International Journal of Spine Surgery, Vol. 14, No. 1, 2020, pp. 59–65
https://doi.org/10.14444/7008

Computerized Tomography–Based Morphometric Analysis of Odontoid in 100 Egyptian Patients

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ABSTRACT

Background: There is still no consensus in the literature regarding the use of 1 screw or 2 screws. A number of studies have proved ethnic variations in the morphometry of the odontoid. There is no literature on the morphometry of odontoid in Egyptian patients.

Methods: Computerized tomography (CT) scans of the head and cervical spine of 100 healthy (no evidence of cervical spine fracture) patients of Egyptian origin were studied. Measurements were performed using Horos software, which allowed exact morphometric measurements to be taken at a specific angle in the axial, coronal, and sagittal planes.

Results: The mean age was 48.57 ± 15.39 years (range, 18–79 years; 56 male and 44 female patients). The mean radiologically calculated screw length and the mean radiologically calculated screw insertion angle were 38.21 ± 2.2 mm and 55.7° ± 3.84°, respectively. The mean anteroposterior and transverse diameter of the odontoid at the waist in the axial cut were 11.02 ± 1.05 mm and 8.92 ± 0.93 mm, respectively. A total of 54% and 6% of the study sample had the transverse waist diameter of the odontoid in the axial cut below 9 mm and 7.4 mm, respectively. A total of 48% of the male and 61% of the female patients had their transverse diameter of the odontoid at the waist below 9 mm. There was a statistically significant difference in all the measurements of the odontoid between the male and female patients except in the anteroposterior diameter of the base of odontoid ($P = .06$) in the axial cut, and the radiologically calculated screw insertion angle ($P = .57$). The mean distance between the apex of the odontoid and the screw exit was 1.8 ± 0.75 mm (range, 0–3 mm).

Conclusions: CT-based morphometric analysis of the odontoid is necessary before using 2-screw fixation technique. Single 4.5-mm Herbert screws could be used in all Egyptian patients without the need for CT-based morphometric analysis of the odontoid. The posterior screw can violate the posterior wall of the odontoid, with a reduced fracture hold and a chance of injuring the thecal sac.

Cervical Spine

Keywords: anatomy, computed tomography, fixation, fracture, odontoid, spine

INTRODUCTION

Fracture of the odontoid constitutes more than 50% of the fractures involving the C2 vertebrae.[1] The odontoid acts as a pivot for the C1 to C2 joint, and this accounts for about 50% of the rotational movement of the cervical spine.[2–4] Because the dens is tightly held between the anterior arch of the atlas and the transverse ligament, it does not allow for excessive flexion-extension movement at the C1 to C2 joint, contributing to only 10% of flexion-extension movement.[2–4] Hence, excessive flexion or extension forces can fracture the dens at the waist because it is the narrowest part. The treatment options available for the odontoid fracture are external immobilization, anterior odontoid screw (either 1 or 2 screws), and posterior C1 to C2 arthrodesis. External immobilization is poorly tolerated by the elderly and is frequently associated with nonunions. Posterior C1 to C2 arthrodesis gives a good clinical result; however, the rotational movement at the C1 to C2 joint is lost. If anatomic closed reduction is achievable, anterior percutaneous odontoid screw fixation is an attractive option, because it preserves the mobility of the C1 to C2 joint.[5] There is still no consensus in the literature regarding the use of 1 screw or 2 screws.[6–9] The proponents of 2 screws claim better rotational stability; however, this necessitates a minimum transverse diameter of 9 mm. A number of studies have proved ethnic variations in the morphometry of the odontoid.[10–17] There is no literature on the morphometry of odontoid in Egyptian patients. With this background, the authors decided to

