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ORIGINAL ARTICLE / *ORJİNAL ÇALIŞMA*

ANATOMICAL COMPARISON BETWEEN HUMAN AND CALF SACRAL SPINE: FIRST SACRAL VERTEBRA PEDICLE MORPHOLOGY

İNSAN VE DANA VERTEBRASININ ANATOMİK KARŞILAŞTIRILMASI: BİRİNCİ SAKRAL OMUR PEDİKÜLÜNÜN MORFOLOJİSİ

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SUMMARY:

Study Design: *Quantitative anatomic*

Background Data: *There is no anatomical comparative study between human versus calf first sacral vertebra in English literature.*

Purpose: *To determine quantitative anatomic data of the first sacral vertebra of calf and compare to the human cadaver.*

Material and Methods: *3 linear and 2 angular parameters were obtained from twelve fresh frozen calves (2 years old) first sacral vertebras and compared twelve female human cadaver measurements. Anterior-posterior width of S1 pedicle (W), pedicle length (XP), cephalad-caudad height of S1 pedicle (H), transverse (T˚) and sagittal (S˚) angle of S1 pedicle were measured. The measurements between calf and human specimens for each parameter were compared with using a two-tailed Student t test.*

Results: *The mean cephalad-caudad height of pedicle (H) were measured 13.6 ± 2.3 mm in the human and 44.4 ± 4.34 mm in the calf (p<0.05). Anterior-posterior width (W) of the S1 pedicle was measured as 22.5 ± 2.6 mm on an average in the human. In the calf, width was measured as 26.02 ± 1.95 mm (p<0.05). The mean length of S1 pedicle (XP) was measured 50.7 ± 3.7 mm in the human, and 76.1 ± 4.3 mm in the calf (p<0.05). The mean S and T angles of S1 pedicle were measured 19˚ ± 2.9˚ and 43˚ ± 2.3˚, respectively in the human. In the calf, the mean S and T angles were 16.37˚ ± 2.5˚ and 44.04˚ ± 5.84˚, respectively. There was a statistical significant difference between human and calf mean sacral T angles (p< 0.05). However, there was no statistical differences between mean S angles (p>0.05).*

Conclusion: *Although there were some statistical differences between the human and calf S1 vertebras, the good comparability with the human spine encourage the use of the two years old calf S1 spine as a model for human sacral spine research.*

Keywords: *Calf, Sacrum, Cadaver, Pedicle*

Level of Evidence: *Level I, Experimental Anatomic Study*

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ÖZET:

Çalışma Dizaynı: *Kantitatif anatomik*

Geçmiş Bilgiler: *Literatürde insan ve dana 1. sakral (S1) vertebrasını anatomik olarak karşılaştıran bir çalışma bulunmamaktadır.*

Amaç: *Dana S1 vertebrasında kantitatif anatomik ölçümler yapmak ve bunu mevcut insan kadavra ölçümleri ile karşılaştırmak.*

Materyal ve Metod: *12 adet taze donmuş dana omurgasından elde edilen (2 yaş) 3 liner ve 2 açısal ölçüm, 12 insan kadavrasına ait ölçümler ile karşılaştırıldı. Dana S1 vertebra pedikül anterior-posterior genişliği (W), pedikül uzunluğu (XP), sefalo-kaudad yüksekliği (H), transvers (T˚) ve sagital (S˚) açılarının ölçümü yapıldı. İnsan ve dana kadavra ölçümlerinden elde edilen veriler 'two-tailed Student t test' kullanılarak karşılaştırıldı.*

Sonuçlar: *Ortalama pedikül sefalo-caudad yüksekliği (H) insanda 13.6 ± 2.3 mm iken, dana kadavrasında 44.4 ± 4.34 mm olarak ölçüldü (p<0.05). S-1 pedikül anterior-posterior genişliği (W) insanda ortalama 22.5 ± 2.6 mm iken danada 26.02 ± 1.95 mm olarak bulundu (p<0.05). Ortalama pedikül (XP) uzunluğu insanda 50.7 ± 3.7 mm iken, bu mesafe dana kadavrasında ortalama 76.1 ± 4.3 mm ölçüldü (p<0.05). S1 pedikül ortalama S and T açıları insanda sırasıyla 19˚ ± 2.9˚ ve 43˚ ± 2.3˚ olarak bulunurken, aynı ölçümler dana kadavrasında sırasıyla 16.37˚ ± 2.5˚ ve 44.04˚ ± 5.84˚ olarak ölçüldü. Dana ve insan sakrumlarındaki T açıları ortalamaları istatistiki olarak önemli bir fark saptanırken (p< 0.05), S açıları ortalamaları arasında istatistiki bir fark bulunamamıştır (p>0.05).*

