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Description, Significance and Frequency of the Acetabular Crease of the Hip Bone

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ABSTRACT The acetabular crease is a linear indentation located in the antero-superior quadrant of the surface of the acetabulum at the level of the Byers Feature 17. Considered by palaeoanthropologists as a discrete trait, it has received scarce attention and the mechanisms underlying its formation and variations according to sex and age remain largely unclear. The purpose of this study, carried out on a large sample from a historic population in France, was to (i) analyse variations according to side, sex and estimated age at death; (ii) assess diachronic variations; and (iii) compare prevalence in various prehistoric and historic populations. Hip bones from a total of 425 subjects of both sexes and all ages were studied. Specimens were from two French historic samples dating from the 11th to 13th centuries and 16th to 17th centuries. The proportion of subjects that died young was higher in the 11th to 13th century group, but the prevalence of the acetabular crease was comparable between the two groups regardless of site or laterality (unilateral or bilateral). No sexual dimorphism or correlation with age was noted at either period. The acetabular crease appears to be a stable anatomical trait throughout adult life, with no predominant side and no correlation with sex. The significantly higher prevalence of the acetabular crease in some historic French samples and in prehistoric native Canadian populations could be linked to greater biomechanical stress during childhood in rural medieval populations and in the prehistoric period.

Key words: acetabular crease; hip bone; Byers Feature 17; non-metric trait; historic populations; prehistoric populations; France; North America

Introduction

Numerous studies have been carried out to compare determinant mechanisms and non-metric trait variations in contemporary or archaeological populations (Berry & Berry, 1967; Ossenberg, 1969; Sjøvold, 1977; Lane, 1978; Hanihara & Ishida, 2001a,b,c) and even fossilised human remains (Manzi *et al.*, 2000). Most of these studies have focused on skull traits. Little attention has been devoted to discrete postcranial skeletal traits. Based on the unproven assumption that genetic determinism is involved, these traits have been used to compare archaeological populations (Anderson, 1968; Finnegan & Faust, 1974; Finnegan, 1978). Aetiological mechanisms and factors influencing the frequency of each trait are often unclear (Saunders, 1989). Since both inter- and intra-observer variations can be great (Saunders, 1978; Donlon, 2000), the mechanisms underlying the formation and variations of each non-metric trait according to side, sex and age must be studied in large sample populations before being used to compare populations.

The descriptive and functional anatomy of the acetabulum of the pelvis has been extensively studied not only to understand its fundamental role in hip biomechanics, but also to design hip

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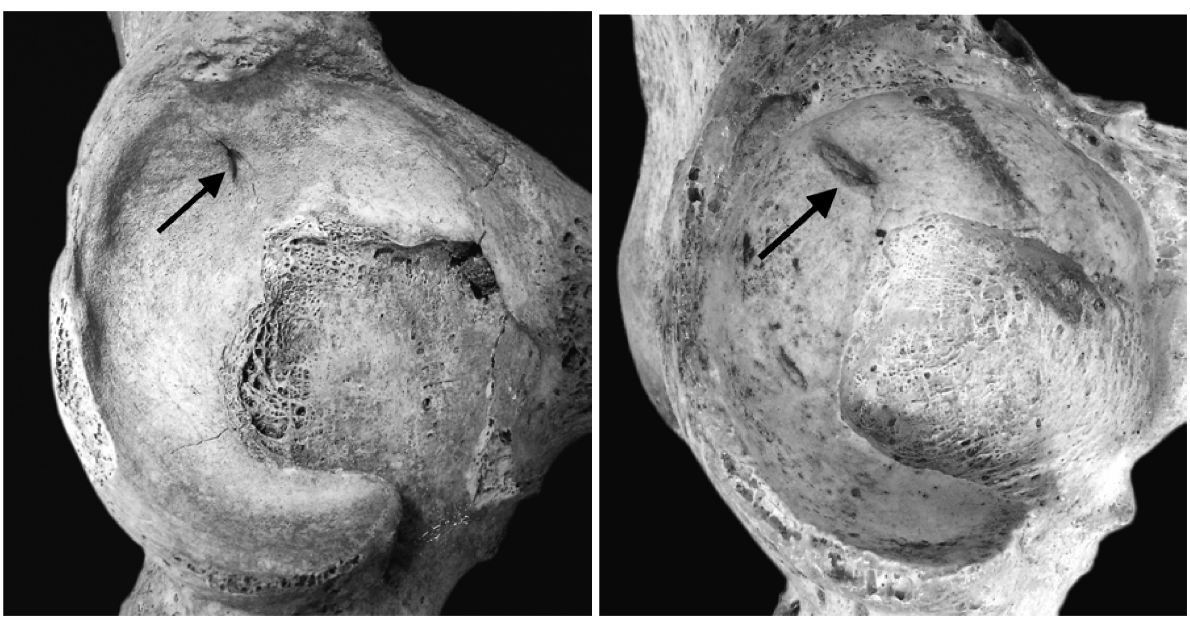
prostheses that function like natural joints. To our knowledge, however, the presence of an indentation or crease in the anterosuperior quadrant of the surface of the acetabulum has not been mentioned in any anatomical description (Gray, 1901; Poirier & Charpy, 1911; Testut & Latarjet, 1928; Paturet, 1951).