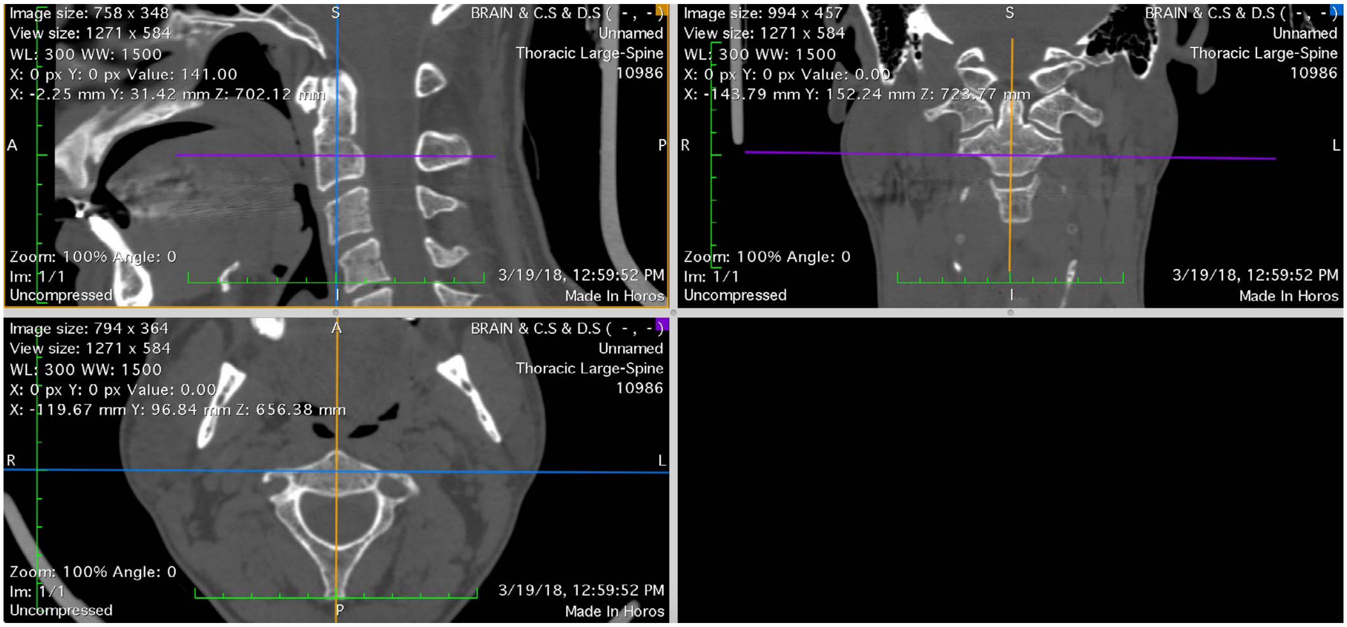

Figure 1. This computerized tomography image shows the orientation of the sagittal (orange), axial (purple), and coronal (blue) sections of the odontoid in the Horos software.

analyze the morphometry of the odontoid in Egyptian patients and determine the feasibility of using 2 screws.

PATIENTS AND METHODOLOGY

This project was started after approval by the hospital's Institutional Review Board. There are no conflicts of interest, and accepted principles of ethical and professional conduct have been followed during the research. This is a cross-sectional study of computerized tomography (CT) scans of the head and cervical spine of 100 healthy patients of Egyptian origin, who presented to El-Hadra Orthopedic Hospital in Alexandria, Egypt, with head injury or polytrauma. Patients with radiologic evidence of cervical spine fractures were excluded from the study. We used a 64-slice Siemens SOMATOM Sensation CT system (Siemens Medical Solutions, Alexandria, Egypt), and the CT scan cuts were taken at 0.5-mm intervals. Measurements were performed using the 3D Curved MPR reconstruction mode of the Horos software (version 3.2.1), which allowed exact morphometric measurements to be taken at a specific angle in the axial, coronal, and sagittal planes.

We illustrate the steps for performing the measurement here:

Step 1: The image is first centered and positioned such that it is passing through the midline in all 3 (axial, sagittal, and coronal) planes (Figure 1).

Step 2: Three points are defined (Figure 2A).

Point A: Anteroinferior point of the C2 vertebral body.

Point B: Posteroinferior point of the C2 vertebral body.

Point C: A point along the anterior cortex of the odontoid such that distance AC is equal to distance AB.

Point D: The apex of the odontoid (the most cranial point on the odontoid).