Tartışma: *İnsan ve dana S1 vertebraları arasında istatistiksel olarak fark olmakla beraber, insan kadavrası ile karşılaştırılabilirliği açısından, sakral vertebra araştırmalarında dana sakrumu kullanımı cesaret vericidir.*

Anahtar Kelimeler: *Dana, Sakrum, Kadavra, Pedikül*

Kanıt Düzeyi: *Düzey I, Deneysel Anatomik Çalışma*

INTRODUCTION:

Fresh human cadaver specimens are difficult to obtain for *in vitro* experiments. It is expensive and limited by availability. Animal specimens are more easily available and show much better homogeneity than human specimens when selected for breed, gender, age, and weight. Therefore, animals are becoming more and more common as *in vivo* and *in vitro* models for the human spine. Calf sacral spine has been used for experimental studies for a time [4,7,9]. There is no anatomical comparison between human versus calf sacrum in English literature. The aim of this study is to determine quantitative anatomic data of the first sacral vertebra of calf and compare it directly with the corresponding data of the human cadaver. The database generated in this study may be helpful for planning experimental studies using a calf sacral spine model.

MATERIAL AND METHODS:

Twelve calves (2 years old) were harvested and stored at –20°C. The sacrum did not have any bony disease or deformity. All parameters were measured bilaterally using calipers accurate to 0.1 mm and a goniometry accurate to 1°. Three linear and 2 angular measurements were performed on sacrum.

- Description of Landmarks and Distances of Linear and Angular Measurement:

W distance: Anterior-posterior width of first sacral vertebra (S1) pedicle was measured between anterior and posterior cortex of S1 pedicle (Fig. 1).

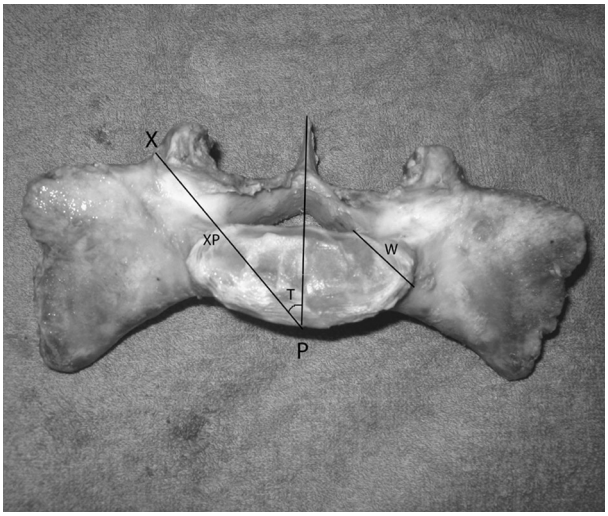

Figure-1. T angle in the superior view of the S1 vertebra.

X point: This is a landmark that shows a point below and lateral to the inferior tip of the superior articular process of S1 and represents the entrance point of S1 screw insertion (Fig. 1-2).

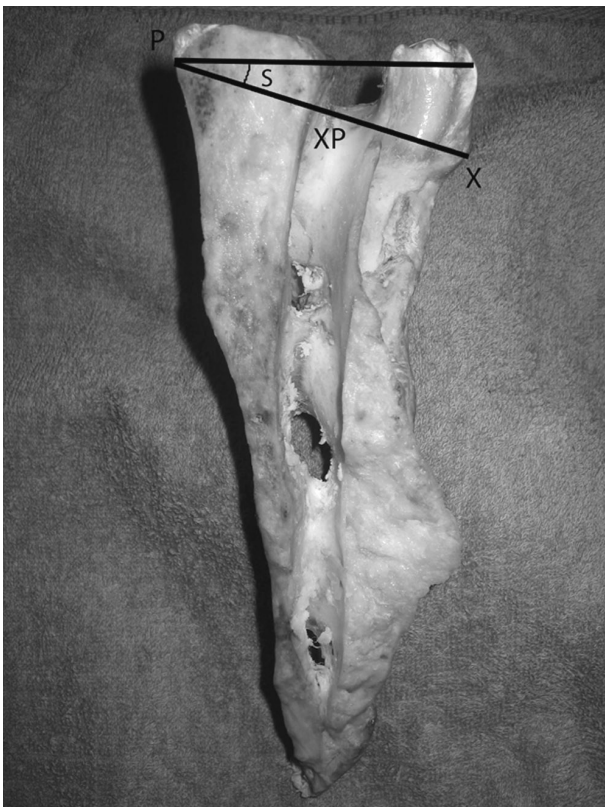

Figure-2. Posterior view of the S-1 vertebra.

