Morphometric Study of Orientation of Superior Articular Facets of Thoracolumbar Vertebral Column in North Indian Population

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Received: May 2018
Accepted: May 2018

ABSTRACT

Background: The orientation of superior articular processes in the thoracic & lumbar vertebrae differs. These processes play an important role in weight transmission & determining the range & direction of movements between any two vertebrae. **Methods:** The present study has been conducted on the articular processes of 510 vertebrae (thoracic:360; lumbar: 150) with the aim to investigate the possible mehanism for the change from a posterolaterally facing superior articular surface in the thoracic region to posteromedially facing curved articular surface in the lumbar region. **Results:** In thoracic region, the angle varied between 112o to 120o but suddenly decreased to 85o (R) and 92.1o (L) at T12. In lumbar region, it showed a marked decrease at L1(R:32o; L:34.2o) which further decreased upto L3 and again increased upto L5. Thus, the above observations indicated that between T1-T11 the facet was directed posterolaterally, at T12 it was almost posterior and at L1 it changed its orientation to posteromedially and remained so in whole of the lumbar region. This change in orientation of superior articular processes at the thoracolumbar junction was abrupt at T12-L1 level or gradual over T11-L1 in almost equal number of columns. **Conclusion:** Clinical implication: The pattern of orientation not only guides & limits the excursion of motion segments but also is relevant in axial weight bearing.

Keywords: Superior articular facet, Sagittal angle, Orientation, Mortice joint, Weight transmission.

INTRODUCTION

The orientation of superior articular facets of vertebrae at various levels changes according to the functional & mechanical requirement of the vertebral column. In thoracic region, they face posteriorly & are directed a little superolaterally whereas in lumbar vertebrae, these face posteromedially.[1] The change in orientation of SAFs from thoracic to lumbar type usually occurs at T11 but rarely at T12 or T10.[2-4] This change is either sudden, at one vertebral level or gradual, over two or more than two vertebral levels.[2-5] According to Davis,[2] at the thoracolumbar transitional region, one zygapophyseal joint was neither like a typical thoracic nor like a typical lumbar joint. He named this a "mortice joint" because of resembalance to a carpenter's mortice. He further demonstrated that it was adapted to withstand marked compressive forces transmitted from the relatively immobile thoracic segment to the highly mobile lumbar segment. Orientation of articular facets not only guides the extent & direction of vertebral movements but also relevant in axial weight bearing. In the thoracic region, lack of upward inclination of SAFs prohibits much flexion & extension. However, direction of SAFs allow free lateral rotation.[2] The lumbar extension is wider in range than flexion; rotation is limited by the absence of common centre of curvature for right & left SAFs.[6]

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MATERIALS AND METHODS

The present study was conducted in the Department of Anatomy, Govt. Medical College, Amritsar after getting approval from institutional ethical committee, on SAFs (right & left) of 30 human adult male thoracolumbar vertebral columns. The vertebrae in each column, were thoroughly cleaned and boiled. These were labeled from T1 to L5 depending upon the vertebra and bound in a wire in the correct sequence. The saggital angle of SAFs on both sides was measured using a rubber band, bent hair pin & a protractor (as described by Patel and Singel.[7] For measuring the angle, a steel wire was fixed with rubber band on the superior surface of body of vertebra in midsagittal plane. Then the zero line of protractor was kept along the wire and the U pin was brought in contact with the superior articular facet (See photograph no.1). Then the angle was measured on the protractor.

RESULTS

[Table 1] compares the sagittal angle of superior articular facet on both sides from T1 to L5 as observed in the present study with the earlier authors. In thoracic region, its mean value varied between 112o to 120o but suddenly decreased to 85o on right side and 92.1o on left side at T12. In lumbar region, it showed a marked decrease at L1 (R:32o; L:34.2o) which may be due to change in the orientation of superior articular facets from posterolateral to posteromedial direction. Thus between T1-T11 the facet was directed posterolaterally, at T12 it was almost posterior and at L1 it changed its orientation to posteromedially. The same was observed by Patel et al.[8] As we moved caudally, the angle first decreased from L1 to L3 (R:28.8o; L:28.6o) and again increased to L5 (R:36.9o; L:40.4o). However, in whole of the lumbar region it was oriented posteromedially. When compared on two sides, it was found to be more on left side at all the levels by 0.2o-7o (except at L4) and the difference was non significant (unpaired t test).

