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Avulsion Injuries of Vertebral Endplates

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ABSTRACT Bone changes resulting from avulsions involving vertebral endplates have had little, if any, systematic attention in palaeopathological literature. To gain insight into their occurrence and into their variety, two archaeological skeletal collections covering the period AD 1455–1824 were examined. Additional skeletal material was used to illustrate typical examples. A quarter of the 44 adults who had adequate numbers of vertebrae at all spinal levels showed minor to major vertebral endplate changes as a result of avulsion injuries. The male/female ratio was 7:4. The ratio of individuals with injuries contracted during their youth and during their adulthood was 3:8 ($n = 11$). Approximately half of the affected individuals showed such changes in multiple vertebrae. In about one third of the cases, concomitant vertebral fractures, which did not involve the endplates, were recorded. Since the existing classifications of endplate changes from avulsion injuries were developed on the basis of clinical diagnoses made by means of X-ray or by autopsy, an adapted and extended outline for palaeopathological use is proposed. A series of differential diagnoses is discussed. Although, in general, the poor preservation of archaeological spines hampers epidemiology, the diagnosis of spinal avulsion injuries offers interesting information at the individual level. Copyright © 2000 John Wiley & Sons, Ltd.

Key words: spine; vertebra; avulsion; endplate; fracture

Introduction

In the literature of palaeopathology, bone changes resulting from healed avulsions (disruptions) involving vertebral endplates have had little, if any, systematic attention. There are some past accounts (Schmorl & Junghanns, 1959), and there is, to a limited extent, forensic and radiological literature on present day cases (Schmorl & Junghanns, 1959; Hilton & Ball, 1984; Edeiken-Monroe *et al.*, 1986; Resnick, 1989; Jonsson *et al.*, 1991a,b; Lin *et al.*, 1991; Swärd *et al.*, 1993). Predilection sites have proven to be the anterior vertebral corners of the lower cervical, thoracolumbar and the lumbosacral transition areas. Posterior corners seldom seem to be involved (Swärd *et al.*, 1993; Martinez-Lage *et al.*, 1998). Avulsions involving the vertebral endplate should not be confused with flexion-distraction fractures named after Chance, which are horizontal transverse fractures within the vertebral body (Chance, 1948; Hall & Robertson, 1985; Cope *et al.*, 1987; LeGay *et al.*, 1990). These do not involve the endplates. Probably because, in modern life, avulsions are associated with whiplash traumas of the cervical spine as a result of initial motor vehicle accidents, one tends to overlook their possible occurrence at other levels of the vertebral column in the present-day, and at all levels in archaeological specimens (Hilton & Ball, 1984). However, in former times, endplate injuries from avulsions must have happened also, caused, for instance, by falls, horse-riding accidents, hits from bars, blunt abdominal traumas, minor traumas, etc. Another factor contributing to the scant attention awarded to avulsions, may be that they often seem to cause surprisingly few bodily complaints.

From a biomechanical point of view, avulsions at the endplate are caused by abrupt hyperflexion-hyperextension (i.e., acceleration-deceleration) movements. As a result, the transition area from the bony vertebral body to the fibrocartilagenous intervertebral disc becomes

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alternately compressed and stretched (distracted) in an uncontrolled manner. The resulting dislocation injury of the spine differs between children and adolescents on the one hand, and adults on the other. In the first place, in the growing vertebral body we are dealing with the unfused status of the superior and inferior annular (ring, rim) epiphyses of the endplates. In the second place, the annulus fibrosus of the fibrocartilaginous intervertebral disc is firmly attached to the hyaline cartilaginous endplate by traversing Sharpey's fibres to the annular epiphysis. However, there is a relatively weak attachment at the site of the cartilage proliferation zone of the cartilaginous endplate to the bony endplate of the body. In adults, lacking the proliferation zone of the cartilaginous endplate, the annulus fibrosus of the disc is directly and firmly connected to the rim (fused annular epiphysis) of the bony endplate of the body.

In clinical literature, the following vertebral endplate changes are mentioned in the case of children and adolescents: (1) from hyperflexion, an avulsion of the superior annular epiphysis, together with a compression fracture of the antero-superior corner of the vertebral body; after healing a 'bow-shaped' antero-superior border is seen because of fusion of the avulsed annular epiphysis; (2) from hyperextension (cervical only?),an avulsion of the inferior annular epiphysis; after healing a 'teardrop osteophyte' at the antero-inferior corner of the vertebral body may be found as a result of fusion of the avulsed annular epiphysis.