Line AE: Drawn such that it is located at a minimum perpendicular distance of 2.5 mm ($1.75 + 0.75$ mm; 1.75 mm is the radius of the 3.5-mm screw, and 0.75 mm is the minimum cortical hold required for a proper purchase of the screw) from point C and directed towards the apex of the odontoid. Therefore, point E may either coincide with point D or be located slightly posterior to it. (Figure 2B).

Line AE: The axis of the Odontoid screw.

Line DE: The horizontal distance between the points D and E.

Angle EAC: The angulation of the screw with respect to the inferior end plate of the C2 vertebral body.

Step 3: Keeping the orientation along the midline in the coronal plane and perpendicular to screw axis in the axial plane, the cuts are advanced

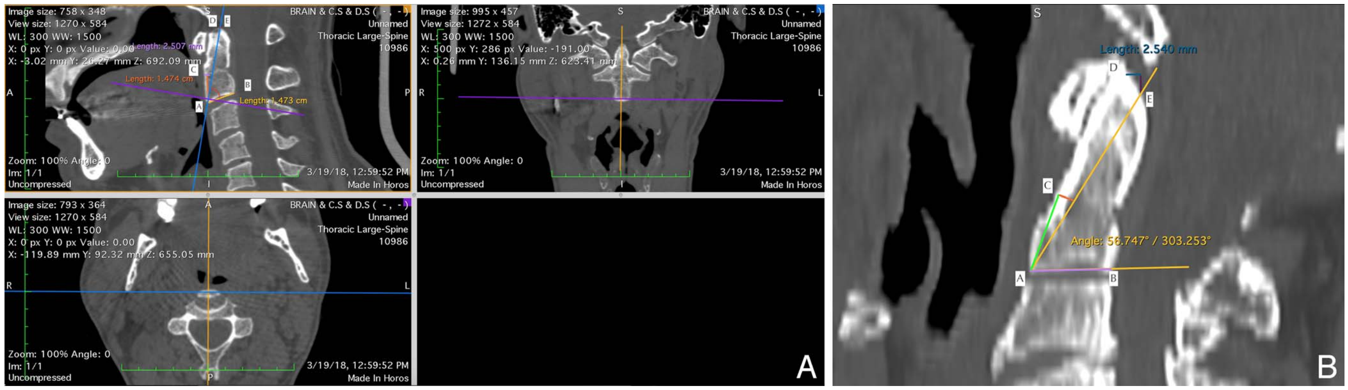

Figure 2. (A) Computerized tomography image shows the points A, B, C, D, and E. Line AB (yellow), line AC (orange), line AD (blue), and angle DAC (screw insertion angle). (B) Computerized tomography image shows the axial cut is oriented perpendicular to the screw insertion axis.

cranially until the first well-defined odontoid boundaries are identified (Figure 3). This represents the base of the odontoid.

Anteroposterior (AP) and transverse diameter of the odontoid are measured in the axial plane at this level (Figure 4).

Step 4: The axial cut is advanced cranially until the waist of the odontoid (a constriction in the dimensions of the odontoid easily identifiable in the coronal plane and axial plane; Figure 5). At this level in the axial cut, AP and transverse diameter of the odontoid are measured (Figure 6). In the coronal plane at the waist, the width of the odontoid is measured (Figure 7).

All measurements were performed by 2 independent observers (spine fellows). SPSS software v 19 (SPSS Inc, Chicago, IL) was used to calculate the statistics. Pearson correlation coefficients were to measure interobserver differences and to correlate axial and coronal measurements at the waist of the odontoid. The r values > 0.8 were interpreted as excellent agreement, 0.61 to 0.80 as good agreement, 0.41 to 0.60 as moderate agreement, and values ≤ 0.40 as poor agreement. Two-tailed unpaired t test was used to compare the means of male and female measurements. A P value of $< .05$ was considered significant.

