INTRODUCTION

The accurate radiological evaluation and assessment of the morphometric parameters of the odontoid are critical in achieving stable fixation and fusion of odontoid fractures.[1] Fractures of the odontoid process account for 50–60% of all fractures of C2, 7–27% of all cervical vertebral column fractures and 1–2% of all vertebral column fractures.[6] The technique of internal fixation of the odontoid process is directly related to the dimensions of the odontoid process.[8] Fixation with two screws has high consolidation rates, better rigidity, and gives higher rotational stability.[1] Here, utilizing CT, we determined how many patients’ odontoid processes could accommodate 1 versus 2 screws for odontoid spinal fixation.

MATERIALS AND METHODS

This is a retrospective analysis of the CT studies of the odontoid process performed in 200 asymptomatic adults (2018–2020). The measurements were performed by a single observer.
The CT scans were randomly collected from our hospital radiology archives along with relevant variables; there were multiple inclusion and exclusion criteria [Tables 1 and 2].

**Statistical analysis**

Statistical comparisons between variables within gender were tested using the Student’s *t*-test after verifying that the distribution of the variables was normal (*P* < 0.05 is significant). The Fisher's exact test was used to examine the significance of the association between sex and minimum external transverse diameter (METD) smaller than 9 mm (Statistical Package for Social Sciences – Version 11.0).

**RESULTS**

There were 200 CT studies of odontoid processes. Ten (5%) patients had transverse diameter (TD) <7.4 mm, while none of the patients had diameters of <5.5 mm. The mean minimal external antero-posterior (AP) diameter of the entire population was 10.17 mm (range 7.10– 13.05 mm, SD 1.09 mm), while the mean length of the implant was 36.45 mm. The mean angle of screw insertion was 60.34° [Table 3]. The two-tailed *P* value equals 0.446 and this difference was considered to not be statistically significant.

**DISCUSSION**

In this study, we evaluated the morphology of the odontoid process using an accurate and reliable CT-based measurement method. The external CT measurements correlated well with calliper-derived data.[4]

Several studies evaluated the size of the odontoid process

Kulkarni *et al.*, [5] found that AP and TD were 11.52 mm and 9.85 mm, respectively. Yusof *et al.*, [12] found that 28% of odontoid processes had a cross-sectional diameter of <9.0 mm, making it impossible to perform fixation with two 3.5 mm screws. Daher *et al.* similarly found 39% of Brazilian subjects had similar measurements, while. [2] Nucci *et al.* [9] found in the American population, that only 5% of subjects had a minimum TD of less than 9.0 mm. [2,9] In our study 118 (59.0%) subjects had a METDs of <9 mm, precluding two screw fixation. Hence, two 2.7 mm screws could be used safely in 95% of patients, while a single 4.5 mm Herbert screw could be used safely in the entire population. We also found that 82 (41%) of patients required an implant screw length of < 36 mm [Table 4].

**Angle of screw insertion**

The mean angle of screw insertion was 60.34° (60° on average in females and 60.53° average in males). In Tun *et al.*, [11] the mean value of the angle of the odontoid screw

| Table 1: Patient demographics, inclusion and exclusion criteria. |
|------------------|------------------|
| **Total number** | 200              |
| **M:F**          | 127:73           |
| **Mean age**     | 47 years (Range 18–60) |
| **Inclusion criteria** | Skeletally mature, age range of 18–60 years |
| **Exclusion criteria** | Fracture, tumour, infection, or metabolic disease affecting the dens like rheumatoid arthritis. |

| Table 2: CT variables |
|----------------------|
| **LI** | Distance between the apex of the odontoid process and anterior border of the axis [Figure 1] (Signifies the length of the implant). |
| **AI** | Angle between the line of the apex of the odontoid process to the anterior edge of the axis and tangent to the plateau below the axis [Figure 2]. (Denotes the trajectory the screw has to be placed in). |
| **MITD** | Smallest measurement of internal cortex of odontoid in coronal plane [Figure 3a]. |
| **METD** | Smallest measurement of external diameter of odontoid in the coronal plane [Figure 3b]. |
| **MEAD** | Smallest measurement of external diameter of odontoid in the sagittal plane [Figure 4a]. |
| **MIAD** | Smallest measurement external diameter of odontoid in the sagittal plane [Figure 4b]. |
| **C2 AP base/LI** | Indicates the shape of the odontoid [Figure 5]. |

**Figure 1:** Estimated length of the implant (LI) (distance between the apex of the odontoid process and anterior border of the axis).
was 62.4 ± 4.7° on CT and 64.2 ± 4.1° on X-rays (i.e., a statistically significant difference in the two measurements of the screw angle).

