GENDER-RELATED VARIATIONS IN THORACIC PEDICLE MORPHOMETRY: A STUDY OF 1,200 PEDICLES

Ashwini Shetty *1, Avadhani R 1, Yashodar Bhandary 2.

*1 Department of Anatomy, Yenepoya Medical College Yenepoya University Mangaluru, Karnataka, India.
2 Research Center, Yenepoya Medical College Yenepoya University Mangaluru, Karnataka, India.

ABSTRACT

Background: The pedicles exhibited significant variability in their shape and orientation, not only from region to region within the thoracic spine, but also within the same region and even within the same pedicle. The diameter of the spinal canal is also of great significance in thoracic spine fractures. The canal diameter of the thoracic spine is narrower than that of the cervical and lumbar

Pedicle is the most important part of the thoracic vertebrae in instrumentation of the spinal column, in the curvature corrections or in case of any spine abnormalities. Pedicles connect the vertebral bodies to the posterior elements. The pedicles exhibited significant variability in their shape and orientation, not only from region to region within the thoracic spine, but also within the same region and even within the same pedicle. The diameter of the spinal canal is also of great significance in thoracic spine fractures. The canal diameter of the thoracic spine is narrower than that of the cervical and lumbar...
spine. The orientation and shape of the pedicles in the thoracic spine are different from those of their lumbar counterparts and can often preclude pedicle fixation. The pedicle isthmus width is smaller in the thoracic spine than in the lumbar spine. Morphometric measurements of a spine in the particular geographical area will help in proper implant selection during spinal surgeries, designing of best suited implant, understanding the biomechanics and pathoanatomy of the spine, precise clinical diagnosis and management of the population under consideration. Furthermore, the midthoracic region is predisposed to higher rotational stress, which may have a bearing on the rate of disc degeneration. There is a demand for quantitative data concerning the thoracic pedicle using different measurement techniques. Computerized Tomography scan (CT) is preferred for evaluation of the morphometry of the thoracic spine. More precise measurements and dimensions of various anatomical parts of the selected vertebrae can be acquired from Computerized Tomography (CT) [1,2].

These factors demand for studies of the thoracic pedicle morphometry in the population of different regions. Hence this study was undertaken to analyze the pedicle morphometry from a large dataset of CT scan and direct measurement with the following objectives: To determine the morphometry changes related to normal ageing and to analyze the difference of thoracic morphometry in between the genders.

MATERIALS AND METHODS

The data were collected from the vertebra of cadavers that were available in the department of Anatomy. About 100 (58 males and 42 females) thoracic spine (T1 to T12) aged between 35 to 80 years were included in the study. The cadavers with congenital spinal deformities, had undergone surgical treatments (like implants), were excluded from the study. The Institutional Ethical Committee Clearance was taken before the study started.

Morphometric measurement of 1200 thoracic vertebrae from 100 cadavers were studied using CT scan measurement and directly on bones. The part with the intact spine was separated from the cadaver after dissection. All the organs in the anterior part of thorax and abdomen were removed. Dissection of the thoracic spine section was done in the upper back. Following measurement by the CT scan the direct measurement was carried out. The linear measurements were performed at the different vertebral levels with the digital Vernier caliper (resolution 0.01 mm) and the angular measurements were done with a goniometer (resolution 1°) and CT scanner (GE health care).

The following parameters were measured

**Pedicle width (PW):** The outer cortical transverse width of the mid pedicle

**Sagittal diameter of the pedicle or pedicle height (PH):** The superior inferior outer cortical length of the pedicle measured at mid pedicle (minimum sagittal diameter)

**Chord length (CL):** Measured from the posterior cortical entry point of the pedicle to the anterior vertebral cortex along the axis of the pedicle.

**Vertical interpedicular distance (VIPD):** Vertical distance between the two pedicles of two vertebrae at the midpoint.

**Transverse interpedicular distance (TIPD):** Transverse distance between the two pedicle at the midpoint.

**Transverse angle (TA):** Measured by the angle between the pedicle axis and a line parallel to the vertebral midline measured in the transverse plane

**Sagital angle (SA):** Measured as angle between the sagittal pedicle axis and the superior border of the vertebral body in the sagittal plane.

All the linear measurements were made using digital vernier calipers with resolution (0.01mm). Angles were measured by a goniometer (resolution 1°) and confirmed using a protractor after tracing the outline of the vertebrae onto a paper.

RESULTS

**Variation between measurement of male and female thoracic vertebra in direct and CT measurements**

**Chord Length (CL):** Mean Chord Length for
males and females values recorded from direct and CT measurements are given in Table 1.
CL increased from T1 to T12 vertebral level in males and females groups in direct and CT measurement. Male cadaver had larger mean CL than female cadaver at all thoracic spine levels in both the techniques and chord length had maximum mean value at T12 with 43.61 ± 0.08 mm in males and 30.25 ± 0.18 mm in females at direct measurement and 42.63 ± 0.28 mm in males and 30.26 ± 0.15 mm in CT measurement and observed minimum mean value at T1 with 28.38 ± 0.39 mm in males and 20.36 ± 0.16 mm in females in CT measurement and 29.56 ± 0.19 mm in males and 21.68 ± 0.19 mm in females at direct measurements. The differences were statistically significant (p < 0.05) at the spine levels from T1 to T12.