RESULTS

The mean age of the study population was 48.57 ± 15.39 years (range, 18–79 years) (Table 1). There were 56 male and 44 female patients. There

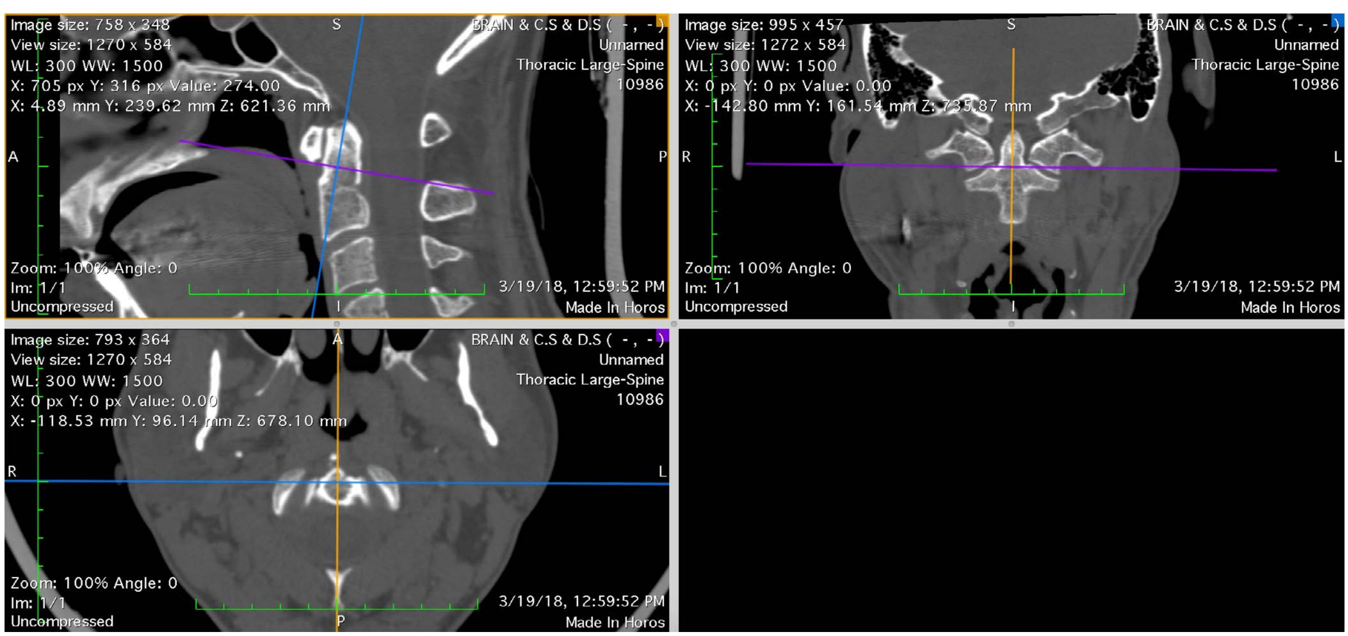

Figure 3. Axial cut through the base of the odontoid and oriented perpendicular to the screw insertion axis.

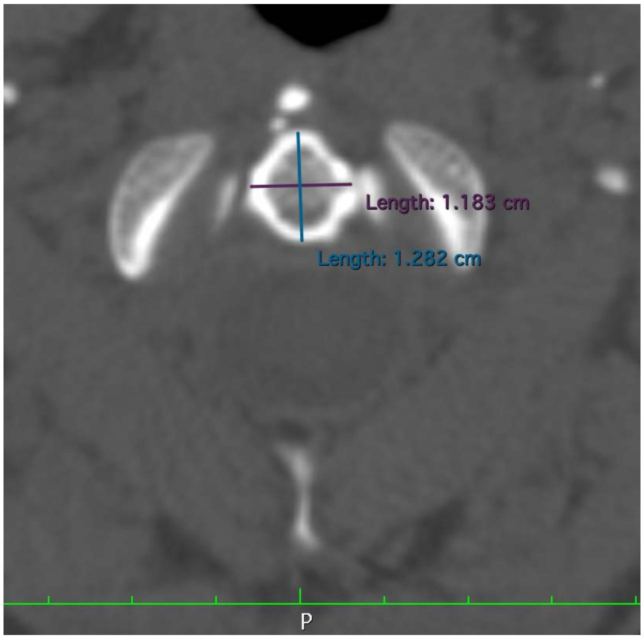

Figure 4. Measurement of the anteroposterior and transverse dimensions at the base of the odontoid in the axial cut.

was no statistically significant difference between the ages of the 2 sexes ($P = .87$). There was a good correlation between the measurements of the observers for all values ($r \geq 0.88$) except for radiologically calculated screw insertion angle ($r = 0.66$) (Table 2). This can be expected because small changes in the dimensions can greatly change the angular measurements.