Photograph 1: Showing the measurement of sagittal angle of Superior articular facet

Table 1: Comparison Of Sagittal Angle Of Superior Articular Facet

Parameter		Sagittal angle of superior articular facet(Degree)				
Author		Pal et al9, 2000	Patel et al8, 2004	Present study		
Population		Indian	Indian	North Indian		
		Mean	Mean	Mean	Range	P value
T1	R	99.58	99.58	112.5	92-140	0.643
	L	99.03	99.03	114.0	93-140	
T2	R	106.89	106.89	114.9	100-134	0.393
	L	105.2	105.2	117	100-138	
T3	R	107.42	107.42	116.6	101-132	0.222
	L	109.5	109.5	119.5	100-136	
T4	R	-	105	114.3	100-126	0.184
	L	-	106	117.5	100-136	
T5	R	-	107	117.6	101-148	0.931
	L	-	106	117.8	95-138	
T6	R	-	107	117.2	102-130	1.00
	L	-	107	120.3	103-140	
T7	R	-	106	115.6	102-132	0.590
	L	-	106	117	98-140	
T8	R	-	106	114.1	102-132	0.565
	L	-	105	115.7	100-138	
T9	R	-	105	114.3	102-138	0.768
	L	-	103	115.1	100-134	
T10	R	-	106	112.2	100-135	0.705
	L	-	105	113	101-134	
T11	R	-	105	112.3	75-130	0.429
	L	-	106	114.3	82-132	
T12	R	-	87	85	30-125	0.344
	L	-	87	92.1	36-134	
L1	R	-	37	32	8-53	0.516
	L	-	36	34.2	10-64	
L2	R	-	26	29	17-38	0.271
	L	-	29	29.8	15-36	
L3	R	-	25	28.8	10-40	0.925
	L	-	29	28.6	6-44	
L4	R	-	40	34.1	22-54	0.413
	L	-	35	32.1	18-46	

L5	R	-	41	36.9	22-53	0.169
	L	-	44	40.4	27-62	

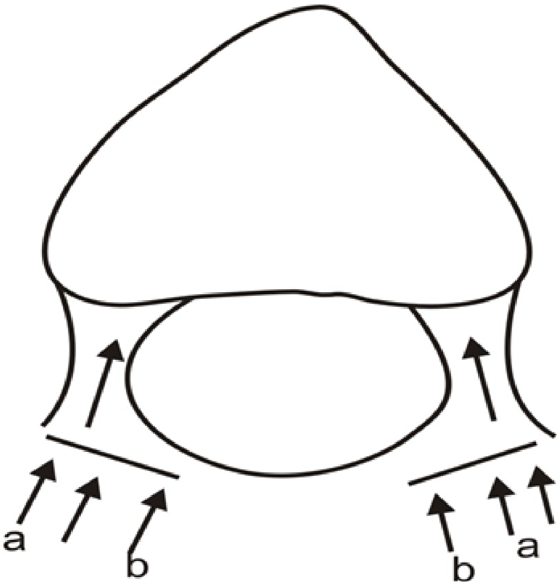

Figure 1: Diagrammatic representation of a typical thoracic vertebra seen from above. From the lateral part of articular surface forces are transmitted to the pedicle (a), whereas from medial part forces are transmitted below to the lamina (b).