**Pedicle height (PH):** Mean pedicle height for males and females values recorded from direct and CT measurements are given in Table 1.2. PH was maximum at T12 vertebral level in direct measurement and CT measurement in males (11.46 ± 0.16 mm in DM), (11.59 ± 0.26 mm in CT) and in females (11.55 ± 0.219 mm in DM) (11.48 ± 0.19 mm in CT) and PH increased from T2 to T12 vertebral level in male and female subject groups. PH was more in females compare to males at all the vertebral levels. There was no significant difference (p > 0.05) between males and females except at T10 and T12 there are significant difference (p < 0.05) between males and females.

**Pedicle width (PW):** Mean pedicle width for males and females values recorded from direct and CT measurements are given in Table 1.3
PW was maximum at T1 in males (7.63 ± 0.18 mm in DM) (7.60 ± 0.21 mm in CT) and females (7.67 ± 0.14 mm in DM) (7.67 ± 0.22 mm in CT) and maximum value observed at T11 in males 7.58 ± 0.17 mm and females 7.64 ± 0.205 mm in direct measurement and T12 in males (7.63 ± 0.21 mm) and females (7.64 ± 0.25 mm) in CT measurement. Minimum value observed at T5 in males 4.49 ± 0.18 mm and at T4 vertebral level in females 4.49 ± 0.17 mm in direct measurement, whereas minimum value observed in males (4.50 ± 0.16 mm) and females (4.57 ± 0.30 mm) in CT measurement at T6 vertebral level. The PW was higher at upper and lower thoracic level compare to mid thoracic region in males and females in direct and CT measurements. There was no significant difference (p > 0.05) between the males and females in all the vertebral level except at T8 (p < 0.05).

**Sagittal Angle (SA):** Mean sagittal angle for males and females values recorded from direct and CT measurements are given in Table 1.4
SA showed significant difference (p < 0.05) between males and females in all vertebral levels except T2, T3, T11, and T12. SA was maximum at T4 vertebral level in males in direct measurement (17.84 ± 0.24 degree) and in CT measurement (17.78 ± 0.26 degree) and in females direct measurement showed maximum value of (17.75 ± 0.23 degree) and CT measurement (17.59 ± 0.39 degree) at T4 vertebral level.

**Transverse angle (TA):** Mean transverse angle for males and females values recorded from direct and CT measurements are given in Table 1.5
The TA decreased from T1 to T12 vertebral levels in males and females. The maximum TA observed at T1 vertebral level (30.51 ± 0.16 degree) in males in direct measurement and (29.59 ± 0.17 degree) in CT measurement and (30.54 ± 0.26 degree) in females in direct and (29.73 ± 0.44 degree) in CT measurements. Minimum TA observed in T12 vertebral level in males (8.53 ± 0.19 in DM) (8.55 ± 0.25 degree in CT) and females (8.56 ± 0.15 degree in DM) (8.61 ± 0.17 degree in CT). There was no significant difference (p > 0.05) between the males and females in the TA at all the vertebral level except at T9 and T11 it was significant (p < 0.05).

**Transverse Inter Pedicular Distance (TIPD):** Mean Transverse Inter Pedicular Distance (TIPD) for males and females values recorded from direct and CT measurements are given in Tab.1.6
The TIPD was increased from T4 to T12. The maximum TIPD was at T12 vertebral level in males (31.73 ± 0.20 mm in DM, 31.82 ± 0.12 mm in CT) and females (31.59 ± 0.22 mm in DM, 31.77 ± 0.13 in CT). The minimum TIPD was observed at T4 vertebral level in males (18.36 ± 0.06 mm in DM) (18.55 ± 0.19 mm in CT) and females (18.39 ± 0.11 mm in DM) (18.60 ± 0.26 mm in CT). There was significant difference (p < 0.05) between males and females in all
**Table 1.1**: Variation in the male and female thoracic vertebral morphometry for chord length in direct measurement and CT measurement. Values are Mean ± SD (n=100).

