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MORPHOMETRIC STUDY OF LUMBAR VERTEBRA PEDICLES

LOMBER VERTEBRA PEDİKÜLLERİNİN MORFOMETRİK ÇALIŞMASI

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SUMMARY:

Purpose: The aim of this study is to investigate the anatomic morphometry of the lumbar pedicles and support to calculate the best diameter and length of screws used in lumbar instrumentation.

Materials-Method: We inspected 86 patients' data retrospectively from the patient files. We measured the lumbar vertebras pedicles diameters from the thickest pedicle image shown in axial bone images of computed tomography (CT) and length of the pedicle-corpus distance from the beginning of posterior pedicle to the end of the corpus vertebra with the line passes through the middle of the pedicle. All of the lumbar vertebrae were measured bilaterally from L1 to L5.

Results: Fifty-six patients were male (65.1 %), and 30 were female (34.9 %). Mean age of the patients was 40.8 ± 15.6 (18-60) years. Analyses revealed that only pedicle diameters at L2, L4, and L5 levels were similar between males and females, and all other measurement were significantly different between. The measurements were significantly higher in males, when compared to females. The results showed that pedicle diameters were significantly increased from L1 through L5, both in left and right sides ($p<0.001$, for each). The pedicle-corpus diameters were also showed significant differences between lumbar vertebras ($p<0.001$, for each), and L4 and L5 values significantly lower than the others at right, and L4 values significantly lower than the others at left side.

Conclusion: Preoperative CT based lumbar pedicle morphometric data assessment in preoperative planning of spinal surgery is advisable because of the large variations, so that intra and postoperative complications can be avoided.

Key Words: Lumbar vertebra morphometry, Lumbar vertebra pedicle morphometry, Lumbar vertebra pedicle diameter

Level of evidence: Retrospective clinical study, Level III

ÖZET:

Amaç: Bu çalışmanın amacı lomber omurga pedikül morfometrisini incelemek ve lomber enstrümantasyon ameliyatlarında kullanılan pedikül vidaları için en doğru kalınlığını ve uzunluğunu belirlemeye yardımcı olmaktır.

Materyal-Metod: Retrospektif olarak 86 hastanın dosyası incelendi. Lomber vertebra pedikül çapları ince kesit bilgisayarlı tomografi (CT) aksiyel görüntülerinden pedikküllerin en kalın olduğu kesitlerden ve pedikül ile vertebra korpusun ön sınırını birleştiren yerden uzunluk olarak ölçüldü. L1 seviyesinden L5 seviyesine kadar tüm vertebralar çift taraflı olarak ölçüldü.

Sonuçlar: Elli altı erkek hasta (% 65.1) ve 30 kadın hasta (% 34.9) incelemeye alındı. Ortalama hasta yaşı 40.8 ± 15.6 (18-60) olarak hesaplandı. Analiz sonucunda kadın ve erkek hastaların sadece L2, L4 ve L5 vertebra özellikleri benzer görüldü ve diğer ölçümler anlamlı olarak farklı bulundu. Ölçümlerde erkek hastaların değerleri kadın hastalara göre anlamlı derecede büyük çıkmıştır. L1 seviyesinden L5 seviyesine inildikçe pedikül çapları pedikül çapları anlamlı olarak artmaktadır ($p<0.001$, her taraf için). Pedikül-korpus arası uzunluk L1 seviyesinden L5 seviyesine doğru gidildikçe anlamlı olarak azalmıştır ($p<0.001$, her biri için), ve L4 - L5 sağ uzunluk değerleri diğerlerinden düşük, L4 sol taraf uzunluk değerleri de diğer uzunluklardan düşük bulunmuştur.

Çıkarım: Preoperatif CT kullanılarak lomber pedikül morfometrik veri değerlendirilmesi lomber pedikül anatomisindeki çeşitli varyasyonlar nedeni ile mutlaka önerilmelidir. Böylece ameliyat sırasında ve ameliyat sonrasında karşılaşılabilecek komplikasyonların önüne geçilebilir.

Anahtar Kelimeler: Lomber vertebra morfometrisi, lomber vertebra pedikül morfometrisi, lomber vertebra pedikül çapı

Kanıt Düzeyi: Retrospektif klinik çalışma, Düzey III

INTRODUCTION

Lumbar morphometry is important not only for understanding of biomechanics of lumbar spine but also for surgical techniques aimed to stabilization and correction of deformities. First application of the pedicle screw plating system for the lumbar spine had been made by Roy-Camille et al[20]. Since then pedicle screw fixation has become an increasingly popular technique of instrumentation to treat spinal disorders by providing stable fixation and correcting spinal deformities[16].

