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Feasibility of Two-Screw Anterior Fixation for Odontoid Fractures in a Chinese Population: A Morphometric Study Based on Computed Tomography

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Background: To evaluate the feasibility of treating odontoid fractures in the Chinese population with two cortical screws based on computed tomography (CT) scans and describe a new measurement strategy to guide screw insertion in treating these fractures.

Methods: A retrospective review of cervical computed tomographic scans of 128 patients (aged 18–76 years; men, 55 [43.0%]) was performed. The minimum external transverse diameter (METD), minimum external anteroposterior diameter (MEAD), maximum screw length (MSL), and screw projection back angle (SPBA) of the odontoid process were measured on coronal and sagittal CT images.

Results: The mean values of METD and MEAD were 10.0 ± 1.1 mm and 12.0 ± 1.0 mm, respectively, in men and 9.2 ± 1.0 mm and 11.0 ± 1.0 mm, respectively, in women. Both measurements were significantly higher in men ($p < 0.001$). In total, 87 individuals (68%) had METD > 9.0 mm that could accommodate two 3.5-mm cortical screws. The mean MSL value and SPBA range were 34.4 ± 2.9 mm and 13.5°–24.2°, respectively, with no statistically significant difference between men and women.

Conclusions: The insertion of two 3.5-mm cortical screws was possible for anterior fixation of odontoid fractures in 87 patients (68%) in our study, and there was a statistically significant difference between men and women.

Keywords: *Odontoid process, Computed tomography, Computer-assisted image processing, Bone screws, Fracture fixation*

Odontoid fractures are the most common and isolated spine fractures, which account for 15%–20% of all cervical spine fractures.[1] They manifest with a range of symptoms, including neck pain, cervical instability, and neurologic complications.[2] The integrity of the odontoid process is crucial for the cervical stability and proper functioning of the atlantoaxial articulation. Based on the Anderson D'Alonzo Classification,[3] type II odontoid fracture is the most common and unstable type, accounting for 65%–74% of all odontoid fracture cases.

Anterior screw fixation is a standard operation for Type II odontoid fractures,[4] which is associated with a higher union rate and preservation of C1–C2 mobility.[5] Fixation with two cortical screws is generally better than one, as it improves rotational stability.[6] However, the insertion of two screws into the odontoid process is technically challenging for surgeons. To safely place two 3.5-mm screws, the transverse diameter of the odontoid process should be larger than 9 mm.[7]

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Determining the appropriate odontoid dimension is important to avoid complications associated with screw placement.[8] The anatomical parameters of the odontoid process are ethnically related (Table 1)[7,9-17]; however, there are no reports on the diameter of the dentition in the Chinese population. However, there is no report on the diameter of the odontoid process in the Chinese population. In addition, a validated description of any differences in treatment strategies between men and women is lacking. Therefore, the main aim of this study was to evaluate morphometric parameters of the odontoid process using computed tomography scans and assess whether anterior fixation with two 3.5-mm screws is feasible in the Chinese population. Meanwhile, a new measurement strategy including maximum screw length (MSL) and screw projection back angle (SPBA) is introduced to offer guidance for surgeons.

METHODS

This study was exempt from Ethical Committee review because medical research using human information data could be granted an exemption from ethical review by relevant guidelines and regulations. Written informed consent was obtained from all participants.

A retrospective review of cervical spine computed tomography (CT) scans was carried out. The inclusion criteria for this study were adults who had intact C1–C2 vertebrae with no signs of instrumentation, deformity, infection, or tumor. Based on the inclusion criteria, a total of 128 patients comprising 55 men (43.0%), with a mean age of 47.6 ± 13.2 years (range, 18–76 years) were included in this study. All the scans were performed with 64 CT Scanner (Philips Brilliance, Best, Netherlands). After image processing, all morphometric analyses were performed manually with a digital cursor in the multiplanar reconstructions.

The minimum external transverse diameter (METD) and the minimum external anteroposterior diameter (MEAD) were defined as the narrowest part of an odontoid process in the coronal plane (Fig. 1A) and sagittal plane (Fig. 1B), respectively. The MSL was the length from the screw insertion point to the posterior dens tip (Fig. 1C). The SPBA was the angle formed by the line of screw insertion and the posterior edge of the odontoid process (Fig. 1D). The definitions of the parameters used are provided in Table 2.

