

The Vertebral Tropism Unit, A New Research Model Studying Zygoapophysial Joint Tropism in the Spine, Literature Review

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ABSTRACT

AIM: To study the effect of Zygoapophysial Joint Tropism in the vertebrae after changing the point of reference by looking into a new research model, the Vertebral Tropism Unit (VTU) and delineate its uniqueness.

METHODS: 44 papers in the current literature were studied. The endpoint of the research was correlated to the results. The correlation between tropism and fractures, demographics pertaining to age, spinal level, and morbidity were studied in order to study the validity of the VTU model. For the purpose of this study, the sagittal orientation of the Zygoapophysial joints (ZAJ) of 398 vertebrae in 75 patients was measured on MRI scans.

RESULTS: 509 ZAJ pairs studied. In 199 Thoracic ZAJ pairs, 121 presented with a fracture, 41% demonstrating tropism; while 78 had no fracture, 42% demonstrating tropism. In 310 Lumbar ZAJ pairs, there were 196 with a fracture, 76% demonstrating tropism; there were 114 with no fracture, 43% demonstrating tropism.

CONCLUSION: Our study suggests that if the centre point of reference in the study of tropism is changed to the vertebral body instead of the Intervertebral Disc (IVD), then a correlation between the emergence of pathological fractures in the spine and tropism is evident.

Key words: Tropism; Facet tropism; Lumbar spine; Thoracic spine; Spinal fractures

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INTRODUCTION

Zygoapophysial Joint (ZAJ) orientation in the human spine varies by less than 7° in between the two sides^[1]. When this difference between two ZAJ of the same level is in excess of 7° then this is defined as tropism^[2].

Tropism has already been correlated to degenerative changes in the spine^[3-7]. Currently there are 44 published papers quoted in the literature, studying the effect of tropism in IVD degeneration, spondylolisthesis or post operative recuperation and osteoarthritis, based on previous research^[3-7]. All previous studies^[8-26] have investigated the emergence and the effect of Tropism in the Functional Spinal Unit (FSU) model which involves the superior and inferior vertebra and the intervertebral disc at a said level in the spine (Figure 1). In these studies, the centerpoint of reference for measurement of the effect of tropism was the IVD. This means that all previous studies were looking into the effect of the ensuing change in the exerted forces and all the biomechanics changes using the IVD as the point of reference and studying the effect this might have in the degeneration of the IVD. According to the aforementioned data, all the studies in the literature study the effect of tropism in the FSU.

The purpose of this study was to investigate the role of ZAJ tropism under a different research approach, by changing the centre reference point of the forces studied from the intervertebral disc (IVD) to the vertebral body. We propose a new model of research where the point of reference is the vertebral body itself, so the correlation we are trying to study is the effect of all possible changes in exerted forces and biomechanics alterations as applied to the vertebral body (Figure 2). The most readily available result that this can be associated to is the emergence of pathological fractures. For this

reason, the model we propose is referred to as the Vertebral Tropism Unit (VTU, Figure 2) and is comprised of a specific vertebra and the superior and inferior ZAJ pair associated with it (Figure 2).

METHODS

Different methods have been validated for grading the orientation of the ZAJ, in a two dimensional as well as a three dimensional plane^[27]. The most practical method is to measure the Zygoapophysial Surfaces Angle (ZSA) as seen on magnetic resonance (MR) axial images (Figure 3).

Review of the literature revealed 44 papers in peer reviewed journals that were investigating the effect of tropism on the spine. A total of 9,876 patients were reviewed for a time period extending from 1983 to 2013. The model used in each of these papers was the FSU. All techniques used for measuring ZSA difference were comparable. 4 papers stratified the measured tropism in grades of severity while the rest just looked into the emergence or absence of tropism. None of the papers in the current literature stratified ZSA according to the presence of fractures or not. None of the papers were referring to a model similar to the VTU and none of the papers were studying the effect of tropism in the structural integrity of the vertebra itself.

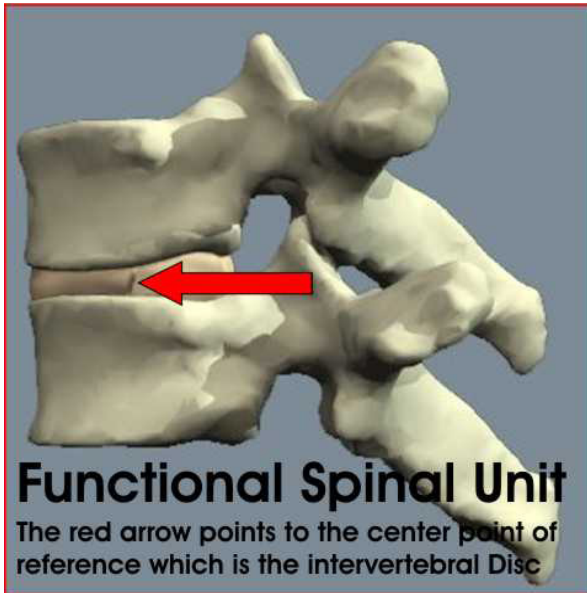


Figure 1 Functional Spinal Unit (FSU) model.