To prevent impingement of the neural structures, accurate and safe pathway of the pedicle is important and requires precise and accurate knowledge of bony and neural structures[4]. There are complications associated with oversized pedicle screw such as dural tears, leakage of cerebrospinal fluid and injuries to nerve roots from the medial wall[13].

The purpose of this study was to investigate the anatomic morphometry of the lumbar pedicles and support to calculate the best diameter and length of screws used in lumbar instrumentation.

MATERIALS AND METHOD

We inspected 86 patients' data retrospectively from the patient files. The patients between the ages of 18 to 60 who had been imaged with lumbar vertebral multi-sliced computed tomography were included. The exclusion criteria were emergency patients, having degenerative spinal disease, fractures, spondylolysis and spondilolystesis. We measured the lumbar vertebras pedicles diameters from the thickest pedicle image shown in axial bone images of CT and length of the pedicle-corpus distance from the beginning of posterior pedicle to the end of the corpus vertebra with the line passes through the middle of the pedicle (Figure-1). All of the lumbar vertebras were measured bilaterally from L1 to L5 by Osirix® software.

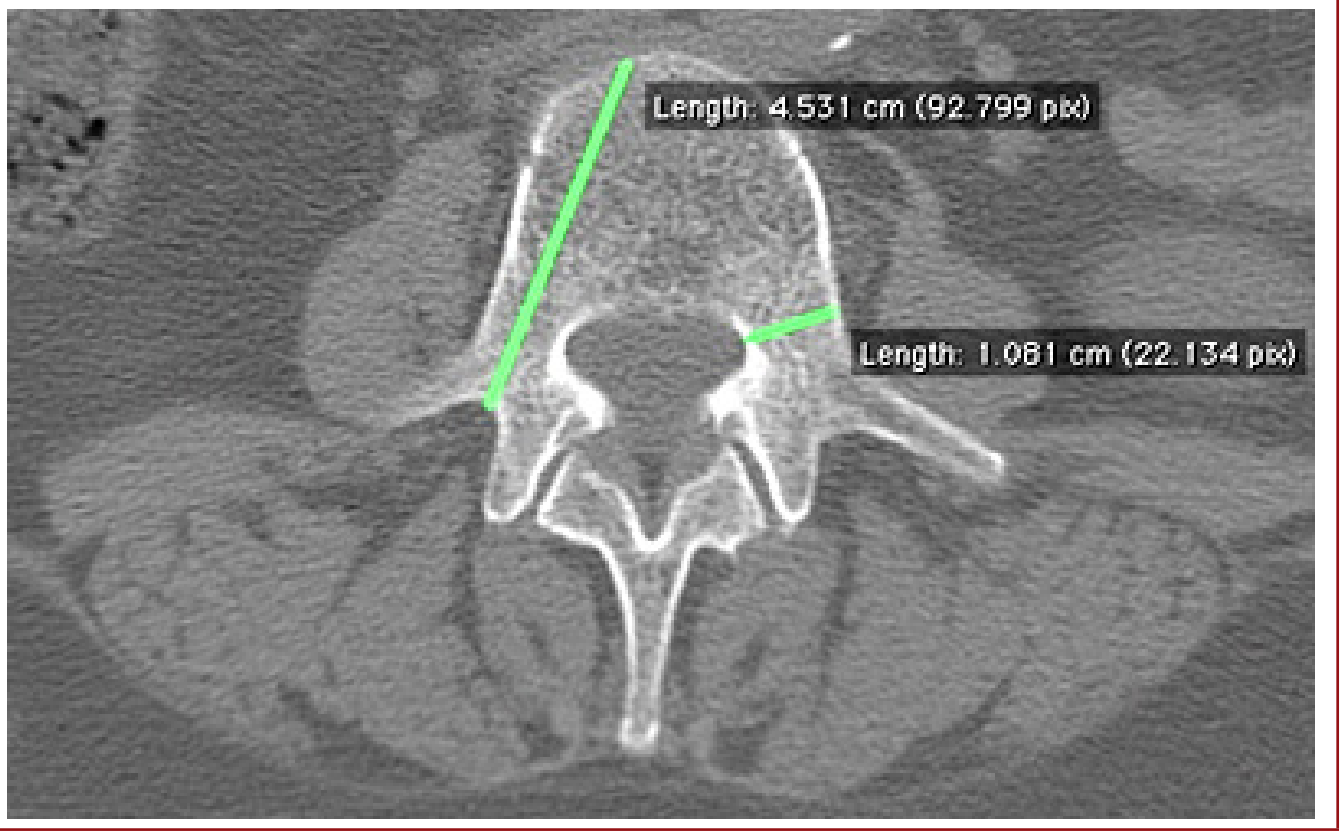

Figure-1. Measurement example of pedicle diameter and pedicle-corpus lenght prepared with Osirix®

