Higher values in the other studies may be the result of racial variations.

**Table 7: Comparison of Maximum Antero-Posterior Diameter of Superior Articular Facet of Axis**

| Author | Origin | Dimension (mm) | |
|---|---|---|---|
| | | Right | Left |
| Kandziora et al | European | 17.0 ± 1.1 | |
| Konig et al | German | 19.1 ± 2.1 | 18.7 ± 2.2 |
| Sengul et al | Turkish | 17.5 ± 1.4 | 17.5 ± 1.5 |
| Gomez-Olivencia et al | Spanish | 17.7 ± 1.2 | 18.1 ± 1.4 |
| Cattrysse et al | Belgian | 17.9 ± 1.8 | 17.7± 1.4 |
| Present study | Indian | 17.42 ± 1.73 | 17.64 ± 1.51 |

The table 7 reveals that there is similarity between the values of the present study and most of the previous studies. Konig et al[23] has used a grid system to measure the dimensions which might have lead to higher values. Cattrysse et al[24] evaluated pairs of atlas and axis vertebrae from same spine and found that the C1 IAF has lower APD than the SAF of C2.

**Table 8: Comparison of Maximum Transverse Diameter of Superior Articular Facet of Axis**

| Author | Origin | Dimension (mm) | |
|---|---|---|---|
| | | Right | Left |
| Kandziora et al | European | 16.6 ± 1.25 | |
| Konig et al | German | 15.3 ± 2.0 | 16.4 ± 1.8 |
| Sengul et al | Turkish | 14.1 ± 1.6 | 14.0 ± 1.5 |
| Gomez-Olivencia et al | Spanish | 16.4 ± 1.3 | 16.3 ± 1.4 |
| Cattrysse et al | Belgian | 17.5 ± 1.9 | 17.2 ± 2.8 |
| Present study | Indian | 15.31 ± 1.44 | 15.17 ± 1.48 |

The table 8 shows that the readings in the present study are in agreement with most of the available studies in the data. Kandziora et al[20], Gomez-Olivencia et al[21] and Cattrysse et al[24] have higher values than our study. Whereas Sengul et al[10] has lower value, Konig et al[22] is closest. The variations depict that these could be as a result of racial and ethnic differences between these study groups.

**Table 9: Comparison of Maximum Antero-Posterior Diameter of Inferior Articular Facet of Axis**

| Author | Origin | Dimension (mm) | |
|---|---|---|---|
| | | Right | Left |
| Sengul et al | Turkish | 11.7 ± 1.7 | 11.4 ± 1.3 |
| Gomez-Olivencia et al | Spanish | 10.1 ± 1.4 | 10.1 ± 1.4 |
| Present study | Indian | 11.54 ± 1.66 | 12.14 ± 1.58 |

**Table 10: Comparison of Maximum Transverse Diameter of Inferior Articular Facet of Axis**

| Author | Origin | Dimension (mm) | |
|---|---|---|---|
| | | Right | Left |
| Sengul et al | Turkish | 9.6 ± 1.7 | 9.4 ± 1.5 |
| Gomez-Olivencia et al | Spanish | 11.2 ± 1.2 | 11.2 ± 1.5 |
| Present study | Indian | 9.23 ± 1.70 | 9.41 ± 1.61 |

In both table 9 and 10 when comparing the APD and TD of IAF between right and left sides in the present study the difference in values were minor and statistically insignificant. While there are small differences in the values when comparing with those of other workers, these can be explained on the basis of racial variations.

The lateral superior and inferior articular facets of the atlas and axis create a biconvex surface. This biconvex nature means that cervical spine flexion and extension often create motion in the direction opposite that being experienced in the atlas. Thus when cervical spine is flexing, the atlas extends, and when the cervical spine extends, the atlas flexes. This coupling motion is possible because the atlas is balanced on the concavity of the axis, and is a unique characteristic of the spine[25].

Posterior transarticular fixation at the level of SAF of axis and IAF of atlas provides rigidity as well as preserves motion between atlanto-occipital joint. This procedure is advantageous in situations such as significant disruption of C1 posterior arch, canal comprise, posterior subluxation and congenital anomalies. For the locations of points of screw insertion on the SAF the knowledge of its dimensions is necessary. Moreover, axis vertebra being atypical variations in its normal anatomy may infringe on these techniques.

## CONCLUSION

Transarticular screw fixation has become one of the primary treatment options for C1-C2 instability. The trajectory and angulation while screw placements is crucial because of the surrounding neurovascular structures, i.e. vertebral artery and spinal cord. The knowledge of the APD and TD dimensions of SAF can help in the safe planning of these screw placements.

The overall goal of this study was to generate information that would be useful for geometric modelling of vertebrae and give necessary morphometric data on human atlas and axis vertebrae in subjects of Indian origin.

## ACKNOWLEDGEMENT

I would like to thank Dr Poonam Singh( Prof and Head) and Dr Ajay Kumar(Associate Professor),Deptt of Anatomy ,DMCH Ludhiana, for their esteemed guidance in the completion of this manuscript.