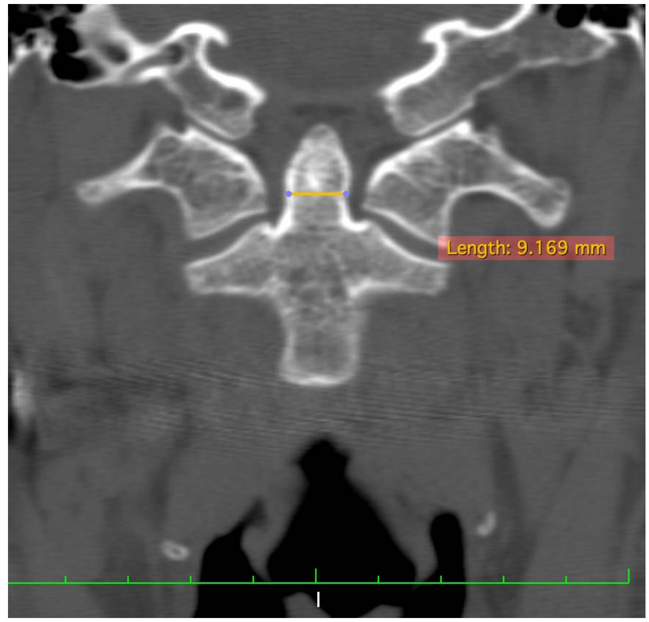

Figure 6. Measurement of the anteroposterior and transverse dimensions at the waist of the odontoid in the axial cut.

The mean radiologically calculated screw length was 38.21 ± 2.2 mm (range, 31–43.8 mm), and the mean radiologically calculated screw insertion angle with respect to the inferior end plate of the C2 body was 55.7° ± 3.84° (range, 47.1°–63.2°) (Table 1). The mean AP and transverse diameter of the odontoid at the waist in the axial cut were 11.02 ± 1.05 mm (range, 9.21–14.3 mm) and 8.92 ± 0.93 mm (range, 6.27–11.3 mm), respectively