| Thoracic vertebral level | Sex   | Direct measurement | CT measurement |
|--------------------------|-------|--------------------|----------------|
|                          | Male 58 | Female 42 | p’ Value | Male | Female | p’ Value |
| T1                       | Male   | 29.56±0.18 | <0.001** | 28.38±0.40 | 0.001** |
|                          | Female | 21.67±0.18 | 0.001**  | 20.37±0.15 | <0.001** |
| T2                       | Male   | 32.29±0.11 | <0.001** | 31.45±0.27 | <0.001** |
|                          | Female | 22.62±0.14 | 0.001**  | 22.77±0.10 | 0.001**  |
| T3                       | Male   | 33.21±0.14 | <0.001** | 32.60±0.26 | 0.001**  |
|                          | Female | 23.33±0.27 | 0.001**  | 23.71±0.22 | <0.001** |
| T4                       | Male   | 34.86±0.17 | <0.001** | 33.94±0.36 | 0.001**  |
|                          | Female | 24.74±0.31 | 0.001**  | 23.81±0.20 | 0.001**  |
| T5                       | Male   | 35.45±0.07 | <0.001** | 34.63±0.35 | <0.001** |
|                          | Female | 23.47±0.08 | 0.001**  | 23.38±0.10 | 0.001**  |
| T6                       | Male   | 38.61±0.05 | <0.001** | 37.71±0.36 | 0.001**  |
|                          | Female | 24.38±0.21 | 0.001**  | 24.24±0.23 | 0.001**  |
| T7                       | Male   | 40.24±0.14 | <0.001** | 39.47±0.26 | 0.001**  |
|                          | Female | 25.39±0.10 | 0.001**  | 25.26±0.19 | 0.001**  |
| T8                       | Male   | 42.30±0.13 | <0.001** | 41.52±0.30 | 0.001**  |
|                          | Female | 26.59±0.13 | 0.001**  | 26.68±0.11 | 0.001**  |
| T9                       | Male   | 42.19±0.19 | <0.001** | 41.94±0.28 | 0.001**  |
|                          | Female | 27.39±0.21 | 0.001**  | 27.40±0.10 | 0.001**  |
| T10                      | Male   | 42.65±0.14 | <0.001** | 41.64±0.37 | <0.001** |
|                          | Female | 28.83±0.17 | <0.001** | 28.42±0.06 | 0.001**  |
| T11                      | Male   | 42.69±0.12 | <0.001** | 41.78±0.32 | <0.001** |
|                          | Female | 29.36±0.19 | 0.001**  | 29.47±0.05 | <0.001** |
| T12                      | Male   | 43.61±0.08 | <0.001** | 42.63±0.28 | <0.001** |
|                          | Female | 30.25±0.19 | 0.001**  | 30.26±0.16 | 0.001**  |

**Statistically significant difference (p<0.001)**

**Table 1.2**: Variation in the male and female thoracic vertebral morphometry for pedicle height in direct measurement and CT measurement. Values are Mean ± SD (n=100).

| Thoracic vertebral level | Sex   | Direct measurement | CT measurement |
|--------------------------|-------|--------------------|----------------|
|                          | Male 58 | Female 42 | p’ Value | Male | Female | p’ Value |
| T1                       | Male   | 8.38±0.36 | p > 0.05 | 8.46±0.45 | p > 0.05 |
|                          | Female | 8.39±0.37 | p > 0.05 | 8.43±0.49 | p > 0.05 |
| T2                       | Male   | 8.32±0.39 | p > 0.05 | 7.70±0.49 | p < 0.05* |
|                          | Female | 8.35±0.38 | p > 0.05 | 7.99±0.64 | p > 0.05  |
| T3                       | Male   | 8.45±0.16 | p > 0.05 | 8.42±0.41 | p > 0.05  |
|                          | Female | 8.50±0.18 | p > 0.05 | 8.55±0.41 | p > 0.05  |
| T4                       | Male   | 8.50±0.17 | p > 0.05 | 8.53±0.15 | p > 0.05  |
|                          | Female | 8.51±0.18 | p > 0.05 | 8.55±0.17 | p > 0.05  |
| T5                       | Male   | 8.47±0.18 | p > 0.05 | 8.51±0.18 | p > 0.05  |
|                          | Female | 8.50±0.20 | p > 0.05 | 8.56±0.20 | p > 0.05  |
| T6                       | Male   | 9.45±0.16 | p > 0.05 | 9.56±0.19 | p > 0.05  |
|                          | Female | 9.42±0.22 | p > 0.05 | 9.55±0.24 | p > 0.05  |
| T7                       | Male   | 9.49±0.18 | p > 0.05 | 9.68±0.20 | p > 0.05  |
|                          | Female | 9.50±0.18 | p > 0.05 | 9.73±0.19 | p > 0.05  |
| T8                       | Male   | 9.52±0.16 | p > 0.05 | 9.52±0.19 | p < 0.05* |
|                          | Female | 9.57±0.14 | p > 0.05 | 9.60±0.17 | p > 0.05  |
| T9                       | Male   | 9.52±0.18 | p > 0.05 | 9.54±0.16 | p > 0.05  |
|                          | Female | 9.53±0.20 | p > 0.05 | 9.55±0.19 | p > 0.05  |
| T10                      | Male   | 10.52±0.15 | p < 0.05* | 10.63±0.18 | p < 0.05* |
|                          | Female | 10.61±0.20 | p > 0.05 | 10.71±0.24 | p > 0.05  |
| T11                      | Male   | 10.59±0.21 | p > 0.05 | 10.61±0.19 | p > 0.05  |
|                          | Female | 10.56±0.18 | p > 0.05 | 10.59±0.17 | p > 0.05  |
| T12                      | Male   | 11.47±0.17 | p < 0.05* | 11.49±0.19 | p < 0.05* |
|                          | Female | 11.56±0.22 | p < 0.05* | 11.59±0.26 | p < 0.05* |