All statistical analyses were performed using IBM SPSS Statistics ver. 20 (IBM Corp., Armonk, NY, USA). All data were expressed as mean ± standard deviation. Student *t*-test was used to calculate the mean differences of different parameters within each sex. Correlations between age and height with odontoid dimensions were determined using the Pearson correlation coefficient. Two orthopedic surgeons (GM and YY) independently and in a blinded manner measured all parameters twice, and intraclass correlation coefficients (ICC) were used to evaluate intra- and interobserver reliability. A p-value < 0.05 was considered statistically significant.

Table 1. Summary of Measurement Variability in the Odontoid Process

Study	Measurement method	Population	Sex difference	METD (mm)
Daher et al.[9]	Computer	Brazilian	No	9.2 ± 0.9
Yusof et al.[10]	Computer	Malaysian	No	10.2 ± 0.8
Marwan et al.[11]	Computer	Arab	Yes	8.7 ± 1.0
Gehweiler et al.[12]	Computer	European	Yes	10.2 ± 0.9
Nucci et al.[7]	Computer	Caucasian	No	10.4 ± 1.1
Puchwein et al.[13]	Computer	Caucasian	Yes	10.0 ± 1.1
Xu et al.[14]	Manual	American	Yes	8.7 ± 1.2
Schaffler et al.[15]	Manual	American	Yes	9.3 ± 0.9
Stulik at al.[16]	Manual	European	Yes	10.1 ± 1.1
Kandziora et al.[17]	Manual	European	No comment	9.7 ± 0.8

Values are presented as mean ± standard deviation.
METD: minimum external transverse diameter.

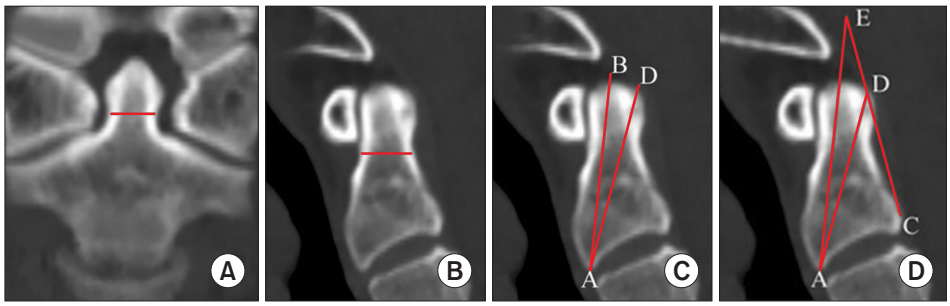

Fig. 1. Odontoid process parameters in computed tomography images. (A) Minimum external transverse diameter of the odontoid process on the coronal view. (B) Minimum external anterior-posterior diameter. (C) Screw length toward the posterior odontoid tip (AD). (D) Screw projection back angle at point E and point D.

Table 2. Reference Points and Parameters Used in the Study

Parameter	Reference point
Screw insertion point	A
Apex of odontoid	B
Posterior-inferior point of the body of axis	C
Posterior odontoid tip	D
Point at which imaginary lines extending through AB and CD meet to form an angle	E
Screw projection back angle at point D	ADC
Screw projection back angle at point E	AEC

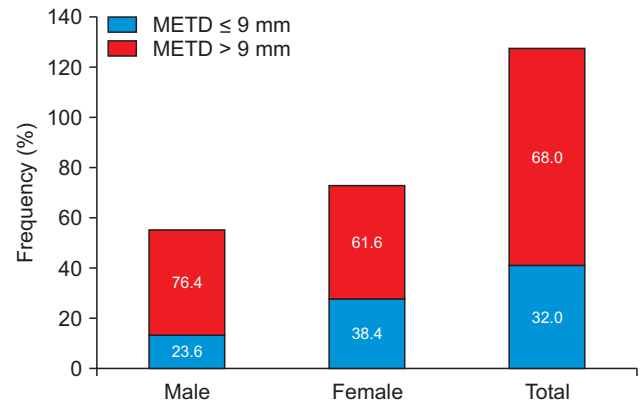

Fig. 2. Percentage of individuals in each sex stratified by 9 mm of minimum external anteroposterior diameter (METD).

Table 3. Mean Parameters of the Odontoid Process and Comparison between Sexes

Variable	Male	Female	Total	*p*-value
METD (mm)	10.0±1.1	9.2±1.0	9.5±1.1	< 0.001
MEAD (mm)	12.0±1.0	11.0±1.0	11.5±1.1	< 0.001
MSL (mm)	35.7±2.5	33.3±2.7	34.4±2.9	< 0.001
SPBA to apical odontoid (°)	14.1±3.6	13.0±3.1	13.5±3.3	0.066
SPBA to posterior odontoid tip (°)	24.4±3.1	24.0±3.0	24.2±3.1	0.383

Values are presented as mean ± standard deviation.
METD: minimum external transverse diameter, MEAD: minimum external anteroposterior diameter, MSL: maximum screw length, SPBA: screw projection back angle.