In the case of adults: (1) from hyperflexion, a compression fracture of the anterio-superior corner of the vertebral body, resulting in a 'step-off' after healing, and/or sometimes an avulsion fracture of the antero-inferior corner of the vertebral body; (2) from hyperextension (cervical only?), an avulsion fracture of the antero-inferior corner of the vertebral body.

Frequently, spinal injuries do not come alone. Depending on the literature cited, multilevel noncontiguous injuries are said to occur concomitantly in 4.5–50% of patients (Haumann, 1930; Hellner, 1931; Schmorl & Junghanns, 1959; Resnick, 1989; Riddervold, 1991). In addition there were further avulsions or avulsion fractures, compression and burst fractures, facet locks because of facet dislocations (facet jumping), fractures of spinous- and transverse processes and facets and vertebral arch fractures, including spondylolysis with or without listhesis. To gain insight into the occurrence of healing, and into the variety in type of endplate lesions from avulsions, archaeological skeletal material was examined.

Material

Two ordinary skeletal collections were screened. The 'Gorinchem' collection was excavated in 1998 by the archaeologist Floore at the 'Varkenmarkt' in the City of Gorinchem (project 1998-X-1; Floore *et al.*, 1998). The skeletons originated from a part of the graveyard for citizens of a former Franciscan Friary 'Onze Lieve Vrouwe te Bethlehem' (Our Lady at Bethlehem). They had been buried during the period AD 1455–1572. All individuals were adults, except for one. All 24 skeletons were found articulated and were almost complete.

The second, the 'Breda' skeletal collection was excavated in 1994 by the Department of Archaeology of the Municipality of the City of Breda (code: BR-25-94; Jansen, 1994; van den Eynde & Carmiggelt, in preparation. De grote of Onze Lieve Vrouwe Kerk te Breda. In: *Archeologisch en Bouwhistorisch Onderzoek in Breda*. Breda: Municipality of Breda (no. 4)). This burial place was situated outside along the southwestern wall of the so-called 'Grote' or 'Onze Lieve Vrouwe Kerk' (Our Lady Church) of the City of Breda. The collection consists of 95 complete and incomplete articulated skeletons. The remains originated from citizens buried during the 17th century and up to AD 1824.

The texture of the bone tissue was moderate to good. A review of the main demographic data on both collections is found in Table 1. The age at death distributions, especially of the Breda sample, were characteristic for pre-industrial societies (Figures 1 and 2; Waldron, 1994). The general health status of both populations and their moderate performance in contracting mechanical traumas is reflected in the frequencies of main pathological changes (Table 2).

Table 1. Main demographic data

	Gorinchem	n^a	Breda	n^a
Number of examined skeletons		24		95
Horizontal cranial index, overall (mesocranic)	76.6	21	77.4	23
Percentage of individuals under 20 years	4%	1	29%	28
Percentage of individuals over 20 years	96%	23	71%	67
Percentage of adult males	52%	12	46%	27
Percentage of adult females	48%	11	54%	32
Mean age at death of population over 20 years	52.1 years	21	49.7 years	38
Idem, for males	53.3 years	12	47.8 years	18
Idem, for females	50.6 years	9	51.8 years	20
Stature of adult males (Breitinger, 1937)	169.7 cm	11	171.3 cm	19
Stature of adult females (Trotter & Gleser, 1952)	160.7 cm	11	160.6 cm	23
Mean maximum femoral length of adult males	45.7 cm	11	47.5 mm	14
Mean maximum femoral length of adult females	43.6 cm	10	43.2 mm	14

[a] n = number of individuals inspected

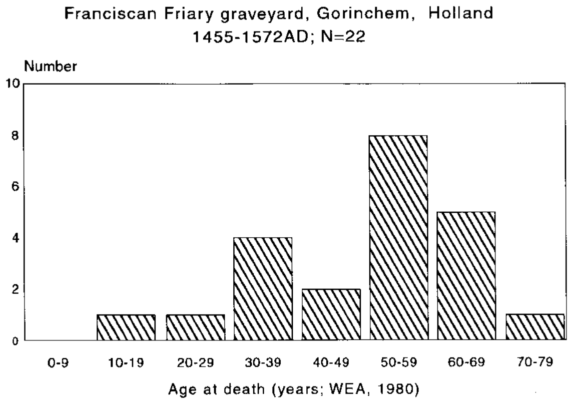

Figure 1. Age at death distribution of the Gorinchem collection.