P point: Promontorium (Fig. 1 and Fig. 3).

XP distance: Pedicle length is the distance from entrance point (X) to promontorium (P) (Fig. 1).

H distance: Cephalad-caudad height of S1 pedicle. H distance was measured between the most superior border of the S1 foramen and superior surface of body of S1 (Fig. 3).

Figure-3. Frontal view of the hemisacrum.

T angle: Transverse angle of S1 pedicle. T angle represents the angle between vertebral antero-posterior midline of S1 and XP line on transverse plane (Fig. 1).

S angle: Sagittal angle of S1 pedicle. S angle represents the angle between transverse plane of superior surface of S1 and XP line on sagittal plane (Fig. 4).

The measurements between calf and human specimens for each parameter were compared with using a two-tailed Student t test. For this comparison, the data of human cadaver were using from the article which is published in 2003 [6]. All comparisons were made at a statistical significance level of 0.05 or 95 % confidence.

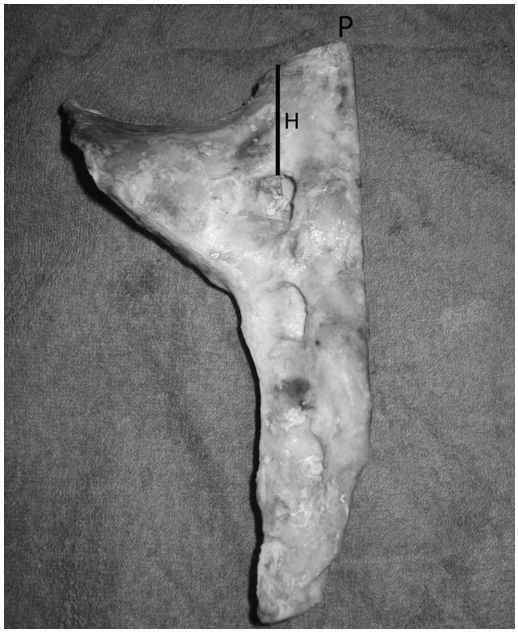

Figure-4. S angle in the sagittal view of the hemisacrum.

RESULTS:

Totally 12 specimens were measured, distinguishing between calf and human specimens for each parameter. Anterior-posterior width (W) of the S1 pedicle was measured as 22.5 ± 2.6 mm on an average in the human. In the calf, width was measured as 26.02 ± 1.95 mm on an average ($p<0.05$). The mean length of S1 pedicle (XP) was measured 50.7 ± 3.7 mm in the human, and 76.1 ± 4.3 mm in the calf ($p<0.05$).

The mean cephalad-caudad height of pedicle (H) were measured 13.6 ± 2.3 mm in the human and 44.4 ± 4.34 mm in the calf ($p<0.05$). The mean S and T angles of S1 pedicle were measured 19° ± 2.9° and 43° ± 2.3°, respectively in the human. In the calf, the mean S and T angles were 16.37° ± 2.5° and 44.04° ± 5.84°, respectively. There was a statistical significant difference between human and calf mean sacral T angles ($p< 0.05$). However there was no statistical differences between mean S angles ($p>0.05$) (Table-1 and 2).

Table - 1. Summary of anatomic measurement of calf S1 pedicle

Specimen	H (mm)	W (mm)	XP (mm)	T˚ (derece)	S˚ (derece)
1	48	25.7	80.5	41	19.1
2	39.5	26.5	81	51	16.2
3	45.5	28.3	79.8	47.5	20.1
4	48	25.5	76.5	53.5	19
5	47	26.1	76.4	50	15.8
6	48	27.5	75.2	41.5	16.1
7	41	26.6	65.7	39	10.2
8	43.1	22.2	77.8	49	16.1
9	52.2	23.4	79.2	41	15.1
10	42.5	24.5	70.5	40.5	16.8
11	38.5	29	75.6	39.5	15.7
12	39.5	27	75	35	16.3
Mean	**44.4**	**26.02**	**76.1**	**44.04**	**16.37**

H distance; Cephalad-caudad height of S1 pedicle.
W distance; Anterior-posterior widht of S1 pedicle.
XP distance; Pedicle length is the distance from entrence point (X) to promontorium (P).
T angle; Transverse angle of S1 pedicle.
S angle; Sagittal angle of S1 pedicle.