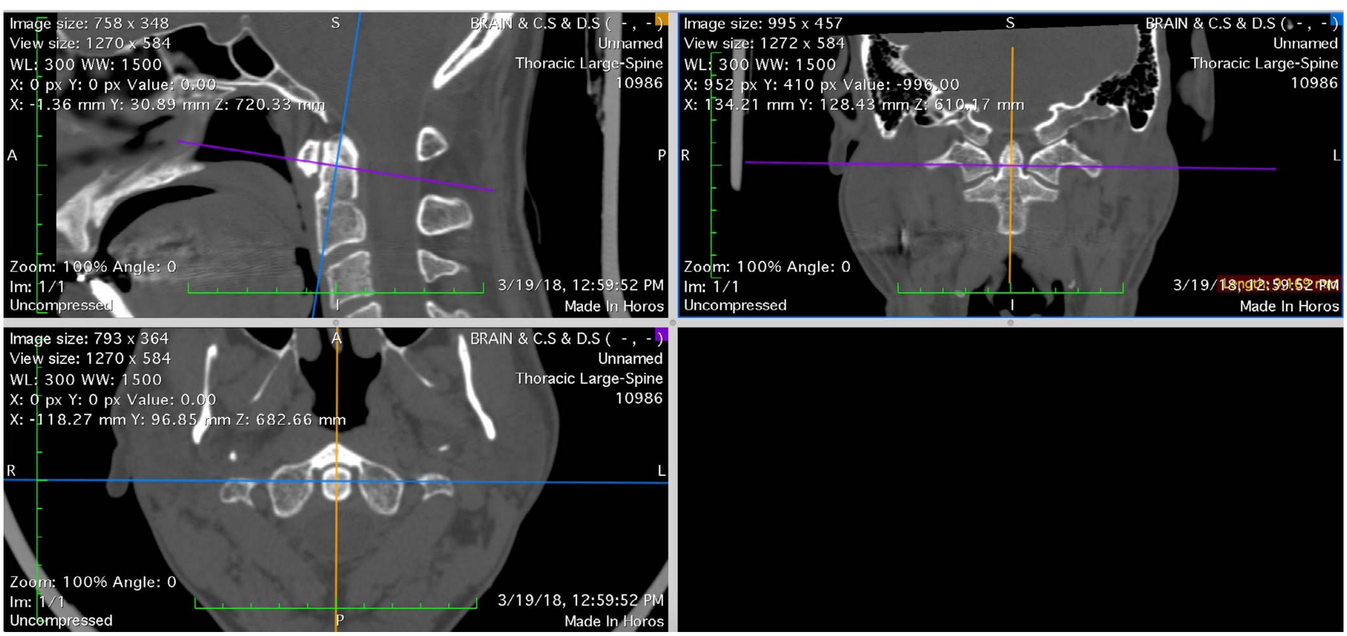

Figure 5. The orientation of the images in the axial coronal and sagittal plane. The axial cutis through the waist of the odontoid and perpendicular to the screw insertion axis.

Table 1. Measurements.

Parameter	Mean	SD	Range
Age, yrs	48.57	15.39	18–79
Sagittal cut screw length, mm	38.21	2.29	31–43.8
Screw insertion angle, °	55.78	3.84	47.1–63.2
Axial cut base AP, mm	11.84	1.15	9.06–14.59
Axial cut base TR, mm	11.08	1.38	8.09–14.05
Coronal cut waist TR, mm	8.61	0.91	5.55–11
Axial cut waist AP, mm	11.02	1.05	9.21–14.3
Axial cut waist TR, mm	8.93	0.94	6.27–11.3
Distance of screw exit from apex, mm	1.8	0.75	0–3

Abbreviations: AP, anteroposterior; TR, transverse.

(Table 1). A total of 54% and 6% of the study sample have the transverse waist diameter of the odontoid in the axial cut below 9 mm and 7.4 mm, respectively (Figures 8 and 9). There was a statistically significant difference in all the measurements of the odontoid between the male and female patients except in the anteroposterior diameter of the base of odontoid ($P = .06$) in the axial cut and the radiologically calculated screw insertion angle ($P = .57$) (Table 2) . A total of 48% of the male and 61% of the female patients had their transverse diameter of the odontoid at the waist below 9 mm (Figure 9). The mean distance between the apex of the odontoid and the screw exit was 1.8 ± 0.75 mm (range, 0–3 mm) (Table 1).

DISCUSSION

This is a radiologic study describing the morphometry of the odontoid process and its clinical importance with respect to anterior screw fixation in healthy Egyptian patients. It is likely that these measurements represent the Egyptian population at large. Because these patients did not sustain any fracture of the cervical spine after head injury or polytrauma, there is a bias of including only patients with biomechanically strong (good cortical thickness) odontoid. Therefore, the measurements could

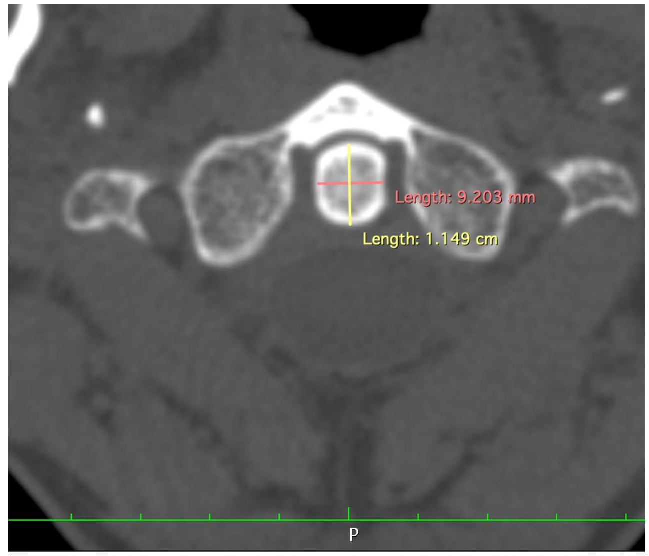

Figure 7. Measurement of the width at the waist of the odontoid in the coronal cut.