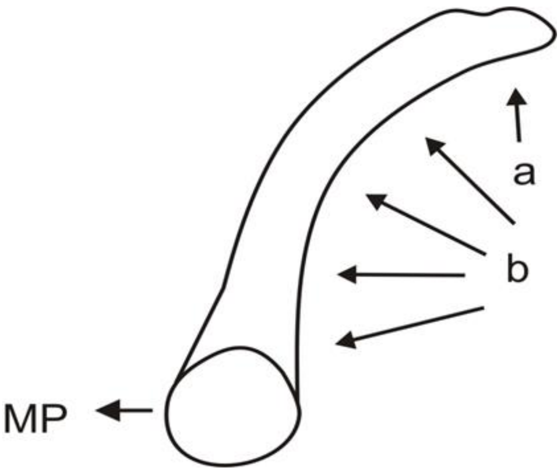

Figure 2: Diagrammatic representation of a transverse section passing through a typical lumbar superior articular process. Forces act at right angle to articular surface. The articular surface facing dorsally transmits the load to the pedicle (a) and a large surface facing medially transmits the forces laterally to the superior articular process (b). MP: mamillary Process. From the superior articular process the forces converge to be transmitted to the inferior articular process.

DISCUSSION

Most of the anatomists agree without reserve that superior articular facets face superolaterally in thoracic region and superomedial in lumbar region but very few mention that this change usually occurs at T11, but rarely at T10 or T12. Davis found the most frequent site of transition at zygapophyseal joint between T11 and T12 vertebrae i.e. superior articular process of T12 and inferior articular process of T11.[2] He further emphasized that at thoracolumbar transitional region, one zygapophyseal joint was neither like a typical thoracic nor like a typical lumbar and named it a 'Mortice joint' because of its resemblance to a carpenter's mortice. If we go by only mean value of sagittal angle of superior articular facet, the same was true in the present study where superior articular facet of T12 was directed almost posteriorly and the zygapophyseal joint between T11 and T12 was the mortice joint.

However, if we study the values of this angle in all the vertebrae, it was seen that at T11 the facet was directed posteromedially in one column (Column No.7); at T12, sagittal angle of superior articular facet was slightly <90o in 14 (46%) columns on right side and 9 (30%) columns on left side i.e. directed almost posteriorly, being >90o in the rest i.e. directed posterolaterally. At L1 this angle was quite <90o in all i.e. facet was directed posteromedially. Thus change was gradual in over T11-L1 in 46% columns on right side and 30% columns on left side, over T10-L1 in 3.33% columns on both sides and abrupt over T12-L1 in the rest. So the above explanation stands a good steed in 50% of columns on right side and 33% on left side while in the others where the change was gradual this explanation fails.

Pal & Routal threw a flood of light in an attempt to find an answer to the question why and how the posterolateral facing flat articular facet in thoracic region change to posteromedially facing curved surfaces in lumbar region.[10] For this, they stressed upon knowing the mechanism of weight transmission in the thoracic and lumbar region of vertebral column which according to them depends upon 3 factors:-

(i) Zygapophyseal joints are involved in weight bearing and a considerable proportion of weight is transmitted through lumbar facet joints.

(ii) Forces act at right angles to the plane of any articular surface.

(iii) Line of gravity passes anterior to the vertebral bodies in thoracic region (because of thoracic kyphosis) and posterior to them in lumbar region (because of lumbar lordosis) crossing the column at T11 and T12 vertebral level.

Weight transmission through zygapophyseal joints situated at the thoracic and lumbar regions

As the thoracic column is concave anteriorly and the line of gravity passes anterior to the vertebral bodies, there is tendency for accentuation of load on the vertebral bodies. Hence the weight acting at the zygapophyseal joints is also transmitted towards the vertebral body. This is supported by the fact that the superior articular surface faces posterolaterally and thus would transmit the weight anteromedially to the body through its pedicles [Figure 1]. In the lumbar region the line of gravity passes posterior to the vertebral bodies; there is therefore a tendency for weight to be accentuated on the zygapophyseal joints. The posteromedially facing curved articular surface of the lumbar vertebrae is excepted to receive the load from the inferior articular process of the upper vertebra and transmit it to anterolaterally to its strong wall [Figure 2]. From the superior articular process this load is transmitted inferiorly to the lamina. The superior articular processes in the lumbar region are curved because they have to embrace the inferior articular processes intimately to receive the load and then to transmit it below to the lamina.