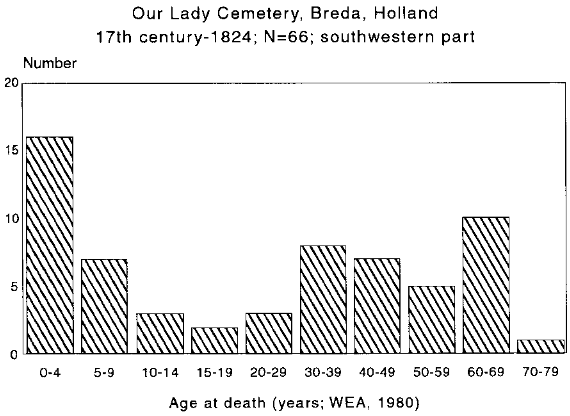

Figure 2. Age at death distribution of the Breda collection.

Further, to illustrate the variety in type of endplate changes from avulsions, characteristic examples were selected from other skeletal collections which are currently under study in our department.

Methods

Methods for sex and age determination were applied according to the Workshop of European Anthropologists (Workshop of European Anthropologists, 1980). Stature of the adults was calculated after Breitinger for males and after Trotter and Gleser for males and females (Breitinger, 1937; Trotter & Gleser, 1952, 1958). Cranial and long bone measurements were taken as defined by Knussmann (1988).

Because avulsions affect the locomotor system, it is necessary to state that criteria for the diagnosis of the arthropathies, which include vertebral osteophytosis, vertebral and peripheral osteoarthritis, Diffuse Idiopathic Skeletal Hyperostosis (DISH), von Bechterew's disease, Reiter's syndrome and psoriatic osteoarthritis, were those of Rogers & Waldron (1995), supplemented with some minor conditions by Maat *et al.* (1995). Only unequivocal cases from skeletons having adequate numbers of vertebrae from all spinal levels (cervical, thoracic and lumbar) were taken into account in this study (Table 2).

Table 2. Frequency of main pathological changes in adults

Pathology	Gorinchem		Breda	
	n[a] affected	*n*[a] inspected	*n*[a] affected	*n*[a] inspected
Traumas				
Healed fracture	11	NA	21	NA
Multiple fractures	5	NA	11	NA
Ossified epidural haematoma			1 (3%)	38
Spondylolysis, lumbar	3	NA	2	NA
Pubic parturition scar			1 (fem.)	NA
Vertebral endplate avulsion	4 (29%)	14	7 (23%)	30
Infections:				
Periostitis, haematogenous	1 (5%)	20	1 (4%)	24
Periostitis, trauma, tibia			1 (4%)	24
Osteomyelitis, haematogenous			1 (4%)	24
Abscess, vault			1 (3%)	38
Suppurative arthritis			1	NA
Maxillary sinusitis			1 (3%)	38
Deficiency disease				
Rickets, healed:				
Adults			8 (33%)	24
Non-adult			3 (25%)	12
Scurvy, healed			1 (4%)	24
Cribra orbitalia:				
Adults			1 (3%)	38
Non-adults			2 (17%)	12
Tumours				
Osteoma, cranial	1	NA	4	NA
Meningeoma			1 (3%)	38
Hypophyseal			1	NA
Enchondroma, tibia	1 (5%)	20		
Multiple myeloma	1 (4%)	23		
Metastases			2	NA
Arthropathies				
Suppurative arthritis, hip			1 (3%)	37
Vertebral osteophytosis (VO)	8 (57%)	14*	12 (40%)	30*
Vertebral osteoarthritis (VOA)	7 (50%)	14*	12 (40%)	30*
Peripheral osteoarthritis (POA)	16	NA	19	NA
DISH	6 (42%)	14*	6 (20%)	30**
Von Bechterew's syndrome			1 (3%)	30**
Reiter's syndrome			1 (3%)	30**
Psoriatic arthritis			1 (3%)	30**
Subacromial bursitis			2	NA
Miscellaneous				
Hyperostosis frontalis interna			1	NA
Exostosis arcus atlantae	1 (9%)	11		
Osteochondritis dissecans	3	NA	4	NA
Paget's disease			1 (3%)	38
Dental wear channels (pipe)	1 (14%)	7	10 (71%)	14

n = number of individuals.
* = all spinal levels inspected, cases complicated by other arthropathies excluded.
** = all spinal levels inspected.
NA = Not applicable.