possibly reflect the better cohort of patients. Morphometric studies on various ethnic groups of the population have demonstrated that odontoid may be too narrow to accommodate two 3.5-mm screws in a substantial section of the population. A total of 5% of the people in North America,[17] 30% in Europe,[11] 35% in Brazil,[13] 33% in Malaysia,[15] 55% in India,[14] and 61% in Kuwait[10] have their odontoid dimension below 9 mm. In our study, however, the measurement technique was different. We have centralized the image in all cuts (sagittal, coronal, and axial). For the odontoid base and waist dimensions, we have taken the measurements in a plane perpendicular to the screw insertion axis and not to the long axis of the odontoid, as was done in other studies (except for a study by Puchwein et al[11] on the European population). In our study, 54% of the Egyptian population had their dimensions below 9 mm. The similar finding can be expected in the

Table 2. Comparison of means for the various parameters between male and female patients.

	Male Patients (n = 56)			Female Patients (n = 44)			
Parameter	Mean	SD	Range	Mean	SD	Range	*P* Value
Age, y	48.78	16.05	18–79	48.29	14.69	22–77	.87
Sagittal cut screw length, mm	39.09	2.23	31–43.8	37.1	1.86	31.5–41	<.0001
Screw insertion angle, °	55.97	3.57	48.02–62.38	55.53	4.19	47.1–63.2	.57
Axial cut base AP, mm	12.03	1.21	9.06–14.59	11.6	1.03	9.45–13.98	.06
Axial cut base TR, mm	11.32	1.39	8.69–14.05	10.78	1.31	8.09–13.55	.0496
Coronal cut waist TR, mm	8.74	0.93	6.19–11	8.43	0.86	5.55–10.5	.049
Axial cut waist AP, mm	11.25	1.06	9.21–14.3	10.725	0.96	9.27–13.41	.0104
Axial cut waist TR, mm	9.1	0.88	6.6–10.7	8.69	0.95	6.27–11.3	.0275
Distance of screw exit from apex, mm	1.85	0.79	0–3	1.7	07	0–2	.048

Abbreviations: AP, anteroposterior; TR, transverse.

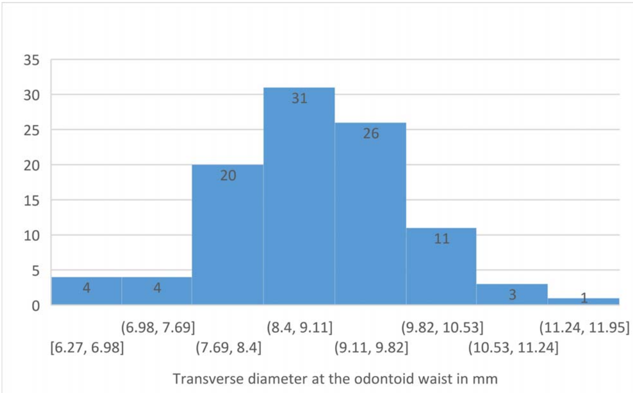

Figure 8. Histogram showing the distribution of the measurement value of the transverse diameter of the odontoid at the waist taken in the axial cut.

North African region, and regional morphometric studies must be conducted to validate this point.