*Statistically significant difference (p<0.05) between male and females.
Table 1.3: Variation in the male and female thoracic vertebral morphometry for pedicle width in direct measurement and CT measurement. Values are Mean ± SD (n=100).

| Thoracic vertebral Level | Sex     | Direct measurement | CT measurement |
|--------------------------|---------|--------------------|----------------|
|                          | Male-58 | Female-42          |                |
| **Pedicle width**        |         | Mean 'p' Value     | Mean 'p' Value |
| T1                       | Male    | 7.63±0.12 > 0.05   | 7.61±0.21 > 0.05|
|                          | Female  | 7.66±0.14          | 7.68±0.22      |
| T2                       | Male    | 5.64±0.16 > 0.05   | 5.67±0.30 > 0.05|
|                          | Female  | 5.71±0.25          | 5.77±0.32      |
| T3                       | Male    | 4.55±0.14 > 0.05   | 5.10±0.52 > 0.05|
|                          | Female  | 4.62±0.28          | 5.26±0.51      |
| T4                       | Male    | 4.50±0.18 > 0.05   | 4.60±0.18 > 0.05|
|                          | Female  | 4.50±0.17          | 4.61±0.16      |
| T5                       | Male    | 4.50±0.15 > 0.05   | 4.53±0.24 > 0.05|
|                          | Female  | 4.56±0.28          | 4.64±0.38      |
| T6                       | Male    | 4.59±0.15 > 0.05   | 4.50±0.17 > 0.05|
|                          | Female  | 4.63±0.26          | 4.57±0.31      |
| T7                       | Male    | 4.57±0.19 > 0.05   | 4.84±0.38 > 0.05|
|                          | Female  | 4.61±0.26          | 4.94±0.40      |
| T8                       | Male    | 4.57±0.17 < 0.05*  | 4.72±0.38 < 0.05*|
|                          | Female  | 4.67±0.27          | 4.92±0.42      |
| T9                       | Male    | 5.59±0.19 > 0.05   | 5.65±0.20 > 0.05|
|                          | Female  | 5.62±0.18          | 5.70±0.18      |
| T10                      | Male    | 7.42±0.35 > 0.05   | 7.44±0.42 > 0.05|
|                          | Female  | 7.32±0.54          | 7.34±0.63      |
| T11                      | Male    | 7.59±0.17 > 0.05   | 8.38±0.58 < 0.05*|
|                          | Female  | 7.65±0.21          | 8.60±0.48      |
| T12                      | Male    | 7.53±0.18 > 0.05   | 7.64±0.21 > 0.05|
|                          | Female  | 7.51±0.25          | 7.64±0.26      |

Table 1.4: Variation in the male and female thoracic vertebral morphometry for sagittal angle in direct measurement CT measurement. Values are Mean ± SD (n=100).

| Thoracic vertebral level | Sex     | Direct measurement | CT measurement |
|--------------------------|---------|--------------------|----------------|
|                          | Male-58 | Female-42          |                |
| **Sagittal angle**       |         | Mean ± SD 'p' Value | Mean ± SD 'p' Value |
| T1                       | Male    | 16.11±0.13 <0.001** | 16.13±0.14 <0.001** |
|                          | Female  | 16.28±0.32         | 16.30±0.36      |
| T2                       | Male    | 17.47±0.36 > 0.05  | 17.59±0.30 > 0.05|
|                          | Female  | 17.38±0.38         | 17.53±0.39      |
| T3                       | Male    | 17.42±0.22 > 0.05  | 17.29±0.08 > 0.05|
|                          | Female  | 17.43±0.33         | 17.28±0.11      |
| T4                       | Male    | 17.84±0.21 < 0.05* | 17.79±0.26 < 0.05*|
|                          | Female  | 17.75±0.24         | 17.65±0.34      |
| T5                       | Male    | 17.35±0.04 <0.001** | 17.34±0.05 <0.001** |
|                          | Female  | 17.42±0.10         | 17.39±0.09      |
| T6                       | Male    | 15.92±0.28 > 0.05  | 15.85±0.30 > 0.05|
|                          | Female  | 16.06±0.39         | 15.99±0.42      |
| T7                       | Male    | 16.34±0.15 > 0.05  | 16.46±0.25 > 0.05|
|                          | Female  | 16.42±0.16         | 16.58±0.27      |
| T8                       | Male    | 15.21±0.25 <0.001** | 15.37±0.23 <0.001** |
|                          | Female  | 15.41±0.31         | 15.52±0.26      |
| T9                       | Male    | 10.24±0.24 <0.001** | 10.35±0.20 <0.001** |
|                          | Female  | 10.63±0.64         | 10.63±0.45      |
| T10                      | Male    | 10.50±0.22 < 0.05* | 10.28±0.15 < 0.05*|
|                          | Female  | 10.60±0.24         | 10.38±0.14      |
| T11                      | Male    | 7.56±0.32 > 0.05   | 7.45±0.13 < 0.05*|
|                          | Female  | 7.67±0.28          | 7.50±0.13       |
| T12                      | Male    | 5.51±0.33 > 0.05   | 4.57±0.46 < 0.05*|
|                          | Female  | 5.59±0.37          | 4.66±0.51       |