Features indicating possible healed endplate lesions could only be partially derived from the radiological studies and forensic autopsies mentioned in the introduction. Vertebral marks searched for in this study were the presence of any of the following: (1) anatomical discontinuity (malalignment); (2) 'bow-shaped' superior border of the vertebral body; (3) 'step-off' of the antero-superior corner of the body; (4) 'elevation' of the antero-inferior corner; (5) 'teardrop

Table 3. Healed avulsion injuries of vertebral endplates in adults (7 males and 4 females affected)

Individuals	Gorinchem collection		Breda collection		Overall	
	n^a affected	n^a inspected*	n^a affected	n^a inspected*	n^a affected	n^a inspected*
Avulsion injuries:						
Overall	4 (29%)	14	7 (23%)	30	11 (25%)	44
Multiple	3 (21%)	14	3 (10%)	30	6 (14%)	44
Cases with concomitant:						
Avulsion injuries	3 (75%)	4	3 (43%)	7	6 (55%)	11
Vertebral fractures	1 (25%)	4	3 (43%)	7	4 (36%)	11
Any other fracture	0 (0%)	4	2 (29%)	7	2 (18%)	11

[a] n = number.
* = all spinal levels inspected.

osteophyte' at the antero-inferior corner; (6) regular uniform porotic endplate.

Results

A review of the occurrence of healed endplate avulsions and concomitant injuries in both collections is given in Table 3. Since both samples were relatively small, and differences between the two were of a minor degree, they are dealt with together in the following presentation.

About a quarter (25%) of the individuals for whom all spinal levels could be inspected showed minor to major vertebral endplate changes as a result of avulsion injuries. The male/female ratio was 7:4. Over half of the affected individuals (55%) showed such changes in multiple vertebrae. In about one third (36%) of the cases concomitant additional vertebral fractures not involving the endplate were recorded. These were additional impression fractures of the entire vertebral body in two individuals, a fracture of a spinous process in one individual, and spondylolysis of lumbar vertebrae in two individuals. Some individuals with endplate injuries also showed healed extraspinal fractures in other body parts: a humerus shaft fracture (one case) and femur shaft fracture (one case).

In three individuals, the endplate changes were anteriorly displaced annular epiphyses, representing injuries inflicted during their growth period (youth). These injuries involved the superior endplate in one individual, the inferior in another, and both in yet another.

Endplate changes contracted during adulthood were: compression (in six individuals) and avulsion (in two individuals respectively) fractures of the antero-superior corner of the vertebral body and compression (in five individuals) and avulsion (in one individual respectively) fractures of the antero-inferior corner. No avulsion injuries were seen of the posterior corners.

No (partial) uniform regular porotic endplates representing post-traumatic replaced haematomas were found.

Discussion

Whilst we appreciate that it is an almost impossible task to ensure the appearance of a pathological specimen is indeed indicative of the pathology attributed to it, the overall occurrence of healed avulsion injuries of the vertebral endplate in our skeletal sample seems to be rather high (25% of the adult citizens). However, there is little with which to compare this result. The few data available are all from serious, clinically examined present-day cases. The related publications state repeatedly that the true frequencies are unknown. Some time ago, it was suggested that avulsion injuries of the spine might happen rather frequently (Schmorl & Junghanns, 1959). In a much more recent autopsy study of 'normal spines' of all ages (n = 117) at least one 'rim lesion' was found in the majority of patients over 50 years of age (Hilton & Ball, 1984). Numbers increased with age, and males were affected more frequently. Only 44% could be recognized on radiographs; our results confirm that. It is possible that many cases never came to be studied by a radiologist or a pathologist at all (Hilton & Ball, 1984). This could be caused, in part, by the minimal loss of mobility and tolerable discomfort one suffers if the dislocated structures return to their nearly normal spinal alignment, which they usually do (Jonsson *et al.*, 1991a). In general, it has been stated that avulsion injuries of endplates and other vertebral fractures may result from rather insignificant accidents, such as from children's games, simple gymnastic exercises and diving (Schmorl & Junghanns, 1959; Swärd *et al.*, 1993). As is the case today, many of our skeletons showed concomitant spinal injuries, i.e. multiple avulsion injuries (55% of the affected spines) and additional vertebral fractures (in 36% of the cases). Two cases even had extraspinal fractures. Not excluding the possibility of coincidentally collected traumas during life, the accumulation of physical injuries in some individuals underlined the complex consequences of an accident.