Statistical Analysis:

Descriptive statistics of numerical data were presented as mean, standard deviation, minimum and maximum. The categorical variable gender was presented as frequency and percent. The comparisons between independent two groups were conducted by Mann-Whitney U test. The changes between vertebra levels were compared by using Friedman test, and when a statistically significant difference was observed, post-hoc analyses were performed by Wilcoxon test. SPSS software version 21 (IBM Inc., USA) was used for the statistical analyses. Statistical significance level was considered as 0.05 in the analyses of this study.

RESULTS

Fifty-six patients were male (65.1%), and 30 were female (34.9%). Mean age of the patients was 40.8±15.6 (18-60) years. Mean age of the males and females were statistically similar (p=0.664), and 39.7±15.6 years and 42.9±15.7 years, respectively.

The comparisons of pedicle diameters and pedicle-corpus lengths according to gender are presented in Table-1. Analyses revealed that only pedicle diameters at L2, L4, and L5 levels were similar between males and females, and all other measurement was significantly different between the sexes. The measurements were significantly higher in males, when compared to females.

Table-2 shows the comparisons of pedicle diameters, and pedicle-corpus lengths according to sides. The results showed that pedicle diameters were significantly increased from L1 through L5, both in left and right sides (p<0.001, for each). The pedicle-corpus diameters were also showed significant differences between lumbar vertebras (p<0.001, for each), and L4 and L5 values significantly lower than the others at right, and L4 values significantly lower than the others at left side.

Table-1. Comparisons of pedicle, and pedicle-corpus lengths according to gender. P: pedicle diameter; PC: pedicle-corpus length. *: Statistically significant results in comparisons between males and females (Mann-Whitney U test).

	Male				Female				p
	Mean	SD	Min	Max	Mean	SD	Min	Max	
L1-Right-P	6,71	1,01	5	9,2	5,8	0,83	4,6	7	0,009*
L1-Left-P	6,78	1,1	5,1	9,4	6,05	0,89	4,7	7,8	0,030*
L1- Right -PC	55,6	3,91	47,7	66,7	51,83	2,48	47,7	56,1	0,002*
L1- Left - PC	55,89	3,68	48,3	66,8	52,15	2,33	48,2	55,8	0,001*
L2- Right -P	7,07	1,13	5,2	9,6	6,37	0,8	5,2	8	0,054
L2- Left -P	6,54	2,16	0	9,5	6,48	0,82	5,2	8,2	0,236
L2- Right - PC	55,03	3,78	46,6	66,1	51,19	3,09	46,6	59,1	<0.001*
L2- Left - PC	55,3	3,78	46,8	65,9	51,55	2,93	46,8	57,1	0,001*
L3- Right -P	8,63	1,29	6,1	11,1	7,71	1,13	6,1	10,3	0,026*
L3- Left -P	8,71	1,4	5,7	12,1	7,85	1,42	6,1	10,8	0,036*
L3- Right - PC	55,06	4,36	45,8	63,2	52,25	3,35	45,8	58,5	0,029*
L3- Left - PC	54,91	3,9	46,3	62,5	52,31	3,57	46,3	57,8	0,035*
L4- Right -P	10,37	1,43	7,5	14	9,57	1,58	7,3	12,3	0,143
L4- Left -P	10,5	1,44	8,1	13,4	9,84	1,69	7,8	13,8	0,172
L4- Right - PC	53,05	3,65	44,7	59,5	50,09	3,56	44,6	56,4	0,009*
L4- Left - PC	53,01	3,8	44,9	60,7	49,95	3,26	44,9	56,8	0,007*
L5- Right -P	13,33	1,75	9,6	16,9	12,83	1,57	10,8	16	0,320
L5- Left -P	13,41	1,93	9,8	17,4	12,78	1,96	9,9	17,1	0,284
L5- Right - PC	54	3,85	47,6	63,9	49,8	3,46	42,4	57,8	<0.001*
L5- Left - PC	54,17	3,91	46,5	65,1	50,5	3,07	45,4	57,2	0,003*

Table-2. Pedicle diameters and pedicle-corpus lengths according to the sides.*: Pedicle diameters were significantly increased from L1 through L5, both in left and right sides (Friedman Test). **: Pedicle-corpus lengths on right side showed significant difference in overall comparisons (Friedman Test), and post-hoc analyses revealed that L4 and L5 values significantly lower than the others (Wilcoxon test). ***: Pedicle-corpus lengths on left side showed significant difference in overall comparisons (Friedman Test), and post-hoc analyses revealed that L4 values significantly lower than the others (Wilcoxon test).