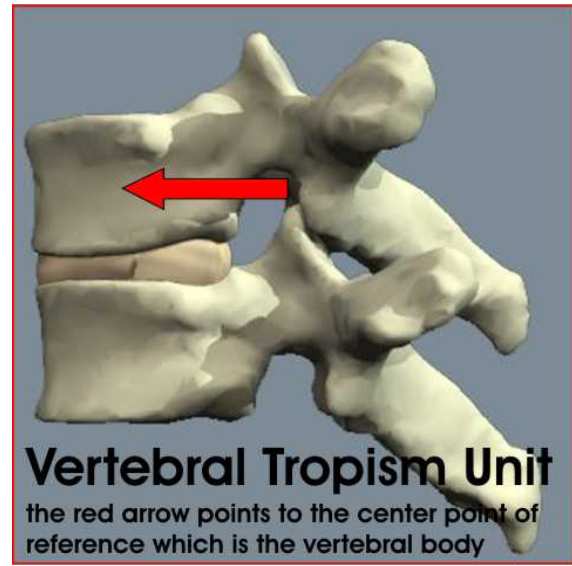
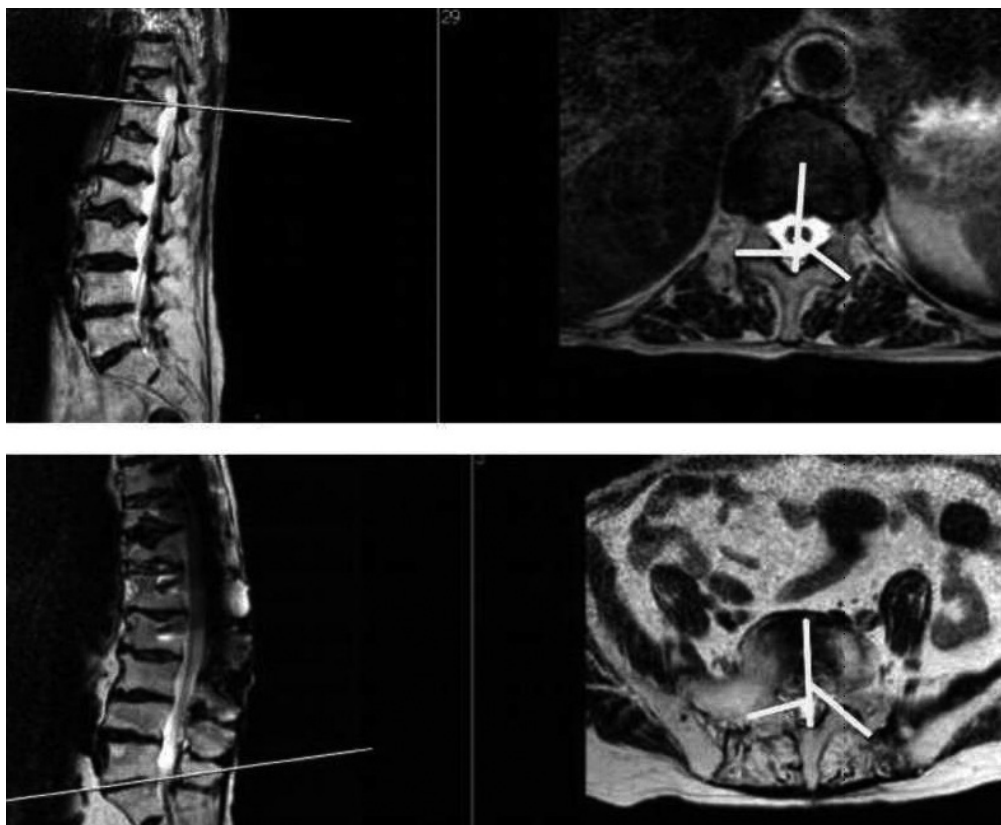


Figure 2 Vertebral Tropism Unit (VTU) model.