Based on a study of a sample from a prehistoric native Canadian population, Anderson (1964) noted the '*presence of a pit, a pleat-like groove or a notch on the acetabular margin*' of the acetabulum. He considered this feature, which he called the 'acetabular crease', to be a non-metric postcranial trait indicative of genetic affinities between populations. After examination of three other sample populations of prehistoric native Canadian groups, Saunders (1978) reported that there were significant differences in the prevalence of this trait between groups. This author made a distinction between an 'acetabular mark' designating a clear-cut indentation corresponding to the acetabular crease as described by Anderson, and an 'acetabular pit' designating a rounded-edged depression. However, because of high discordance between observers for identification, the latter feature (i.e. the rounded-edged indentation) was excluded from the final analysis. Data showed that variation according to side was not significant, but one series showed that the acetabular mark was more common in young adults. Given the vagueness of the term 'mark', the terms 'rounded-edged pit' and 'acetabular crease' have been used to distinguish these two traits in the present study (Figures 1 and 2).

In samples from a historic population that lived in the Provence area of France, we have observed that the acetabular crease was significantly more prevalent in a medieval (11th to 13th century) rural population from La Gayole, Var, than in a late Middle Age (5th to 6th century) urban population from Saint-Victor Abbey in Marseille, France (chi-square test with Yates correction, $P < 0.01$) (Mafart, 1987). Saunders (1978) speculated that the acetabular crease might be a remnant of a supernumerary bone (acetabular bone). Based on our findings, we propose that the acetabular crease is a stress marker, and a possible explanation for this difference would be greater mechanical forces in rural than urban populations. The hypothesis of a supernumerary bone is more in favour of a constitutional mechanism that could be related to genetics, whereas the hypothesis of a biomechanical cause would implicate living conditions and



(a) (b)

Figure 1. Examples of acetabular crease on acetabulum from the French historic sample from Notre-Dame-du-Bourg (see arrows). (a) Small acetabular crease; (b) Large acetabular crease.

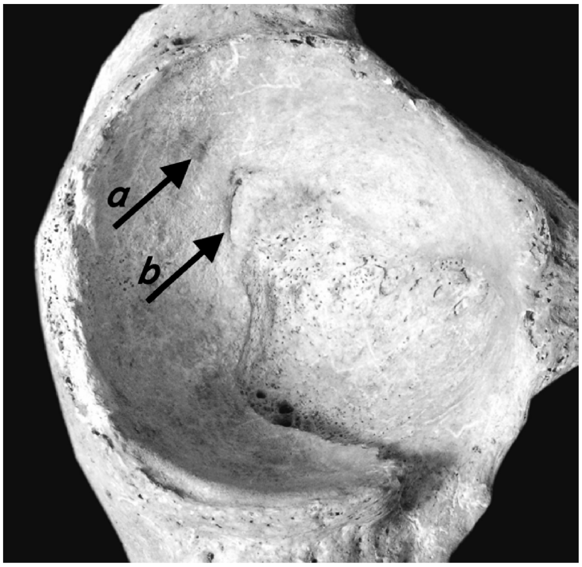


Figure 2. Rounded-edged pit (arrow A) and acetabular notch (arrow B) on an acetabulum from the French historic sample from Notre-Dame-du-Bourg.

environmental factors. The aetiology of this anatomical variation must be discussed in the light of the anatomical and surgical literature.