	Right					Left				
Pedicle diameter	**Mean**	**SD**	**Min**	**Max**	**p**	**Mean**	**SD**	**Min**	**Max**	**p**
L1	6,39	1,04	4,6	9,2		6,53	1,08	4,7	9,4	
L2	6,83	1,07	5,2	9,6		6,52	1,79	0	9,5	
L3	8,31	1,3	6,1	11,1	<0.001*	8,41	1,45	5,7	12,1	<0.001*
L4	10,09	1,52	7,3	14		10,27	1,55	7,8	13,8	
L5	13,15	1,69	9,6	16,9		13,19	1,94	9,8	17,4	
Pedicle-corpus length										
L1	54,29	3,9	47,7	66,7		54,58	3,71	48,2	66,8	
L2	53,69	3,97	46,6	66,1		53,99	3,91	46,8	65,9	
L3	54,08	4,22	45,8	63,2	<0.001**	54	3,95	46,3	62,5	<0.001***
L4	52,02	3,85	44,6	59,5		51,94	3,87	44,9	60,7	
L5	52,54	4,2	42,4	63,9		52,89	4,01	45,4	65,1	

DISCUSSION:

Detailed anatomical descriptions of the morphology and orientation of lumbar vertebrae are necessary for the development and use of implantable devices and spinal instrumentation[3]. The goal of internal fixation for fusion is to reconstruct the compromised columns within a spinal motion segment with non-biologic materials, affording temporary immobilization and stabilization until bony fusion can develop[1].

Fixation is successful when a construct can withstand the wear and tear of stresses and strains until fusion occurs. In the lumbar area, detailed anatomical knowledge is critical for performing a safe operation[22]. It is a common clinical finding that most of the pedicle fractures related to pedicle screws occur at the lateral wall of the pedicle. Misenheimer et al. inserted screws of the different diameters into thoracic and lumbar pedicles[17]. After the use of increased screw diameter, they found changes on the pedicle structure. Although there were as many lateral cutouts as there were medial, they have found that the entrance points for the screws were in the center of the pedicle, they saw 72% pedicle fractures laterally and only 28% medially. The medial wall of the pedicle must be preserved during screw placement into the pedicle to avoid nerve root or dural damage and to preserve biomechanical stability [13]. The definition of the appropriate screw length and diameter usage will decrease the complication risks like anterior corpus and pedicle perforation, dural tear, cerebrospinal fluid leakage, nerve and major vascular injury.

Cansever et al. and Zindrick et al. reported similarly in their studies that pedicle diameter is increasing but length of pedicle is decreasing from L1 to L5[6,22]. Our results are supporting these reports. Acharya et al. and Chadha et al. reported Indian populations' lumbar vertebrae morphology have variations[2,7]. That supports the opinion of morphological characteristics may be varied between different populations. This aspect was also evident in various other ethnic population groups studied by Cheung et al., Hou et al., and Kim et al., for Chinese, Asian and Koreans, respectively[8,10,12].

Many literature have described the morphometric aspects of the lumbar spine and the details of the pedicle sizes and dimensions by means of CT scan, plain image, direct specimen measurement and quantitative 3D anatomic

technique[9,11,14-15,18]. Panjabi et al. provided the most detailed collection of quantitative 3D surface anatomy of the main vertebral parameters for the thoracic and lumbar human spine[19]. The parameters corresponding to the vertebra L5 were not included in the analyses because L5 shows remarkable morphological differences for some parameters when compared with the other lumbar vertebrae as reported by Berry et al., Zindrick et al., Scoles et al. before[5,21,22]. This is probably due to the position of L5 being localized in the final transition zone from lumbar to sacral region[19].

Preoperative computer aided CT based lumbar pedicle morphometric data assessment in preoperative planning of spinal surgery is advisable because of the large variations, so that intra and postoperative complications can be avoided.