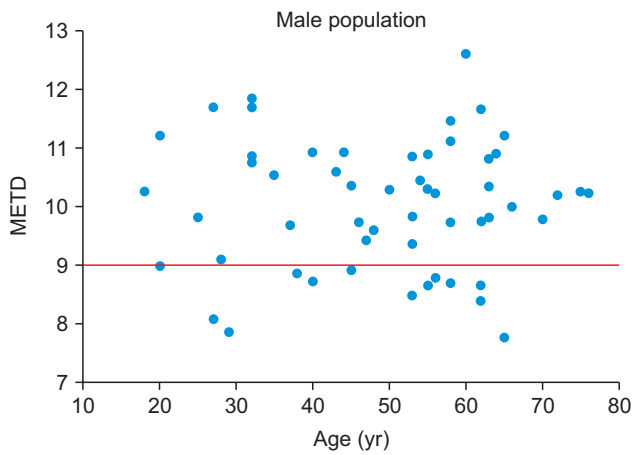

Fig. 3. A scatter graph showing the relationship between the minimum external anteroposterior diameter (METD) and age in each man. There were 13 points below the red line where odontoids were not suitable for two 3.5-mm screws.

RESULTS

The mean METD and MEAD were 9.5 ± 1.1 mm and 11.5 ± 1.1 mm, respectively and MEAD was significantly larger than the mean METD ($p < 0.05$). The mean METD, MEAD, and MSL were found to be significantly higher in men ($p < 0.001$). Table 3 shows the mean values of parameters studied and statistical comparison between men and women. The METD ≤ 9 mm was observed in 13 men (23.6%) and 28 women (38.4%), and 41 of the subjects (32.0%) were not suitable for placing two 3.5-mm screws (Figs. 2-4). The ICC values for the relevant parameters were greater than 0.8 within and between observers, respectively, with high repeatability (Table 4).

MSL was 35.7 ± 2.5 mm and 33.3 ± 2.7 mm in men

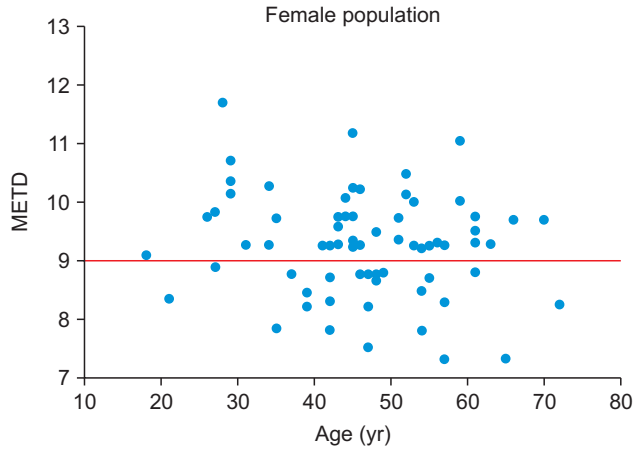

Fig. 4. A scatter graph showing the relationship between the minimum external anteroposterior diameter (METD) and age in each woman. There were 28 points below the red line where odontoids were not suitable for two 3.5-mm screws.

Table 4. Intraobserver Reproducibility and Interobserver Reliability Assessed Using ICCs

Measurement	ICC (95% confidence interval)	
	Intraobserver	Interobserver
METD	0.976 (0.966–0.983)	0.949 (0.928–0.964)
MEAD	0.954 (0.935–0.967)	0.944 (0.921–0.960)
MSL	0.970 (0.958–0.979)	0.921 (0.890–0.944)
SPBA to apical odontoid	0.938 (0.913–0.956)	0.877 (0.831–0.912)
SPBA to posterior odontoid tip	0.930 (0.903–0.950)	0.856 (0.801–0.896)

ICC: intraclass correlation coefficient, METD: minimum external transverse diameter, MEAD: minimum external anteroposterior diameter, MSL: maximum screw length, SPBA: screw projection back angle.

and women, respectively. The screw length should be shorter than MSL to prevent breakthrough of the posterior cortex. There was no statistically significant difference in SPBA between men and women, and the screw insertion angle should be maintained in the range of 13.5° to 24.2°. We found a significantly positive correlation of height with METD and MEAD (height to METD: $r = 0.208$, $p = 0.018$; height to MEAD: $r = 0.299$, $p = 0.001$), while age was not significantly correlated with METD and MEAD (age to METD: $r = –0.008$, $p = 0.930$; age to MEAD: $r = 0.104$, $p = 0.244$).