## REFERENCES

1. Dugailly PM, Sobczak S, Sholukha V, Jan SV, Salvia P, Feipel V, et al. In vitro 3D–kinematics of the upper cervical spine: helical axis and simulation for axial rotation and flexion extension. Surg Radiol Anat. 2010; 32:141-51.
2. Taggard DA, Traynelis VC. Treatment of Occipital C1 Injury. In:Winn HR, Dacey Jr. RJ, Sonntag VK, Vollmer DG, editors. Youmans Neurological Surgery. 5th ed .Philadelphia: Saunders; 2004. p.4925-37.
3. Vilela MD, Jermani C, Braga BP. C1 lateral mass screws for posterior segmental stablization of the upper cervical spine and a new method of three-point rigid fixation of the C1-C2 complex. Arq Neuropsiquiatr.2006; 64(3-B):762-7.
4. Miyamoto H, Uno K. Cervical pedicle screw insertion using a computed tomography cutout technique. J Neurosurg Spine. 2009; 11:681-7.
5. Lalit M, Piplani S, Kullar JS, Arora AK, Mannan R. The morphological analysis of the superior articular facet of the adult human atlas vertebra. JCDR. 2011april; 5(2):274-7.
6. Pait TG, Arnautovic KI, Borba LA. The anatomy of atlantoaxial complex. Perspect Neurol Surg.1997; 7: 91-8.
7. Carvalho MF, Rocha RT, Monteiro JT, Pereira CU, Leite RF, Defino HL. Tomographic study of the atlas concerning screw fixation on lateral mass. Acta Ortop Bras.2009; 17(3):136-8.
8. Johnston M, Ranieri S, de Wit W. Proposal of a new method of treating type II odontoid fractures: Odontoid process prosthetic (Ti). Studies by Undergraduate Researchers at Guelph.2008; 1(2):49-56.
9. Sengul G, Kadioglu HH. Morphometric anatomy of the atlas and axis vertebrae. Turk Neurosurg. 2006; 16(2):69-76.
10. Wysocki J, Bubrowski M, Reymond J, Kwaitkowski J. Anatomical variants of the cervical vertebrae and the first thoracic vertebra in man. Folia Morphol.2003;62(4):357-63.
11. Newell RL, Collins P. Development of the Back. In: Standring S, editor. Gray's Anatomy, the Anatomical Basis of Clinical Practice. 40 th ed. Churchill Livingstone Elsevier; 2008.p.763-73.
12. Newell RL. The Back. In: Standring S, editor. Gray's Anatomy The Anatomical Basis of Clinical Practice. 40th ed. Churchill Livingstone Elsevier; 2008; p.707-48.
13. Paraskevas G, Papaziogas B, Traveas A, Natsis K, Spanidou S,Kitsoulis P. Morphological parameters of the superior articular facets of the atlas and potential clinical significance. Surg Radiol Anat.2008; 30: 611-7.
14. Koksel T, Crockard HA. Atlas and axis through the eyes of the transoral surgeon. Turk Neurosurg.1991; 2: 3-6.
15. Sharma T, Rai H, Kulla JS, Lalit M. Genderwise morphometric database from adult atlas and axis. JPAFMAT. 2008; 8(2): 25-8
16. Wescott DJ.Sex variation in the second cervical vertebra. J Forensic Sci.2000; 45(2): 462-6.
17. Wood-Jones F.The cervical vertebrae of the Australian native. J.Anat.1938; 72(Pt 3): 411-5.
18. Gupta S, Goel A. Quantitative anatomy of the lateral masses of the atlas and axis vertebrae. Neurol India. 2000 june; 48: 120-5.
19. Naderi S, Cakmakc H, Acar F, Arman C, Metrol T, Arda MN. Anatomical and computed tomographic analysis of C1 vertebra. Clin Neurol Neurosurg. 2003; 105: 245-8.
20. Kandziora F, Schulze-Stahl N, Khodadadyan-Klostermann C, Schroder R, Mittlmeier T. Screw placement in transoral atlantoaxial plate systems: an anatomical study. J Neurosurg (Spine1) .2001july; 95: 80-7.
21. Gomez-Olivencia A, Carretero JM, Arsuaga JL, Rodriguez-Garcia L, Garcia-Gonzalez R, Martinez I. Metric and morphological study of the upper cervical spine from Sima de los Huesos site(Sierra de

Atapuerca, Burgos, Spain. J Hum Evol.2007; 53: 6-25.
22. Rocha R, Safavi-Abbasi S, Reis C, Theodore N, Bambakidis N, de Oliveira E, et al. Working area, safety zones, and angles of approach for posterior C1 lateral mass screw placement: a quantitative anatomical and morphometric evaluation. J Neurosurg Spine.2007march; 6(3): 247-54.
23. Konig SA, Goldammer A, Vitzthum HE. Anatomical data on the craniocervical junction and their correlation with degenerative changes in 30 cadaveric specimens. J Neurosurg Spine.2005; 3: 379-85.
24. Cattrysse E, Provyn S, Gagey O, Kool P, Clarys JP, Roy PV. In vitro three dimensional morphometry of the lateral atlantoaxial articular surfaces.Spine.2008; 33(14): 1503-8.
25. Swartz EE, Floyd RT, Cendoma M. Cervical Spine Functional anatomy and the biomechanics of injury due to compressive loading. Journal of Athletic Training.2005; 40(3): 155-61.

**Source of support: Nil, Conflict of interest: None Declared**