Acetabulum ossification and the supernumerary bone hypothesis

The hip bone results from the fusion of three bones: the ilium, ischium and pubis. The cotyloid cavity, or acetabulum, is formed internally by the os pubis, above the ilium and below the ischium (Gray, 1901). During growth, another anatomical component, the triradiate cartilage, plays a fundamental role and constitutes 'the fourth piece' of the coxal bone (Gaye, 1925; Bedouelle, 1954). The triradiate cartilage is a complex structure (Bucholz *et al.*, 1982). In newborns the acetabulum is formed by this hemispheric acetabular cartilage which presents three contiguous extensions of the growth cartilage separating the three bones (i.e. the iliac bone, ischium and pubis). The three extensions meet at the bottom of the acetabulum. Growth of the triradiate cartilage involves progressive ossification, and points of secondary ossification can occur during this process (Perna, 1922; Gaye, 1925; Testut & Latarjet, 1928; Morrison, 1932). Ponsetti (1978) showed that three points of secondary ossification could appear in the hyaline cartilage and are homologous with other epiphyses in the skeleton. The acetabular bone proposed by Saunders (1978) to explain the acetabular crease is homologous with the pubis and forms the anterior part of the acetabulum, but its posterior extension would never reach the zone where the acetabulum crease is observed. Behind this zone there is only the space occupied by the iliac bone. Thus it is unlikely that the crease is related to a point of secondary ossification or to an acetabular ossicle that is not located at this level (Hergan *et al.*, 2000). In some cases there may be a groove, sometimes called the sulcus dorsalis dorsal glenoid incisure, indicative of a coalescence zone between the cartilaginous edges of the iliac bone and pubis. However, this groove is located more anteriorly and may coexist with the acetabular crease.

Biomechanics of the acetabulum and Byers Feature 17

The acetabulum is slightly oval (Dieulafoy, 1931) so that the articular surfaces of the acetabulum and femoral head are non-congruent (Bullough *et al.*, 1968; Frain, 1983). As a result, pressure from the femoral head is progressively distributed with the shifting of the contact points from lateral zones to an upper pole zone under heavy loading conditions (Greenwald & Haynes, 1972; Armstrong *et al.*, 1979; Frain, 1983; Afoke *et al.*, 1987; Ficat & Ficat, 1987). This is possible only because the cornua of the acetabulum has a certain degree of mobility, allowing them to spread so that the head of the femur can come to bear on a larger area of the articular surface (Lazennec *et al.*, 1990; Vandenbussche *et al.*, 1999). A junction zone located on the supermedial part of the acetabular roof represents the biomechanical apex of acetabular mobility. This zone is called by Byers *et al.* (1970) 'Feature 17' (Figure 3).

The structure of Byers Feature 17 is different from that of the rest of the acetabulum (Greenwald & Haynes, 1972; Laudet *et al.*, 1992). Based on histological evidence, Maroudas *et al.* (1973) reported a lower rate of glycosamineglycan in the acetabular cartilage. This finding distinguishes this zone from the hyaline cartilage and

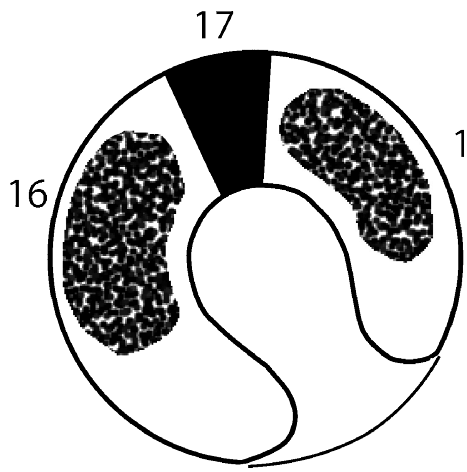


Figure 3. Localisations of three Byers Features on the articular surface of the acetabulum. The Features 15 and 16 are in contact with the femoral head during normal weight-bearing. The Byers Feature 17, located on the supermedial part of the acetabular roof, represents the biomechanical apex of acetabular mobility.

suggests that it is more like fibrocartilaginous tissue between two functionally different zones (Maroudas *et al.*, 1973; Day *et al.*, 1975). Although this histologically documented structural difference in comparison with the hyaline cartilage could determine lower resistance to pressure, it must be noted that this zone is almost completely non-functional and not submitted to regular loading in the normal hip of young people. However, age-related deterioration of the hyaline cartilage of the acetabulum leads to direct contact between the bone and this region (Greenwald & Haynes, 1972; Armstrong *et al.*, 1979; Teinturier *et al.*, 1983). Special arthritic bone changes have been noted in this area. In this regard, several studies on acetabular arthritis have identified an oval-shaped zone (often pitted at the centre) in which degenerative lesions are always found when present (Goodfellow & Bullough, 1968; Bullough & Goodfellow, 1973; Day *et al.*, 1975), and if so, may take the form of an inverted Y (Ficat & Ficat, 1987). This zone also corresponds to the location of the rounded-edged acetabular pit or indentation, which observers have had difficulty in identifying consistently (Saunders, 1978).