Table - 2. Summary of anatomic measurement of human S1 pedicle (Okutan et al)

Specimen	H (mm)	W (mm)	XP (mm)	T˚ (derece)	S˚ (derece)
1	12.92	21	48.63	45.68	19.83
2	14.21	21.2	53.01	41.31	20.24
3	15.84	22.7	53.04	45.82	16.95
4	12.71	25.8	48.8	44.22	16.95
5	10.3	24.1	52.25	44.48	18.85
6	14.26	23.4	49.88	41.07	22.1
7	10.92	15.2	55.77	43.6	18.16
8	10.64	18.5	49.39	44.1	21.82
9	16.53	24.5	50.45	40.15	17.77
10	11.01	23.8	45.21	43.93	20.69
11	16.97	24	46.2	41.18	19.38
12	16.94	25.8	55.8	40.45	15.25
Mean	**13.6**	**22.5**	**50.7**	**43**	**19**

H distance; Cephalad-caudad height of S1 pedicle.
W distance; Anterior-posterior widht of S1 pedicle.
XP distance; Pedicle length is the distance from entrence point (X) to promontorium (P).
T angle; Transverse angle of S1 pedicle.
S angle; Sagittal angle of S1 pedicle.

DISCUSSION:

Achieving fusion across the lumbosacral junction is still serious clinical problem when extending fusion levels to the sacrum. In lumbosacral junction, osteoporotic bone, lumbosacral overloading and increased motion can negative effect on fusion. Transpedicular screw is favorable surgical fixation technique for treatment of spinal disorders. Pedicle screw fixation provides short and rigid segmental stabilization, even in the absence of intact posterior elements. There are different techniques of screw application at sacrum to achieve rigid fusion such as S1 pedicle screw, ala screw, iliac screw, second sacral vertebra pedicle screw or combination of these techniques. S1 pedicle screw insertion is preferable techniques between spine surgeons because the biomechanical advantages [(10)]. Therefore S1 pedicle screw insertion is most critical point of the fixation. Appropriate S1 pedicle screw placement, depends not only entrance point of S1 screw insertion but also the direction of the screw without injury to the adjacent vital structures. There is always risk to damage the nerve root in the S1 foramen if the screw placed very medially and anterior vascular structures if the screw directed very laterally from the widely accepted entry point. In cases in which there is a closed posterior superior iliac spine, its medial situation prevents lateral oblique placement of the screw inserter sleeve and directing the screw to the anteromedial aspect of S-1 and the ilium resection can provide to enable a greater anteromedial trajectory for placement of S-1 pedicle screws [(3)]. Both anatomically and biomechanical most secure first sacral screw placement passes through the first sacral pedicle to the sacral promontory [(1,2,10)].

Pedicle width and sagittal angle of calf S1 pedicle has close similarity compare to human even in statistical differences ($p<0.05$). On the other hand, there was no statistical differences of transverse angle of S1 pedicle between human and calf sacrum ($p>0.05$). These three parameters show that both human and calf S1 vertebra require similar pedicle angular orientation during screw insertion. Based on this study, 40-45 degree medio-lateral and 16-19 degree sagittal orientation is most secure screw direction both human and calf. Peretti et al. notified that the oblique forward and inward degrees of S1 are 15° and 30°, respectively in human [(8)]. Louis also recommended inward screw insertion at an angle of 30-45 degrees in human [(5)].

Height of calf S1 pedicle is 3 times higher than the human which gives more sagittal plan safety zone to calf S1 pedicle for implantation. The mean pedicle length of calf S1 is almost 1.5 times longer than the human S1 pedicle ($p<0.05$). Appropriate mean pedicle screw length is around 50 mm for human and 75 mm for calf S1 pedicle.

CONCLUSION:

Without doubt, calf and human S1 vertebra are different. Calf S1 vertebra pedicle is longer and larger than human S1 vertebra. The statistical evaluation in this study confirmed this difference. Although there were some differences between the human and calf S1 vertebras, the good comparability with the human spine encourage the use of the two years old calf S1 spine as a model for human sacral spine research especially in lumbosacral fixation methods.

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