In our group of 44 adults, who had adequate numbers of vertebrae from all spinal levels for inspection, the ratio between individuals with endplate injuries contracted during their youth, the period of physical trial and error, and of those during their adulthood, the period of decreasing physical flexibility, was 3:8 ($n = 11$). If we accept that bone remodelling during life will hardly alter gross anatomical vertebral changes like 'step-offs', 'elevations', malalignments and fracture fissures, then we might estimate for our sample that the risk of our three adult individuals with changes dating from their youth contracting such a change during their growth period had been 3/44 (circa 7%). The risk of the eight individuals who had contracted endplate changes during adulthood had been 8/44 (circa 18%).

Classifications of endplate changes from avulsion injuries were developed on the basis of clinical diagnoses made by means of X-ray, or by autopsy, shortly after the time of occurrence of the inflicting trauma. In palaeopathology, the situation is different. One has the possibility of direct visual inspection of the dry bone specimen, and at the same time one is often dealing with healed cases of individuals who died long

Figure 3. Superior view of vertebra T10. 'Bow-shaped' antero-superior border after avulsion of the annular epiphysis with anterior displacement. The injury is accompanied by an impression fracture of the antero-superior corner.

after the causal event. Consequently, for palaeopathological diagnosis, an adapted outline would be helpful. Taking the line that the inspected endplate changes resulted from avulsion injuries with displacement, followed by nearly normal realignment of the spine, the following argument is proposed.

If avulsion injuries of the endplate are contracted during youth:

(1) Avulsion of the superior annular (rim) epiphysis with anterior displacement; usually this classical injury is accompanied by an impression fracture of the antero-superior corner of the vertebral body, since it only can happen in case of an unfused annular epiphysis, it is always contracted during youth; it is caused by a hyperflexion displacement; palaeopathology (Figure 3): a typical 'bow-shaped' antero-superior border after fusion of the anteriorly displaced annular epiphysis; behind it lies the depression remaining from the impressed antero-superior corner of the body (Jonsson *et al.*, 1991a).

(2) Avulsion of the inferior annular (rim-) epiphysis with anterior/caudal displacement; usually this is accompanied by an impression fracture of the antero-inferior corner of the vertebral body; since the annular epiphysis is unfused, this type is always contracted during youth; it is caused by a hyperextension displace-

Figure 4. Lateral view of vertebra T5. 'Teardrop osteophyte' at the antero-inferior corner of the body after avulsion of the inferior annular (rim-) epiphysis with anterior/caudal displacement. From this position the impression fracture of the antero-inferior corner of the vertebral body cannot be seen.

ment; from the very few cases mentioned in the literature, one may conclude that its occurrence is low; palaeopathology (Figure 4): a 'teardrop osteophyte' at the antero-inferior corner of the body after fusion of the displaced annular epiphysis (Jonsson *et al.*, 1991a).

If contracted during youth or adulthood:

(3) Complete or partial avulsion (separation) of the intervertebral disc, together with the related cartilaginous endplate from the bony vertebral endplate without concomitant fracture of the bony vertebra (disc bond injury, pseudo-spondylolisthesis; Schmorl & Junghanns, 1959); during life a haematoma is found between the cartilaginous and bony endplate (Jonsson *et al.*, 1991b); this type of avulsion is more easily contracted

Figure 5. Superior view of vertebra L5 (left) and from the inferior side of vertebra L5 of another individual (right). A partial and a complete regular uniform porotic endplate representing a replaced haematoma after avulsion (separation) of the intervertebral disc, together with the related cartilaginous endplate from the bony vertebral endplate of the body.

Figure 6. Superior view of vertebrae L1 and 2 of the same individual. Antero-superior 'step-offs' and accompaying crushed and cavitated annular epiphyses after a compression fracture of the antero-superior corner of both bodies and their related endplates.

during childhood and adolescence, the occurrence is unknown; palaeopathology (Figure 5): we assume that, at least in a number of cases, a partial or complete regular uniform porotic endplate represents the replaced haematoma.