Only one study has been carried out on living subjects: Vallée *et al.* (1988). The purpose was to determine the cause underlying a clear spot in the middle of the acetabular roof that was observed on side-view X-rays in 17% of men (21/123) and 22% of women (41/184). Based on an examination of some dry bones, the authors concluded that the spot corresponded to a depression or crease in the enchondral bone, but did not refer to and/or express any familiarity with the term or work on the acetabular crease.

There may also be an extension of the non-cartilaginous zone from the centre of the acetabulum upwards, overlapping the usual edge of the enchondral bone. Das *et al.* (1985) called this zone, frequently found in fetuses (Walker, 1980), the acetabular notch. However, the term acetabular notch has been used to designate three different zones by Johnstone *et al.* (1982), Portinaro *et al.* (1994) and Vandenbussche *et al.* (1999).

The infrequent association of the acetabular notch and acetabular crease concurs in giving an inverted Y aspect. Because the central zone of the acetabulum displays considerable variability and cannot be conveniently classified, it was excluded from final analysis in this study.

The purpose of this study, carried out on a sample of hip bones from a historic population in France, was to: (i) analyse variations according to side, sex and estimated age at death; (ii) assess diachronic variations; and (iii) detect possible differences from previously reported findings in prehistoric populations.

Material and methods

A total of 425 hip bones from the historic burial site at Notre-Dame-du-Bourg in Digne, France (Alpes-de-Haute-Provence Department), were studied. This site was used from the 4th to the 17th century. To highlight variations over time, we selected hip bones from two historic periods: the 11th to 13th centuries and 16th to 17th centuries. Sex was determined by studying pelvic features (Bruzek, 2002). Age was estimated based on an examination of the sacral joint surface (Lovejoy, modified by Schmitt & Broaqua, 2000), of the iliac crests and the third molars. Samples were classified into three age groups: under 30 years (juvenile sacral joint, incomplete fusion of the iliac crests, and/or ongoing eruption or lack of wear of the third molars); over 60 years (compatible sacro-iliac joint features); and between 30 and 60 (no criteria consistent with the other two age groups).

A search for the presence of the acetabular crease was focused on the anterosuperior quadrant of the acetabulum. The following two features were noted as present or absent:

- rounded-edged pit;
- acetabular crease defined as the presence in the same study zone of a visible indentation delineated by oblique and vertical edges that partially or completely intersects the surface of the acetabular joint along an oblique axis passing from top to bottom and from back to front. Crease shape was variable, with most being linear but some forming an inverted Y.

Statistical analysis was performed using the chi-square, test, evaluated at the conventional level of alpha = 0.05.

Results

The demographic profiles of the Middle Ages and Pre-modern groups selected for this study were different. The sex ratio was 1.56 in the medieval group and 1.27 in the pre-modern group (NS, $P = 1.21$). The proportion of subjects that died before 20 years of age was higher in the Middle Ages group (chi-square test with Yates correction 24.19; $P < 10^{-6}$).

However, as stated by Saunders (1978), the rounded-edged pit accounted for most of the inter- and intra-observer discordance. Inter-observer variation for identification of the rounded-edged pit was significant ($P < 0.01$). Inter- and intra-observer variation for the acetabular crease was not significant ($P = 0.6$). Based on these findings, only data for the acetabular crease were taken into account in the final analysis. Results of the analysis are summarised in Table 1, and prevalences for matched hip bones are given in Table 2.

Prevalence of the acetabular crease was comparable in the two groups (chi-square test with Yates correction: 1.02; $P = 0.31$) regardless of side (chi-square test with Yates correction: 0.02; $P = 0.89$) or laterality (unilateral or bilateral) (chi-square test with Yates correction: 0.43; $P = 0.51$). No sexual dimorphism was noted for either historic period (chi-square test with Yates correction: Middle Ages: 3.18; $P = 0.07$ and Pre-modern: 1.84; $P = 0.17$). Comparison of the young and old groups (i.e. under 30 years versus over 60 years) showed no significant difference (chi-square test with Yates correction: 3.69; $P = 0.054$). Age appeared to have no influence

Table 1. Prevalence of the acetabular crease in the overall sample of hip bones from the French historic population from Notre-Dame-du-Bourg

