Radiographic associations for "primary" hip osteoarthrosis

A retrospective cohort study of 47 patients

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ABSTRACT – This radiographic retrospective cohort study aims to identify relations between the prearthrotic anatomy of the hip joint and the type of subsequent osteoarthrosis (OA). Radiographs of 64 hips in 47 patients were evaluated. Several anatomical indices were measured on radiographs obtained before the onset of OA. The location, type and grade of OA were recorded on subsequent radiographs. Due to the small number of hips available, only three potential risk factors could be considered for both OA location and OA type (weight-bearing surface angle, spherical sector and neck shaft angle for both outcomes). The only variable that was found to be a significant predictor of OA location was the degree of inclination of the acetabular sourcil. Patients with craniomedial sourcils were more likely to have medial OA. No predictors of OA type could be identified. Our results suggest that the anatomy of the hip joint is a factor determining the location of developing osteoarthrosis.

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The various classifications of hip osteoarthrosis (OA) reflect the lack of understanding of the pathogenesis and patterns of progression of the disease. It has been suggested that the type of OA is associated with gender, age (Ledingham et al. 1992) or with other factors, such as Heberden's nodes (Marks et al. 1979) and chondrocalcinosis (Menkes et al. 1985). It is difficult to distinguish confidently between primary and secondary OA, and many of the hips labelled primary OA probably have some underlying abnormality (Murray 1965, Solomon 1976, ARA 1983). The location of acetabular involvement and the patterns of migration of the femoral head provide further criteria for subclassification (Resnick 1975, Hayward et al. 1988). One classification has been proposed based on the type and degree of bone response (Solomon et al. 1982). A proposed theory for a mechanical aetiology of "primary" osteoarthrosis suggested that the orientation of the acetabular sourcil, which represents the weight-bearing surface (WBS) of the acetabulum, determines the direction of migration of the femoral head and the type of bone reaction, in response to local forces (Bombelli 1983, Bombelli et al. 1983). On the basis of force analysis, the authors suggested that departure of WBS orientation from the horizontal can negatively affect the equilibrium of forces acting on the hip and result in the development of OA. They also proposed a classification system for hip osteoarthrosis based on the neck-shaft angle and the sourcil orientation (Figure 1). They considered a normal neck-shaft angle to be between 128° and 135°. Values above 135° indicate a valgus neck and those below 128° a varus one. According to the presence of a normal, varus or valgus neck, they classified hips in three groups that were further subclassified according to the presence of a horizontally, craniomedially or craniolaterally inclined WBS. Furthermore, they introduced the concept of the spherical sector of the femoral head, which represents the area in contact between the femoral head and the acetabular WBS. The size of this area dictates the magnitude of load per surface unit applied on the femoral head

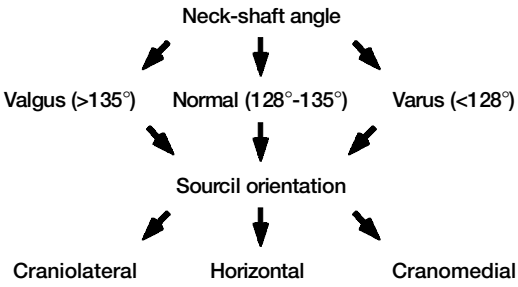

Figure 1. Bombelli's OA classification system according to the neck-shaft angle and sourcil orientation. The system requires the femoral head to be spherical.

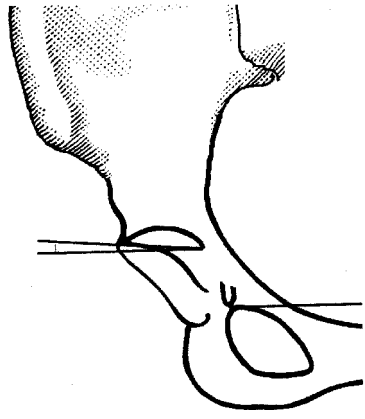

Figure 2. Measurement of sourcil inclination. This angle is formed by a line joining the two ends of the sourcil and a line parallel to the inter-teardrop line, which was used as a reference (Bombelli 1983, Bombelli et al. 1983). Craniolateral and craniomedial inclinations have positive and negative values, respectively, while horizontal was defined as 0.

and therefore, they suggested that a small spherical sector can predispose to the development of OA. Others agree that minor anatomic abnormalities of the hip may play a significant role in the development and the type of hip OA (Murray 1965, Cameron and Macnab 1975). In contrast, Solomon and co-workers (1982) described atrophic and hypertrophic subtypes of OA and postulated that these could represent the end result of distinctly separate nosologic entities.

This radiographical study was undertaken in an attempt to identify any associations between different anatomic indices of the hip joint, the location of OA within the acetabulum and the type of bone reaction.