If contracted during adulthood:

(4) A compression fracture of the antero-superior corner of the body and its related endplate; this is probably the most common and a typical hyperflexion avulsion fracture in adults; it might often stay clinically unnoticed (Hilton & Ball, 1984); palaeopathology (Figure 6): an antero-superior 'step-off' and a locally crushed annular epiphysis; the 'step-off' may show cavitation ('excavation').

Figure 7. Superior view of vertebrae T3 and 4 of the same individual. Discontinuity in the antero-superior rims after union of the displaced fragments after an avulsion fracture of the antero-superior corner of the body together with its related portion of the endplate. The endplates show remaining fracture fissures with sharp edges like in the burst fracture of Figure 10.

(5) An avulsion fracture of the antero-superior corner of the body, together with its related portion of the endplate; this is radiologically a frequently recorded well-know entity; palaeopathology (Figure 7): a discontinuity in the antero-superior rim after union of the (displaced) fragment; the endplate may show a remaining fracture fissure with sharp edges.

(6) A compression fracture of the antero-inferior corner of the body and its related endplate; this is caused by hyperflexion of the adult spine; in comparison with avulsion fractures of the antero-superior corner, it happens only occasionally (Schmorl & Junghanns, 1959); palaeopathology (Figure 8): an anterior 'elevation' with a crushed annular epiphysis of the inferior endplate, the 'elevation' may show cavitation ('excavation').

(7) An avulsion fracture with or without cavitation of the antero-inferior corner of the body; this may be caused by hyperextension (cervical only?) or by hyperflexion of the adult spine (Edeiken-Monroe *et al.*, 1986; Jonsson *et al.*, 1991a); palaeopathology (Figure 8): a discontinuity in the antero-inferior rim after union of the (displaced) fragment, the endplate may show a remaining fracture fissure with sharp edges.

With respect to the differential diagnosis of endplate changes as a result of an avulsion injury, one should keep the following alternatives in mind:

1. A regular compression fracture resulting from axial overloading of the spine without displacement, in such a case the entire body is wedged without an anterior 'step-off' of the superior endplate or a 'anterior elevation' of the inferior endplate (Figure 9);
2. A 'fish vertebra' as a result of senile osteoporosis; the typical rounded and depressed superior and inferior endplates are the result of compression of an architecturally weakened vertebral body;
3. A burst fracture, because of axial overloading of the spine; in these cases often retropulsion is seen of a mid-dorsal body segment into the vertebral canal (Maat *et al.*, 1996), as in a case of union of an avulsed fragment of the anterior corner of the body, the endplate may show multiple fracture fissures with sharp edges which stay after healing (Figure 10);
4. A vertebra with Scheuermann's kyphosis (Scoles *et al.*, 1991); this will show anterior extension, wedging of the entire body and

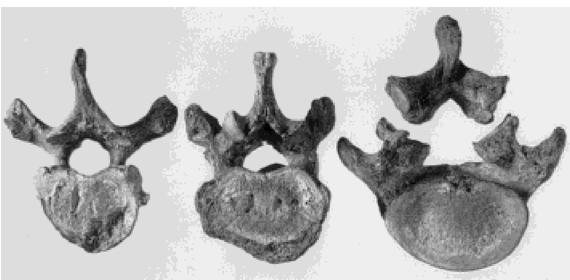

Figure 8. Inferior view of vertebrae T7 and 11 and of vertebra L5 of the same individual. Union of a displaced fragment after an avulsion fracture of the antero-inferior corner of T7 (left). 'Elevation' with a crushed annular epiphysis of the inferior endplate after a compression fracture of the antero-inferior corner of the body of T11. Spondylolysis of vertebra L5.

Figure 9. Lateral view of vertebrae T7 and 8. Two regular compression fractures without displacement. The entire bodies are wedged by mild compression. Note the wrinkles in the anterior surface of the bodies.