Historic periods	Age (Years)	Absent			Present			Total
		Right	Left	Total	Right	Left	Total	
Middle Age	Male							
	< 30	19	18	37	0	0	0	37
	30–60	25	27	52	7	3	10	62
	> 60	28	35	63	6	5	11	74
	Famale							
	< 30	16	16	32	4	5	9	41
	30–60	12	15	27	0	0	0	27
	> 60	16	13	29	6	8	14	43
	Total	116	124	240	23	21	44	284
Pre-Modern	Male							
	< 30	2	2	4	0	0	0	4
	30–60	10	11	21	0	0	0	21
	> 60	22	20	42	6	6	12	54
	Female							
	< 30	4	3	7	0	0	0	7
	30–60	11	11	22	0	0	0	22
	> 60	13	16	29	2	2	4	33
	Total	62	63	125	8	8	16	141

Table 2. Prevalence of the acetabular crease in matched hip bones from the French historic population from Notre-Dame-du-Bourg

Period	Age (years)	Absent	Present			Total
			Right	Left	Both sides	
Middle Age	Male					
	< 30	8	0	0	0	8
	30–60	11	2	0	1	14
	> 60	15	1	0	2	18
	Female					
	< 30	7	0	0	2	9
	30–60	6	0	0	0	6
	> 60	6	0	0	3	9
	Total	53	3	0	8	64
Pre-Modern	Male					
	< 30	2	0	0	0	2
	30–60	10	0	0	0	10
	> 60	15	1	3	2	21
	Female					
	< 30	2	0	0	0	2
	30–60	9	0	0	0	9
	> 60	12	0	0	2	14
	Total	103	4	3	12	122

on trait frequency. Thus it is possible to consider that distinction between historic period, sex and side is unnecessary for study of the acetabular crease in this sample population. The acetabular crease appears to be a stable anatomical trait throughout adult life, with no predominant side and no correlation with sex.

Comparison with previous works is feasible, since inter-observer variation for identification of the acetabular crease was not significant. Prevalence of the acetabular crease was significantly higher in two of the three prehistoric native populations that were large enough to allow analysis, and the percentage was also higher in the three other prehistoric native samples (Table 3). Observed rates have been far higher in all these prehistoric populations.

Discussion

The hypothesis of a supernumerary bone to explain the acetabular crease can be discounted. The absence of correlation with age rules out an age-related mechanism. Nor can the trait be attributed to coxal disease, since no specific dysplastic or degenerative acetabular lesions have been found in association. A genetic

Table 3. Prevalence of the acetabular crease in the French historic sample and prehistoric native Canadian samples, and comparison with the series from Notre-Dame-du-Bourg

Populations	*n*	Acetabular crease			Chi-square test	References
		Present		Absent		
		%	*n*			
French Historic						
Notre-Dame-du-Bourg	425	11.8	50	375		
La Gayole	18	39	7	11	$P < 10^{-2}$	Mafart (1984)
Saint Victor	50	6	3	47	NS	Mafart (1984)
Prehistoric Canadians						
Eskalt	466	25.8	120	346	$P < 10^{-5}$	Saunders (1978)
Mobr	116	19.8	23	93	$P < 0.02$	Saunders (1978)
Libben	159	43.4	69	90	$P < 10^{-6}$	Saunders (1978)

mechanism would be possible, but only if transmission could account for the high prevalence rates observed in some populations.

Since the acetabular crease is located in the Byers Feature 17, which is a hinge zone, it appears valid to envision a biomechanical hypothesis. Thus the acetabular crease could be due to biomechanical factors at this level of the acetabulum during growth prior to ossification of the triradiate cartilage. Such factors could include either high stress or reduced resistance in some subjects.

The high prevalence of the acetabular crease observed in prehistoric native North Americans and in one historic French sample, which showed a statistically highly significant difference from the historic sample studied here, suggests that living conditions and environmental factors may be implicated in occurrence of the acetabular crease. Assuming that the biomechanical hypothesis is true, these discrepancies could be linked to greater stress during childhood in populations exhibiting a higher frequency of acetabular crease, as well as to constitutional differences in the resistance of the triradiate cartilage during childhood at a time when nutritional conditions were probably less favourable than in the historic French samples.

The acetabular crease dilemma illustrates the complexity and our poor understanding of the acetabular region. Further studies of the triradiate cartilage during growth, and comparison with populations from other regions and periods, are needed to refine our understanding about the factors underlying the formation of the acetabular crease and to assess its relationship with the acetabular cartilage and Byers Feature 17, as well as with other anatomical variations of the acetabulum such as the acetabular notch.

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