*Statistically significant difference (p<0.05). **Statistically significant difference (p < 0.001)
Table 1.5: Variation in the male and female thoracic vertebral morphometry for transverse angle in the direct measurement and CT measurement. Values are Mean ± SD (n=100)

| Thoracic vertebral Level | Sex | Direct measurement | CT measurement | 'p' Value | 'p' Value |
|--------------------------|-----|--------------------|----------------|----------|----------|
|                          | Male-58 | Female-42          |                |          |          |
| T1                       | Male    | 30.51 ± 0.17       | 29.59±0.17     | < 0.05*  | < 0.05*  |
|                          | Female  | 30.54 ± 0.26       | 29.74±0.44     | < 0.05*  | < 0.05*  |
| T2                       | Male    | 23.47 ± 0.16       | 23.53±0.31     | > 0.05   | > 0.05   |
|                          | Female  | 23.50 ± 0.17       | 23.62±0.25     | > 0.05   | > 0.05   |
| T3                       | Male    | 18.55 ± 0.19       | 18.60±0.20     | > 0.05   | > 0.05   |
|                          | Female  | 18.50 ± 0.17       | 18.57±0.20     | > 0.05   | > 0.05   |
| T4                       | Male    | 16.50 ± 0.18       | 16.50±0.25     | > 0.05   | > 0.05   |
|                          | Female  | 16.55 ± 0.16       | 16.54±0.25     | > 0.05   | > 0.05   |
| T5                       | Male    | 15.55 ± 0.16       | 15.60±0.21     | > 0.05   | > 0.05   |
|                          | Female  | 15.52 ± 0.14       | 15.62±0.20     | > 0.05   | > 0.05   |
| T6                       | Male    | 14.54 ± 0.18       | 14.50±0.18     | > 0.05   | > 0.05   |
|                          | Female  | 14.57 ± 0.17       | 14.55±0.16     | > 0.05   | > 0.05   |
| T7                       | Male    | 14.55 ± 0.22       | 14.61±0.20     | > 0.05   | > 0.05   |
|                          | Female  | 14.60 ± 0.18       | 14.65±0.20     | > 0.05   | > 0.05   |
| T8                       | Male    | 13.52 ± 0.27       | 13.60±0.28     | > 0.05   | > 0.05   |
|                          | Female  | 13.60 ± 0.20       | 13.70±0.18     | > 0.05   | > 0.05   |
| T9                       | Male    | 11.50 ± 0.25       | 11.62±0.14     | < 0.05*  | < 0.05*  |
|                          | Female  | 11.66 ± 0.39       | 11.69±0.13     | < 0.05*  | < 0.05*  |
| T10                      | Male    | 10.51 ± 0.24       | 9.97±0.57      | > 0.05   | > 0.05   |
|                          | Female  | 10.57 ± 0.19       | 10.10±0.57     | > 0.05   | > 0.05   |
| T11                      | Male    | 9.45 ± 0.18        | 8.77±0.45      | < 0.05*  | < 0.05*  |
|                          | Female  | 9.53 ± 0.17        | 9.02±0.45      | < 0.05*  | < 0.05*  |
| T12                      | Male    | 8.54 ± 0.20        | 8.55±0.25      | > 0.05   | > 0.05   |
|                          | Female  | 8.56 ± 0.16        | 8.62±0.17      | > 0.05   | > 0.05   |

*Statistically significant difference (p<0.05).

Table 1.6: Variation in the male and female thoracic vertebral morphometry for transverse interpedicular distance in the direct measurement and CT measurement. Values are Mean ± SD (n=100)