## Table 3: The dimensions of the odontoid by CT morphometry.

| Number of subject | Age | Minimum transverse diameter (mm) | Minimum antero-posterior diameter (mm) | LI | AI | C2 AP base/LI |
|------------------|-----|----------------------------------|----------------------------------------|----|----|---------------|
|                  |     | External (METD) | Internal (MITD) | External (MEAD) | Internal (MIAD) |     |     |               |
| Total, n=200     |     |                   |                     |                  |                   |     |     |               |
| Mean             | 47.31 | 8.80 | 6.08 | 10.17 | 7.26 | 36.45 | 60.34 | 0.37 |
| Min              | 19   | 6.1  | 3.16 | 7.10  | 3.29 | 24.74 | 48   | 0.17 |
| Max              | 79   | 11.9 | 9.97 | 13.05 | 12.74 | 49.30 | 72   | 1.33 |
| Female n=73      |     |                   |                     |                  |                   |     |     |               |
| Mean             | 45.52 | 8.62 | 5.96 | 10.15 | 7.40 | 35.70 | 60   | 0.35 |
| Min              | 619  | 6.2  | 3.16 | 8.01  | 4.15 | 24.74 | 48   | 0.17 |
| Max              | 173  | 10.6 | 9.09 | 12.38 | 12.74 | 42.12 | 69   | 0.55 |
| Male n=127       |     |                   |                     |                  |                   |     |     |               |
| Mean             | 48.34 | 8.90 | 6.15 | 10.17 | 7.18 | 36.89 | 60.53 | 0.38 |
| Min              | 20   | 6.1  | 3.80 | 7.10  | 3.29 | 26.47 | 49   | 0.19 |
| Max              | 79   | 11.9 | 9.97 | 13.05 | 10.18 | 49.30 | 72   | 1.33 |

LI: Length of implant, AI: Angle of implant, METD: Minimum external transverse diameter, MITD: Minimum internal transverse diameter, MEAD: Minimum external anteroposterior diameter, MIAD: Minimum internal anteroposterior diameter, C2 AP base/LI: Anteroposterior diameter of the axis (C2) divided by the estimated length of the implant

## Table 4: Comparing the odontoid dimensions from the study by Daher et al. 2011 and the C.S.

|                         | METD (mm) | MITD (mm) | MEAD (mm) | MIAD (mm) |
|-------------------------|-----------|-----------|-----------|-----------|
|                         | Daher et al | C. S.    | Daher et al | C. S.    |
| Male                    | 9.36      | 8.90      | 6.37      | 6.15      | 11.59      | 10.17     | 8.17      | 7.18      |
| Female                  | 9.04      | 8.62      | 5.82      | 5.96      | 10.20      | 10.15     | 7.0       | 7.40      |
| Total                   | 9.19      | 8.80      | 6.07      | 6.08      | 10.83      | 10.17     | 7.53      | 7.26      |

C.S.: Current study, METD: Minimum external transverse diameter, MITD: Minimum internal transverse diameter, MEAD: Minimum external anteroposterior diameter, MIAD: Minimum internal anteroposterior diameter

Figure 2: Angle of implant (AI): Angle between the line of the apex of the odontoid process to the anterior edge of the axis and tangent to the plateau below the axis.

Pros for 2 screw fixation

There are considerably higher rates of union with dual screw osteosynthesis.[8] Two 3.5 mm screws versus one 4.0 mm screw give a greater surface area to penetrate the cortical bone of the odontoid tip, and increases the bone/screw interface, especially in osteoporotic patients.[10]

Pros for single Herbert screw placement

For TD measurements of the dens <5.5 mm, only a single 4.5 mm Herbert screw can be safely used. Notably, Lee and...
Sung reported a good union rate and no implant failures using single 4.5 mm Herbert screws.\cite{7}

Use of CT to calculate appropriate screw length and diameter
CT reconstructed images make it possible to calculate the diameter and length of the odontoid process and to estimate the quality of bone and size of the odontoid for the safety/efficacy of anticipated one to two screw fixation.

CONCLUSION
About two-thirds (59%) of the subject in our Indian population had a METD of the odontoid process of <9 mm. This meant that only one screw could be safely placed in an odontoid process for these individuals.

Declaration of patient consent
Patient's consent not required as patients identity is not disclosed or compromised.

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Conflicts of interest
There are no conflicts of interest.

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