The above mechanism of load transmission by the lumbar facet joints is also supported by the findings of Cihak,[11] according to whom the lumbar zygapophyseal joints, at birth, are all oriented in the coronal plane, similar to the joints of thoracic vertebrae. However, during the postnatal growth their orientation starts to change from coronal to sagittal plane. The process of 'sagittalisation' begins at the 6th postnatal month and is completed by the age of 18 months. During this period the articular surface gradually rotates from coronal to sagittal, becoming characteristically curved at the same time. Thus the period of sagittalisation corresponds to the development of lumbar curvature which is associated with the child learning to stand erect and walk. The sagittally oriented curved articular processes are well adapted to bear the load acting at the lumbar zygapophyseal joints.

Weight transmission through zygapophyseal joints situated at the thoracolumbar junction

At the thoracolumbar transitional region the orientation of the articular processes differs from that observed at typical thoracic or lumbar vertebrae. This suggests that mechanism of weight transmission in this region may not be the same as discussed above. As this region is the junction of 2 curvatures, the line of gravity crosses the T11 and T12 vertebrae. Because of this a shift of load from the anterior to posterior components of vertebrae (vertebral bodies to facet joints and laminae) is expected. This change in the direction of load might be achieved by the change in the orientation of the articular processes at this region. The increasing sagittalisation of the articular processes in the transitional vertebrae is likely to be an adaptation to enable a gradual shift of the load from the anterior to posterior components of vertebrae. It is thus evident that the rotation of articular processes at the thoracolumbar junction is associated with the change in the direction of load transmission.

Odgers,[12] however, attributed the rotation of lumbar zygapophyseal joints to the action of multifidus which by pulling the mamillary process swings the lateral extremity of the superior articular processes to a more dorsal position, thereby rotating the plane of joint or by imparting a curvature to it. However, Pal & Routal,[10] agreed with Odgers,[12] only partially and held multifidus responsible only for deepening the curvature of the superior articular process. They further supported their theory of change in orientation of the articular processes being associated with a change in the direction of weight transmission at the thoracolumbar junction as follows:-

As the line of gravity crosses the T11 and T12 vertebrae, these levels are most common sites to show transition from the thoracic to lumbar type of articular process. For the same reason, the gradual sagittalisation of articular processes is also confined between T10 and T11 levels and sagittalisation of articular surface, in the transitional zone always increases with successive vertebrae (craniocaudally). Thus there is a gradual shift of load from the anterior to posterior components of vertebrae (from bodies to neural arches). This is further supported by the fact that none of the vertebral columns shows the reverse orientation once sagittalisation is established, i.e. a posteromedial facing or slightly concave surface is never followed by a coronally oriented or posterolateral facing articular surface in the lower vertebrae. Even if there is bilateral asymmetry in the orientation of articular surfaces, the rotation of the articular surface is always towards further sagittalisation. Thus accentuation of load on the laminae is necessary to obtain the lumbar like articular surface. This is achieved by gradual sagittalisation of articular surfaces when the change is gradual.

CONCLUSION

From the above discussion it may be speculated that the gradual transition may help to protect the spine from fracture at the thoracolumbar junction resulting from sudden vertical impact i.e. a fall from a height as in parachuting injuries. This is because, due to the gradual change, the forces are expected to be transmitted gradually between the anterior and posterior components of vertebrae at the junction of 2 spinal curves. However, where the change is sudden, the single transitional vertebra has to bear the impact of forces, thus making it more liable to fracture. Similarly, a vertebra showing sudden transition is also more susceptible to torsional injuries. As the torsional stress is resisted by the sagitally oriented facet joint, a vertebra showing sudden transition would bear the maximum impact of torsional stress.

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How to cite this article: Gupta R, Singla R, Agnihotri G, Budhiraja V, Goyal N, Bansal S. Morphometric Study of Orientation of Superior Articular Facets of Thoracolumbar Vertebral Column in North Indian Population. Ann. Int. Med. Den. Res. 2018; 4(4):AT29-AT33.

Source of Support: Nil, **Conflict of Interest:** None declared