| Thoracic vertebral Level | Sex | Direct measurement | CT measurement | 'p' Value | 'p' Value |
|--------------------------|-----|--------------------|----------------|----------|----------|
|                          | Male-58 | Female-42          |                |          |          |
| T1                       | Male    | 23.36 ± 0.03       | 23.36±0.09     | < 0.001** | < 0.001** |
|                          | Female  | 23.43 ± 0.12       | 23.47±0.23     | < 0.001** | < 0.001** |
| T2                       | Male    | 23.87 ± 0.18       | 23.94±0.45     | > 0.05   | > 0.05   |
|                          | Female  | 23.78 ±0.23        | 23.85±0.56     | > 0.05   | > 0.05   |
| T3                       | Male    | 19.21 ± 0.13       | 19.47±0.30     | > 0.05   | > 0.05   |
|                          | Female  | 19.29 ± 0.19       | 19.59±0.32     | > 0.05   | > 0.05   |
| T4                       | Male    | 18.36 ± 0.06       | 18.55±0.19     | > 0.05   | > 0.05   |
|                          | Female  | 18.39 ± 0.11       | 18.61±0.26     | > 0.05   | > 0.05   |
| T5                       | Male    | 18.38 ± 0.07       | 18.57±0.19     | > 0.05   | > 0.05   |
|                          | Female  | 18.42±0.16         | 18.59±0.26     | > 0.05   | > 0.05   |
| T6                       | Male    | 23.46±0.06         | 23.71±0.21     | > 0.05   | > 0.05   |
|                          | Female  | 23.46±0.11         | 23.67±0.25     | > 0.05   | > 0.05   |
| T7                       | Male    | 25.78±0.15         | 25.82±0.27     | < 0.001** | < 0.001** |
|                          | Female  | 25.70±0.17         | 25.66±0.24     | < 0.001** | < 0.001** |
| T8                       | Male    | 26.89±0.13         | 26.67±0.25     | > 0.05   | > 0.05   |
|                          | Female  | 26.79±0.21         | 26.52±0.29     | < 0.001** | < 0.001** |
| T9                       | Male    | 27.82±0.22         | 27.80±0.27     | > 0.05   | > 0.05   |
|                          | Female  | 27.72±0.22         | 27.68±0.34     | > 0.05   | > 0.05   |
| T10                      | Male    | 28.25±0.24         | 27.66±0.36     | < 0.001** | < 0.001** |
|                          | Female  | 28.35±0.19         | 27.85±0.31     | < 0.001** | < 0.001** |
| T11                      | Male    | 29.23±0.15         | 29.83±0.94     | > 0.05   | > 0.05   |
|                          | Female  | 29.38±0.22         | 30.48±1.05     | > 0.05   | > 0.05   |
| T12                      | Male    | 31.73±0.20         | 31.82±0.12     | > 0.05   | > 0.05   |
|                          | Female  | 31.60±0.23         | 31.77±0.13     | > 0.05   | > 0.05   |

*Statistically significant difference (p < 0.05), ** statistically significant difference (p < 0.001).
Table 1.7: Variation in the male and female thoracic vertebral morphometry for vertical interpedicular distance in direct measurement and CT measurement. Values are Mean ± SD (n=100)

| Thoracic vertebral Level | Sex   | Direct measurement | CT measurement |
|--------------------------|-------|--------------------|----------------|
|                          | Male  | Female             | Male           | Female         |
| T1                       |       |                    |                |                |
| Male                     | 21.70 ± 0.16 | >0.05 | 21.40 ± 0.59 | <0.05**         |
| Female                   | 21.69 ± 0.13 | >0.05 | 21.11 ± 0.76 | >0.05           |
| T2                       |       |                    |                |                |
| Male                     | 22.65 ± 0.13 | >0.05 | 22.66 ± 0.15 | >0.05           |
| Female                   | 22.61 ± 0.15 | >0.05 | 22.61 ± 0.17 | >0.05           |
| T3                       |       |                    |                |                |
| Male                     | 23.28 ± 0.23 | <0.05* | 23.34 ± 0.18 | <0.001**        |
| Female                   | 23.39 ± 0.24 | >0.05 | 23.44 ± 0.18 | >0.05           |
| T4                       |       |                    |                |                |
| Male                     | 23.91 ± 0.75 | <0.001 | 23.50 ± 0.32 | <0.001**        |
| Female                   | 23.53 ± 0.62 | >0.05 | 23.31 ± 0.27 | >0.05           |
| T5                       |       |                    |                |                |
| Male                     | 23.42 ± 0.13 | >0.05 | 23.47 ± 0.13 | >0.05           |
| Female                   | 23.39 ± 0.21 | >0.05 | 23.45 ± 0.18 | >0.05           |
| T6                       |       |                    |                |                |
| Male                     | 24.33 ± 0.16 | <0.05* | 24.46 ± 0.24 | >0.001**        |
| Female                   | 24.41 ± 0.19 | >0.05 | 24.62 ± 0.25 | >0.001**        |
| T7                       |       |                    |                |                |
| Male                     | 25.38 ± 0.11 | <0.001** | 25.31 ± 0.12 | <0.05*          |
| Female                   | 25.49 ± 0.23 | >0.05 | 25.39 ± 0.18 | >0.05           |
| T8                       |       |                    |                |                |
| Male                     | 26.60 ± 0.11 | >0.05 | 26.65 ± 0.23 | >0.05           |
| Female                   | 26.56 ± 0.16 | >0.05 | 26.58 ± 0.27 | >0.05           |
| T9                       |       |                    |                |                |
| Male                     | 27.33 ± 0.17 | <0.001** | 27.37 ± 0.18 | <0.05*          |
| Female                   | 27.46 ± 0.23 | >0.05 | 27.46 ± 0.25 | >0.05           |
| T10                      |       |                    |                |                |
| Male                     | 28.83 ± 0.21 | >0.05 | 28.77 ± 0.23 | >0.05           |
| Female                   | 28.74 ± 0.25 | >0.05 | 28.69 ± 0.25 | >0.05           |
| T11                      |       |                    |                |                |
| Male                     | 29.33 ± 0.17 | >0.05 | 29.50 ± 0.16 | <0.05*          |
| Female                   | 29.39 ± 0.17 | >0.05 | 29.58 ± 0.18 | <0.05*          |
| T12                      |       |                    |                |                |
| Male                     | 30.21 ± 0.14 | p<0.001** | 30.38 ± 0.28 | <0.001**        |
| Female                   | 30.36 ± 0.24 | >0.05 | 30.58 ± 0.39 | >0.05           |