REFERENCES:

1. Abuzayed B, Tutunculer B, Kucukyuruk B, Tuzgen S. Anatomicbasis of anterior and posterior instrumentation of the spine: morphometric study. *Surg Radiol Anat* 2010; 32(1): 75–85.
2. 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(10): 378-384.
3. Alam MM, Waqas M, Shallwani H, Javed G. Lumbar Morphometry: A Study of Lumbar Vertebrae from a Pakistani Population Using Computed Tomography Scans. *Asian Spine J* 2014; 8(4): 421-426.
4. Attar A, Ugur HC, Uz A, Tekdemir I, Egemen N, Genc Y. Lumbar pedicle: surgical anatomic evaluation and relationships. *Eur Spine J* 2001; 10: 10-15.
5. Berry JL, Moran JM, Berg WS, Steffee AD. A morphometric study of human lumbar and selected thoracic vertebrae. *Spine* 1987; 12: 362–367.
6. Cansever T, Civele E , Çevik H, Sabancı A, Kabataş S, Yılmaz C. Lomber Pediküler Vida Uygulamasında Radyolojik Olarak Anatominin Detaylı İncelenmesi. *Türk Nöroşirürji Dergisi* 2011; 21(3): 236-241.
7. Chadha M, Balain B, Maini L. Pedicle morphology of the lower thoracic, lumbar, and S1 vertebrae: an Indian perspective. *Spine* 2003; 28: 744–749.
8. Cheung KMC, Ruan D, Chan FL, Fang D. Computed tomographic osteometry of Asian lumbar pedicles. *Spine* 1994; 19: 1495–1498.
9. Ebraheim NA, Rollins JR Jr, Xu R, Yeasting RA. Projection of the lumbar pedicle and its morphometric analysis. *Spine* 1996; 21: 1296–1300.
10. Hou S, Hu R, Shi Y. Pedicle morphology of the lower thoracic and lumbar spine in a Chinese population. *Spine* 1993; 18: 1850–1855.
11. Islam C, Güzel MB, Sakul BU. Clinical importance of the minimal cancellous diameter of lower thoracic and lumbar vertebral pedicles. *Clin Anat* 1996; 9: 151-154.
12. Kim NH, Lee HM, Cheung IH, et al. Morphometric study of the pedicles of thoracic and lumbar vertebrae in Koreans. *Spine* 1994; 19: 1390–1394.
13. Kotil K, Şengiz A. Lomber omurganın pedikül vida enstrümantasyonunda pedikül duvarının kalınlığının .nemi: Radyolojik Anatomi çalışması. *J Turk Spinal Surg* 2010; 21(2): 129–136.
14. Kretzer RM, Chaput C, Sciubba DM, Garonzik IM, Jallo GI, McAfee PC, Cunningham BW, Tortolani PJ. A computed tomography-based morphometric study of thoracic pedicle anatomy in a random United States trauma population. *J Neurosurg Spine* 2011; 14(2): 235-243.
15. Kunkel ME, Schmidt H, Wilke HJ. Prediction equations for human thoracic and lumbar vertebral morphometry. *J Anat* 2010; 216: 320–328.
16. Lien SB, Liou NH, Wu SS. Analysis of anatomic morphometry of the pedicles and the safe zone for through-pedicle procedures in the thoracic and lumbar spine. *Eur Spine J* 2007; 16:1215–1222.
17. Misenhimer GR, Peek RD, Wiltse LL, Rohtman SL. Anatomic analysis of pedicle cortical and cancellous diameter as related to screw size. *Spine* 1989; 14 (4): 367-372.
18. Mitra SR, Datir SP, Jadhav SO. Morphometric study of the lumbar pedicle in the Indian population as related to pedicular screw fixation. *Spine* 2002; 27: 453–459.
19. Panjabi MM, Goel V, Oxland T. Human lumbar vertebrae: quantitative three-dimensional anatomy. *Spine* 1992; 17: 299–306.
20. Roy-Camille R, Saillant G, Mazel C. Internal fixation of the lumbar spine with pedicle screw plating. *Clin Orthop Relat Res* 1986; 203: 7–17
21. Scoles PV, Linton AE, Buce L. Vertebral body and posterior element morphology: the normal spine in middle life. *Spine* 1988; 13: 1082–1086.
22. Zindrick MR, Wiltse LL, Widell EH, Thomas JC, Holland WR, Field BT, Spencer CW. A biomechanical study of intrapeduncular screw fixation in the lumbosacral spine. *Clin Orthop Relat Res* 1986; 203: 99–112.