The 2-screw fixation technique was first introduced by Bohler,[18] citing better rotational stability, and was soon adapted my many surgeons worldwide. Biomechanical studies and comparative clinical studies regarding union rates have shown that two 3.5-mm screws do not offer any statistically significant advantage compared with one 3.5-mm screw.[2,3,19,20] To tackle the problem of narrow odontoid, some surgeons advocated using either two 2.7-mm screws or a single 4.5 mm Herbert screw.[7] However, the use of two 2.7-mm screws requires a minimum odontoid diameter of 7.4 mm.[15] It is therefore clear from the study that a surgeon cannot blindly use a 2-screw technique (either 3.5-mm or 2.7-mm screws) in all cases of odontoid fractures, because almost 54% and 6% of the Egyptian study population had their dimensions below 9 mm and 7.4 mm, respectively. This is even more important in Egyptian women, where 61% and 7% of the population had their dimensions below 9 mm and 7.4 mm, respectively. Egyptian women in general have a smaller dimension of the odontoid compared with men; however, the radiologically calculated screw insertion angle does not differ between the 2 groups. Recently, a biomechanical study has shown a 4.5-mm Herbert screw to have significantly greater torsional stiffness and shear stiffness compared with two 3.5-mm screws.[21] Union rates with this technique were comparable to those of 2-screw fixation. Because none of the patients in our study population had the transverse diameter of the odontoid below 6 mm (considering a minimum 0.75-mm bone all around for screw purchase), we recommend using this technique. The surgeon can always study the anatomy of the fracture and odontoid dimension from a CT scan before deciding the operative techniques (single 4.5-mm Herbert screw or two 3.5/2.7-mm screws).

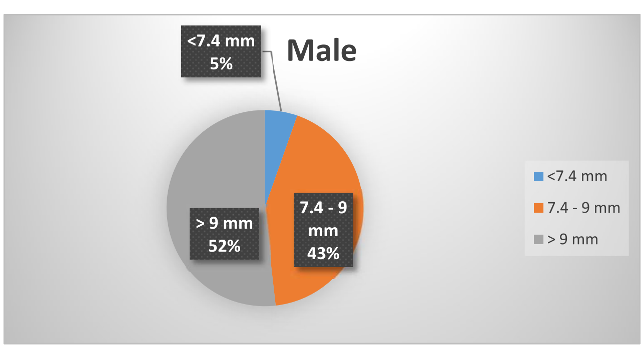

Figure 9. A pie graph showing the distribution of the values for the transverse diameter of the odontoid measured at its waist in an axial cut perpendicular to the screw insertion axis.

We defined a point C such that the distance AC = AB and the line AE (screw axis) is at a minimum 2.5 mm away from the point C. This shows the trajectory of the screw without violating the anterior cortex. This resulted in the screw axis being directed slightly posteriorly. None of the previous studies have taken this factor into account, and this might be responsible for larger radiologically calculated screw insertion angles in their study; 55.78° (current study) versus 59.45° and 62.47° in people from Europe[11] and Turkey.[16] Although the screws were directed to the apex "D," we found the exit point "E" to be located at a distance of 1.8 ± 0.75 mm posterior to the apex. This finding is even more significant when using the 2 screws in anteroposterior orientation. This is not only technically difficult, but the posterior screw will exit far more posteriorly (in the posterior wall of the odontoid), risking thecal sac damage, and will also have less cortical hold of the fracture fragment.[7]

The readers of this study must keep in mind that axial cut waist diameter is not the only factor in deciding fracture treatment. The surgeon must take into account the fracture configuration, fracture comminution, osteoporosis, status of the transverse ligament, type of fracture (traumatic versus pathological versus nonunion), length of the neck, cervical kyphosis, and presence of barrel chest before deciding on the operative technique, because this will greatly affect the operative management and the clinical outcome.

TAKE HOME MESSAGE

1. Egyptian women have a significantly smaller odontoid dimension compared with men.
2. Two-screw anterior screw fixation of odontoid using 3.5 or 2.7 mm may not be possible in 54% and 6% of Egyptian patients.
3. CT-based morphometric analysis of the odontoid is necessary before using 2-screw fixation technique.
4. Single 4.5-mm Herbert screws could be considered in most of the Egyptian patient without the need for CT-based morphometric analysis of the odontoid.
5. The posterior screw can violate the posterior wall of the odontoid, with reduced fracture hold and chance of injuring the thecal sac.

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Disclosures and COI: None of the authors have any conflicts of interest.

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Published 29 February 2020