Statistically significant difference (p<0.05), **statistically significant difference (p<0.001)

the vertebral level as except at T4, T5, T6 it was not significant as p > 0.05

**Vertical Inter Pedicular Distance (VIPD):** Mean Transverse Inter Pedicular Distance (TIPD) for males and females values recorded from direct and CT measurements are given in Table 1.7. The VIPD was increased from T1 to T12 in males and females. There was minimum value of VIPD in males (21.70 ± 0.16 mm in DM, 21.40 ± 0.58 in CT) and females (21.69 ± 0.13 mm in DM, 21.11± 0.76 mm in CT) was at T1. A significant difference (p < 0.05) between males and females were at T3, T6, T7, T9, T12 vertebral level and there was no significant difference (p > 0.05) between males at T1, T2, T4, T5.

**DISCUSSION**

Advancement in the instrumentation for the morphometric measurements have advanced with the invent of CT scan machines. However, given variation in the morphometry of population and possibility of artifacts influencing the morphometric analyses of the thoracic spine and it was necessary to develop database on the thoracic vertebral morphometry for different population. The present study were compared with the previous published studies from India [1,2], Asia [3-6] and western world [7-13]. It included more number of cadaveric specimens in comparison to other studies which included 6-40 cadaveric specimens. In the current study CL was significantly smaller when we compared with Scoles et al. [14] in the direct measurements. To avoid violation of anterior cortex of the vertebral body, the pedicular screw length of 25 mm at the upper thoracic level and 30 mm at mid and lower thoracic levels should be safe. Furthermore the fact that there is significant difference between the males and females in each spinal level in direct and CT measurements. In the present study the pedicle dimensions in the thoracic level vertebrae of females were lower than those of the same vertebrae in males, also the age
has been considered as important variables in describing the pedicular morphology. The assessment and comparison of direct and CT measurements showed in the chord length a significant difference between the two measurements for all the thoracic vertebral level (T1-T12) and it is inferred that direct measurement value is higher compared with CT value.

Transverse diameter of the pedicle is the important dimension as this decides size of the screw to be inserted. Pedicle width decreased from T1 to T5 and gradually increased from T6 to T12 in the present study. Then 35% of all pedicles, 48% of those from T4 through T8 and 68% of those at T6, measured less than 5 mm in a study reported by Cinnotti et al. [15]. In another study by McLain et al. [7] 25% of T1 pedicles, 17% of T2 pedicles, 42% of the T3 pedicles, 61% of T4 pedicles, 67% of T5 pedicles and 75% of T6 pedicles were too small to accept a 5.5 mm screw.

Lieu et al. [16] reported that the 67.8% male and 94.4% females had transverse outer pedicle diameter less than 5-mm at T4; and 62.2% males and 90.0% females at T5 level

Acharya et al. showed that at the lower thoracic spine, pedicles faced more laterally [17]. Going for pedicle screw instrumentation on the basis of other study groups would have lead to the risk of injury to cord and other neural structures. Because of the more lateral angulation of T12 pedicle the CL of the T12 vertebra was also less as compared to other lower thoracic vertebrae.

The present study group had maximum sagittal angle at T4 level (17.8° in DM and 17.7 in CT), where as Zindrick et al. [18] and Datir and Mitra [19] had maximum value at T2 level (17.5° and 17.8° respectively). Sagittal and transverse angles show a significant difference between DM and CT measurements except T4 level

The interpedicular distance was also found to be higher in females in all levels except at T1, T2 and T7 vertebrae. Thus, it was observed that the vertebral canal in female vertebrae was wider than male vertebrae in the present study group. This was in contradiction to other dimensions where values in male vertebrae were found higher than female vertebrae values. The female horizontal and vertical diameters of the pedicles have shown a tendency to increase throughout normal aging [17]. Due to normal ageing, the intervertebral disc height decreases and consequently causes the facet joints to place an increased pressure on each other. This type of overloading is the most common causes of facet hypertrophy (an enlargement of the facet joint) and is also thought to increase the growth of osteophytes in the facet joints [20]. Also this is reflected in our analyses. Understanding this effect is of particular importance with respect to spinal stenosis where a narrowing of the spinal canal causes the impingement of the spinal nerve. In older females, the co-existence of osteoarthritis and osteoporosis has been reported in a study by Verstraeten et al., where the mean age of subjects was 71.5 y. Furthermore, Roaf demonstrated that compressive loading of older disc specimens resulted in collapse of vertebral bodies in addition to greater changes. So most of the changes in the parameters from T1 to T12 can be explained on the basis of local musculoskeletal anatomy and biomechanical stress.