DISCUSSION

Different treatment modalities, including cervical collar immobilization, Halo vest orthosis, and surgery, can be used for odontoid fractures depending on the fracture type, displacement degree, and patient age.[18] Among them, surgery is the most effective option, with a union rate of 80%–100%, compared with only 60% for conservative treatment.[19]

In anterior odontoid surgery, whether to use one or two screws in odontoid fractures has been a debated issue since the introduction of anterior screw fixation with no clear consensus on which approach is better.[20] Several studies have shown no significant difference in union rate between single- and double-screw treatment of patients with odontoid fractures.[6,21,22] Theoretically, two screw fixation provides better rotational stability and a higher union rate in patients with poor bone quality than single-screw fixation.[23,24] However, high-quality clinical evidence on the optimal number of screws in odontoid fractures is lacking.

The application of two screws in the management of odontoid fractures is not always feasible. The transverse diameter of the odontoid process is believed to be more relevant than the anteroposterior (AP) diameter, as two screws are usually placed side by side in the coronal plane.[25] In the present study, AP was generally greater than MTED, suggesting that METD is an important consideration when inserting two 3.5-mm screws. In addition, a minimum of 0.5 mm of cortical bone should be left outside the screws, with a minimum spacing of 1.0 mm between implants. Placement of two screws is only possible on dens with a minimum transverse diameter of more than 9 mm with tapping.[7] The morphologic dimension of the odontoid process varies between populations.[7,9,10,12] Thus, analyzing the patterns of dens dimension in different population groups can facilitate safer screw placement.

In the present study, 32% of the subjects, including 23.6% of the men and 38.4% of the women, could not accommodate two screw placements for anterior fixation of dens fractures. This is consistent with observations in other populations, such as Brazilian (35%)[9] and Malaysian (33%)[10] populations, but different from the Caucasian population, where 82%–95%[7,12] of the odontoid process could accommodate two screws. In our study, odontoid dimensions were positively correlated with height and were independent of age. It might be attributed to the disparity in body shape between different human races.

For individuals with METD < 9 mm, one 4.5-mm screw placement can be considered. Placement of this screw requires a minimum diameter of 5.5 mm, but in the present study, none of the patients had a diameter less than

this value. Biomechanical studies have shown that the 4.5-mm Herbert screw produced greater compression forces than the 3.5-mm hollow screw.[26] The use of a 4.5-mm cannulated Herbert screw demonstrated a similar clinical effect as the use of two 3.5-mm screws for anterior odontoid surgical fixation.[27,28] However, as the Herbert screw lacks an anti-rotation effect, more attention should be paid to restricting the movement of the injured site in the early stage of fracture.

Preoperative planning of the number and length of screws and angle of screw insertion is important for proper fixation and reduced risk of screw misplacement.[29] Shorter screws are associated with lack of interfragmentary compression, which results in ultimate screw failure.[30] In contrast, excessively large screws may extend several millimeters beyond the dens tip, potentially damaging adjacent neurovascular structures. The average screw length toward posterior odontoid tip was 34.4 mm, which is consistent with previously reported results.[29,31]

The SPBA is a newly defined parameter, which can guide the screw insertion by controlling the angles relative to a posterior border of dens. Screw insertion in the sagittal view requires the screw back angles to be controlled within certain ranges between apical dens and posterior dens tip to minimize potential complications caused by screw insertion, including screw cortical breakout and damage to nearby neurovascular structures. In our study, the screw back angle was controlled and maintained between 13.5° and 24.2° on average. Preoperative evaluation of the screw back angle can be used as an alternative to the screw attack angle in determining a safe zone of screw trajectory.

The shortcomings of this study include an insufficient sample size and the limited sampling area. In addition, since this was an observational study, there was no actual intervention. High-quality evidence is still needed to guide the treatment of odontoid fractures. In the Chinese population, placement of two 3.5-mm cortical screws in the transverse position was possible in 76.4% of the men and 61.6% of the women. The screw length and projection back angle were important parameters to avoid complications associated with screw insertion.

CONFLICT OF INTEREST

No potential conflict of interest relevant to this article was reported.

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