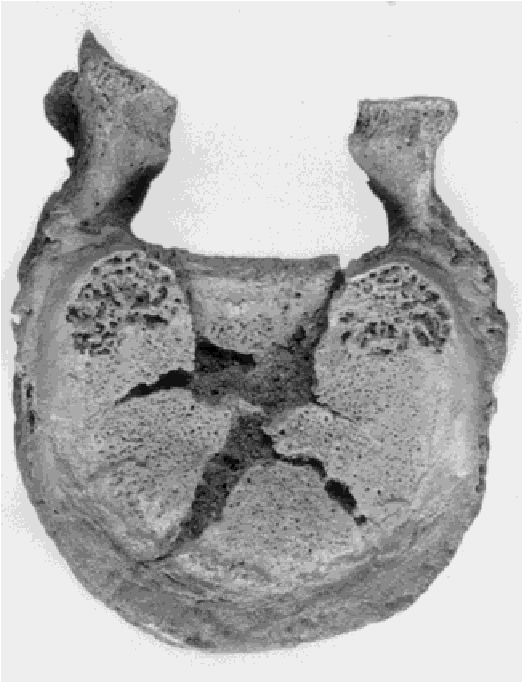

Figure 10. Superior view of a thoracic vertebra. Typical burst fracture with retropulsion of a mid-dorsal body segment into the vertebral canal. Note, as in Figure 7, the multiple fracture fissures with sharp edges in the endplate.

Figure 11. Inferior view of vertebrae T8 and 9 of the same individual. Scheuermann's kyphosis with anterior extension of the bodies 'outside' the annular rings and accompanying Schmorl's noduli. From this position the wedging of the vertebral bodies can not be seen.

frequently Schmorl's nodes; the annular epiphysis stays in place; the extension consists of tissue added anteriorly 'outside' the annular ring as if to sustain the increased pressure from the kyphosis, and thoracic vertebrae are affected in the first place (Figure 11);

5. A vertebra with extensive Schmorl's nodes, as seen in vertebral osteophytosis (Degenerative Disc Disease; Schmorl & Junghanns, 1959; Rogers & Waldron, 1995); the 'nodes' are discrete indentations, sometimes extending posteriorly into the vertebral canal; they remain after herniation of disc material through the cartilaginous endplate into the bony endplate (Schmorl and Junghanns, 1959); they do not have the regular, uniform and diffuse spread out appearance of a porotic surface remaining from replacement of a haematoma after a disc bond injury;
6. A 'limbus vertebra', resulting from a severe herniation of disc material into the endplate, just behind an intact and not anteriorly displaced annular epiphysis (Greenspan, 1988); on first inspection the limbus looks like a 'bow-shaped' antero-superior border resulting from an avulsion during youth, but it is not anteriorly displaced (Figure 12);
7. A vertebra in which a one of the radiating branches of the perichondrial vessels involved in the ossification of the annular epiphysis has remained into adulthood (Töndury & Theiler, 1990); it may be found as a tributary of one of the large tortuous channels (sinusoids) of the basivertebral veins; it runs from inside the vertebral body over a short distance in the plane of the endplate; in addition to its interior connection it may have a direct accessory

Figure 12. Inferior view of vertebrae T12 and L1 of the same individual. 'Limbus vertebra' resulting from herniation of disc material into the endplate just behind an intact and not anteriorly displaced annular epiphysis.

connection with the venous plexus of the vertebral canal; this anastomosis is additional to the usual drainage of the often double basivertebral veins through their foramina in the dorsal wall of the vertebral body;

8. A vertebra with bony outgrowths along the anterior border of its body (marginal osteophytes) as a result of early vertebral osteophytosis, DISH or seronegative arthropathies (von Bechterew's disease, Reiter's syndrome, psoriatic arthritis); all these afflictions may give pseudo-'bow shaped' borders and pseudo-'teardrop osteophytes'; they will not produce anterior displacement of the annular epiphysis, nor will they produce anatomical discontinuities as seen in case of a healed fracture;
9. A vertebra with a coarse pitted endplate as a result of vertebral osteophytosis (Degenerative Disc Disease); in these cases the pitting is very irregular, often showing reactive bone growth, and is almost always accompanied by marginal osteophytes (Rogers & Waldron, 1995); it does not show the typical (partial or complete) regular uniform porotic endplate changes representing a replaced haematoma.

In theory, the frequency of avulsion injuries of the spine could be used as a parameter for the liability of a population to contract mechanical injuries. However, in practice, we expect that the usual poor intact survival of human vertebral columns originating from archaeological excavations will hamper its epidemiological use in most collections. Nevertheless, as shown in our collections, its rather high occurrence in an 'average' population makes it a valuable diagnosis at the individual level.

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