Measuring tropism in T11/T12 (Thoracic ZAJ pair)

Measuring tropism in L5/S1 (Lumbar/Sacral ZAJ pair)

Figure 3 Measuring Tropism.

Our study involved 509 ZAJ pairs in 75 patients (49 females and 26 males). These were selected from our institution's MRI database. Patients age ranged 47 to 89 years (median 67.4) for females and 49 to 87 (median 70.2) for males. Patients with a history of spinal trauma were excluded. All cases were anonymised.

Instead of looking into FSUs, we selected to look into separate VTUs consisting of a vertebral body and its superior and inferior ZAJ pairs. The VTUs were imaged with a 1.5-T MR unit. The ZSA was measured on the axial scans using the method described by Noren *et al*^[7]. On an axial scan that bisected the intervertebral disk, one line was drawn in the midsagittal plane of the vertebra and one through each facet joint tangential to the superior articular process. Resident software was used to calculate the left and right ZSA subtended by each of the oblique lines and the sagittal plane. The difference between the two ZSAs was determined by two investigators, who were blinded to the results of each other. Differences between measurements were looked into by a third investigator that would either provide a median between the two or provide a new measurement.

Statistical analysis was performed using SPSS (version 11.0) software. Measurements were considered significant for Kruskal-Wallis non-parametric ANOVA *p* values < 0.05.

RESULTS

We recovered the files of 75 patients presenting with pathologic spinal fractures having complete MRIs (axial and sagittal scans both). 53 patients (38 Female and 15 male) were suffering from osteoporosis, 15 were suffering from myeloma (6 Female and 9 male) and 7 were suffering from metastatic Ca (5 Female and 2 male) (Table 1).

In these 75 patients we identified 101 Thoracic Vertebrae Fractures and 123 Lumbar Vertebrae Fractures. All fractures were included in our research and there was no stratification between old fractures and new ones. Utilising the same MRIs we counted a further 70 Thoracic Vertebrae and 104 Lumbar Vertebrae in the same patients that did not exhibit Fractures. These numbers were then broken down to ZAJ pairs (per level). After excluding levels that did not have axial views, this yielded 121 Thoracic ZAJ Pairs that were associated with a fractured vertebra and 78 ZAJ Pairs that were in a Non-Fractured Vertebra as well as 196 Lumbar ZAJ pairs that were in a fracture vertebra and 114 ZAJ Pairs that were in a Non-Fractured vertebra.

For the purposes of this study, all ZAJ Pairs were separated in 2

groups, Fractured and Non-Fractured and they were further classified as Thoracic and Lumbar, with or without Tropism We studied 199 Thoracic ZAJ pairs and 310 Lumbar ZAJ pairs (Table 2). Of these, 121 Thoracic ZAJ pairs were in fractured levels and 78 in non-fractured while 196 Lumbar ZAJ pairs were in fractured levels and 114 were in non-fractured levels (Table 2).

In the Fractured group, of the 121 Thoracic ZAJ pairs, 50 had tropism and 71 had No Tropism; of the 196 Lumbar ZAJ pairs, 149 had tropism and 47 had No-Tropism (Table 2).

In the Non-Fractured group, of 78 Thoracic ZAJ pairs, 33 had Tropism and 45 No-Tropism; in the Lumbar group, 49 had Tropism and 65 had No-Tropism (Table 2).

We used the Kruskal-Wallis non-parametric Anova type inter-group analysis test with values of *p*<0.05 considered to be statistically significant. All results were considered to be significantly important for the Lumbar spine vertebrae.

DISCUSSION

Zygoapophysial tropism is defined as asymmetry between the left and right Zygoapophysial joint (ZAJ) angles by more than 7° and presents mainly in the lumbar spine at 10-70.5% of the population^[28-30]. This angular difference has been proven to cause biomechanical instability, which was more pronounced in the lumbar spine^[28-30].

ZAJ degeneration presents when one joint is orientated more coronally than the other. The correlation of coronally facing ZAJs to increased disc herniations due to biomechanical stress over the intervertebral disc has been investigated extensively in the past^[31]. More coronally oriented ZAJ offer less resistance to shear forces and the joints tend to rotate towards the more coronally facing ZAJ, possibly leading to additional rotational stress^[32]. Loback *et al*^[33] proved that ZAJ asymmetry is more pronounced on the side of the coronally facing ZAJ. When tropism was present, the motion segment was found to have a tendency to rotate towards the more oblique joint when axial loads were applied^[32]. This asymmetric axial rotation caused by tropism can place additional torsional loads on the whole VTU. This biomechanical effect has been used to explain the development of lumbar disc herniation, disc degeneration, and degenerative spondylolisthesis associated with ZAJ tropism^[34-36], but up to now, there has been no investigation as to the possible effect this may have on the vertebral body itself. The relevance of this biomechanical effect in pathological fractures has not been previously studied too, but the best opportunity to study this correlation would be in a vertebral model that is prone to collapse due to a weakened bony structure (e.g. osteoporosis).