The results of the present study can help in designing implants and instrumentations, understanding spine pathologies; and management of spinal disorder in this ethnic group. The regression analysis lead to the development of an equation for calculating the actual morphometry of the thoracic vertebrae when the equation was applied with the data obtained for the actual patients, it is correlated well. This will enable the clinical decision maker to take appropriate measure before any invasive interventions as per age and gender.

Conflicts of Interests: None

REFERENCES

[1]. Kadoury S, Cheriet F, Dansereau J, Labelle H Three-dimensional reconstruction of the sciotic spine and pelvis from uncalibrated biplanar X-ray images. Spinal Disorders Techniques 2007;20:160–168.
[2]. Panjabi MM, Oxland TR,Takata K,Goel V, Duranceau J, Krag M, Price M .Human lumbar vertebrae: quantitative three-dimensional anatomy. Spine 1992;17 :299-306.
[3]. Tan SH, Teo EC, Chua HC. Quantitative three-dimensional anatomy of cervical, thoracic and lumbar vertebrae of Chinese Singaporeans. Eur Spine J.2004; 13:137–146.
[4]. Liau KM, Yusof MI, Abdullah MS, Abdullah S, Yusof AH. Computed tomographic morphometry of thoracic pedicles: safety margin of transpedicular screw fixation in Malaysian population. Spine 2006; 31:545–550.

[5]. Ebraheim NA, Rollins JR, Xu R, Yeasting RA. Projection of the lumbar pedicle and its morphometric analysis. Spine. 1996;21:1296–1300.

[6]. Lavaste F, Skalli W, Robin S. Three-dimensional geometrical and mechanical modelling of the lumbar spine. J Biomech 1992;25(7):1153–1164.

[7]. McLain RF, Ferrara L, Kabin M. Pedicle morphometry in the upper thoracic spine: limits to safe screw placement in older patients. Spine 2002; 27(4): 2467–2471.

[8]. Berry JL, Moran JM, Berg WS, Steffee AD. A morphometric study of human lumbar and selected thoracic vertebrae. Spine 1987;12: 362-367.

[9]. Liljenqvist UR, Halm HF, Link TM. Pedicle screw instrumentation of the thoracic spine in idiopathic scoliosis. Spine. 1997;22:2239–2245.

[10]. Christodoulou AG, Apostolou T, Plomis A, Terzidis I, Hantzokos I, Pournaras J. Pedicle dimensions of the thoracic and lumbar vertebrae in the Greek population. Clin Anat. 2005;18: 404–408

[11]. Scoles PV, Linton AE, Latimer B, et al. Vertebral body and posterior element morphology: the normal spine in middle life. Spine. 1988;13:1082–1086.

[12]. Lavaste F, Skalli W, Robin S. Three-dimensional geometrical and mechanical modelling of the lumbar spine. J Biomech 1992;25(7):1153–1164.

[13]. Panjabi MM, O’Holleran JD, Crisco JJ, 3rd, et al. Complexity of the thoracic spine pedicle anatomy. Eur Spine J. 1997;6:19–24

[14]. Scoles PV, Linton AE, Latimer B, et al. Vertebral body and posterior element morphology: the normal spine in middle life. Spine. 1988;13:1082–1086.

[15]. Cinotti G, Gumina S, Ripani M, et al. Pedicle instrumentation in the thoracic spine. A morphometric and cadaveric study for placement of screws. Spine. 1999; 24:114–119.

[16]. Liau KM, Yusof MI, Abdullah MS, Abdullah S, Yusof AH. Computed tomographic morphometry of thoracic pedicles: safety margin of transpedicular screw fixation in Malaysian population. Spine 2006; 31:545–550.

[17]. Acharya S, Dorje T, Srivastava A. Lower dorsal and lumbar pedicle morphometry in Indian population: a study of four hundred fifty vertebrae. Spine 2010; 35(3):378–384.

[18]. Zindrick, M. R.: The role of transpedicular fixation systems for stabilization of the lumbar spine. Orthop. Clin. North. Am. 1991:22:333-36.

[19]. Kothe R, O’Holleran JD, Liu W, Panjabi MM. Internal architecture of the thoracic pedicle. An anatomic study. Spine 1996; 21(6):64-70.

[20]. Hou S, Hu R, Shi Y. Pedicle morphology of the lower thoracic and lumbar spine in a Chinese population. Spine. 1993;18:1850–1855.