The influence of an underlying spinal pathology on the biomechanics of the vertebral body has predominantly been investigated in osteoporosis due to the wide spread incidence and effect this condition has on an ever aging elderly population that no also include octogenarians and nonagenarians.

Osteoporosis is a systemic disease involving more than just one vertebra which when affected exhibit reduced structural strength

Table 1 Demographics.

Patients	Gender	
	Female	Male
Osteoporosis	38	15
Myeloma	6	9
Metastasis	5	2
Total	49	26
Age (years)		
range	47- 89	49 - 87
median	67.4	70.2

Table 2 Stratification of Zygoapophysial Joints (ZAJ) according to site, fracture and tropism.

		Total number of ZAJ pairs (509)	ZAJ pairs exhibiting Tropism	ZAJ pairs with No-Tropism	<i>p</i> value
Thoracic	Associated with Fracture	121	50 (41%)	71 (59%)	0.133
	Non-Fracture	78	33 (42%)	45 (58%)	
Lumbar	Associated with Fracture	196	149 (76%)	47 (24%)	0.001
	Non-Fracture	114	49 (43%)	65 (57%)	

this being one of the more common causes of vertebral collapse in the spine. Vertebral collapse fractures have a gradual onset remain clinically undetected for the most part and are usually not related to traumatic events^[37].

Osteoporotic vertebrae have been studied extensively and the results offer a great insight in the way tropism might influence the compromised biomechanical stability of a pathological vertebra. Osteoporotic vertebrae present “sub-optimal” bone structural design^[38], leading to an uneven load distribution under weight bear and after force application. Compared to the structural design of a healthy vertebra, trabeculae of osteoporotic vertebrae are less numerous, thinner, sparse and more axially oriented thus making them particularly vulnerable to unusual multidirectional loading^[39]. Moreover, longer and thinner trabeculae are more vulnerable to buckling and more easily perforated by osteoclasts^[39]. With increased susceptibility to buckling being extremely important for high loads and weight bearing, this ‘pathologic’ biomechanical model explains the reduced compression strength osteoporotic vertebrae exhibit. This fact is also supported by the suggestion that fractures of osteoporotic vertebrae may be caused both by loads that are higher than normal but also by infrequent loads that are applied in unusual directions^[40]. The load distribution between the different cancellous and cortical parts of the vertebral body is strongly affected by osteoporosis^[40].

The contribution of the cancellous mass in load transfer depends strongly on the location within the vertebra^[38]. Close to the endplates, the cancellous mass bears most of the load, but towards the centre of the vertebra the load becomes more evenly distributed, thus the altering architecture within the cancellous mass. Moving from the endplates toward the centre of the vertebra, the shell curves inward, while simultaneously the outer trabeculae angle from the endplate towards the shell, resulting in the mid-transverse shell “collecting” the load from the outer trabeculae. The contribution to load support of the spongiosa is larger in the healthy vertebra than in the osteoporotic one^[38].

The bone morphology and physiological or external loading are associated and are conjoined in a ‘cause and effect’ model for the duration of the organism’s life expectancy^[41,42]. Vertebral fractures may originate from normal day to day living actions like forward flexion, weight bearing, lifting, and exertion of loads that may not be “physiological” but are also usually non traumatic to a normal vertebra^[42]. The aforementioned changes in pathologic vertebrae structural design may lead to an increased vulnerability and thus a fracture predisposition. This seems to be relevant to the effect of Tropism, since the VTU is suffering from further translation, instability and redistribution of weight loads.

The evidence of this study indicates that tropism in the lumbar spine is significantly associated with pathological fractures as compared to those vertebrae in the same patients without fractures, thus proving the validity of the VTU as a research model.

CONCLUSION

The data presented in this study suggest that ZAJ Tropism is correlated significantly to the appearance of pathologic fractures in the VTU which are involved in frequent segmental motion. The difference in the centre of reference in the VTU which is the centre of the vertebral body provides insight into the effect of tropism in the structural integrity of the vertebrae and the possible predisposition for vertebral collapse and fracture in the pathologic spine.

CONFLICT OF INTERESTS

There are no conflicts of interest with regard to the present study.

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