Patients and methods

We evaluated the radiographs and notes of a consecutive series of 124 patients who were admitted to the Avon Orthopaedic Centre for total hip replacement between August 1996 and January 1997. Patients with rheumatoid or other inflammatory arthritides were not included in the study. Hips with "secondary" osteoarthrosis due to trauma, sepsis, developmental dysplasia, avascular necrosis, Paget's disease or metabolic disorders were also excluded. Of the remaining 106 patients labelled as suffering from "primary" OA, only 47 fulfilled the following inclusion criteria: a) availability of an early AP radiograph of the pelvis and hips, prior to the onset of OA, to allow for reliable measurements of anatomic indices before degenerative changes distorted the anatomic landmarks and b) a good quality subsequent radiograph which permitted evaluation of the type, grade and location of osteoarthrosis. The pre-onset radiographs were identified by searching the notes and X-ray files of the patients. These radiographs had been taken for a variety of reasons. Pain in the hip studied was the reason in 22 of the 47 patients, referred pain due to sciatica in 7, pain in the contralateral hip in 13 and in 5 the indication had been trauma in the area of the hip without bony injury. None of the initial radiographs were diagnostic of hip OA, although, in some, minor joint space narrowing may have been present. There were 25 female and 22 male patients. Mean patient age was 73 (54–95) years (SD 8.3). 17 of the 47 patients had bilateral hip involvement giving a total of 64 study hips.

Measurements were made on the earliest available anteroposterior radiograph of the pelvis and hips, before the onset of OA changes. The radiographical - anatomical variables considered were (a) the orientation and (b) the degree of inclination of the acetabular sourcil (Figure 2), (c) the spherical sector of the femoral head (Figure 3), representing the area in contact with the acetabular weight bearing surface, (d) the acetabular depth-width (D/W) ratio (Figure 4), (e) the peak-edge distance (Figure 5) and (f) the femoral neck - shaft angle as the angle formed between the anatomical axis of the femoral shaft and the axis of the femoral neck. The D/W index and the peak-edge distance

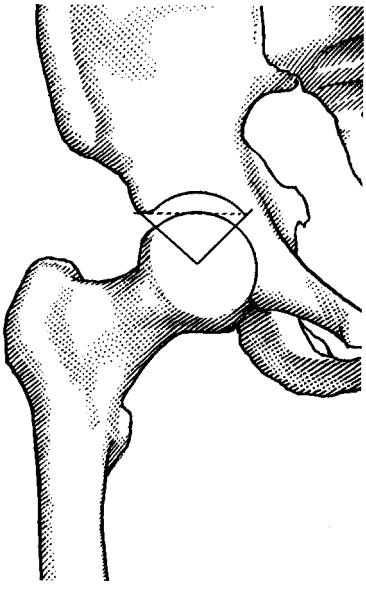

Figure 3. Measurement of the spherical sector of the femoral head. The centre of the femoral head was identified using concentric circles. Lines were drawn from the centre of the head to the two ends of the acetabular sourcil. The angle formed by those two lines (measured in degrees) represents the spherical sector of the femoral head (Bombelli 1983, Bombelli et al. 1983).

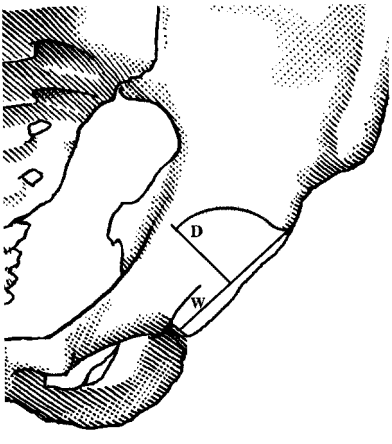

Figure 4. Measurement of depth/width (D/W) index. The width is measured between the superior and inferior edges of the acetabular rim and depth is represented by a line vertical to the previous one drawn from the superior edge of the acetabular fossa (Murphy et al. 1995).

are considered as indices of dysplasia by Murphy et al. (1995).

Subsequently, the most recent radiographs were evaluated with respect to the type, grade and location of osteoarthrosis. OA was classified as atrophic, hypertrophic or destructive (Solomon et al. 1982, Bitounis 1985). Atrophic OA, according to Solomon and co-workers, is characterised by widespread cartilage loss and little bone response, whereas hypertrophic OA shows localised cartilage loss and florid bone formation in the form of osteophytes. The term destructive OA applies to cases with rapid destruction of bone and cartilage from the femoral head and the acetabulum. The severity was graded using Kellgren and Lawrence's method (1957) (Table 1). Finally, the segment of the hip joint that was principally involved and the direction of migration of the femoral head were noted.

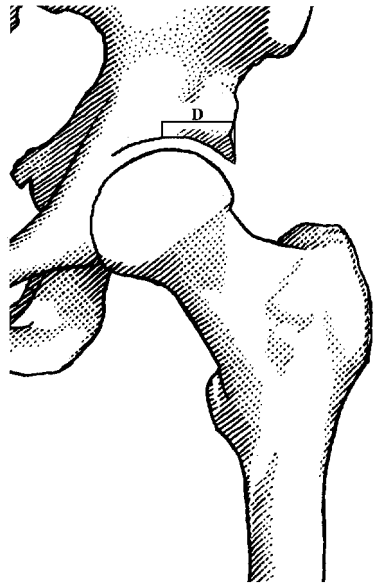

Figure 5. Measurement of peak-edge distance. This is the horizontal distance between the edge and the apex of the acetabular dome (Murphy et al. 1995).

From the available radiographs, the status of the ipsilateral knee was also assessed. 9 of the 47 patients had osteoarthrosis of the ipsilateral knee, but in none of those was the knee in more than 10° of varus or valgus. 5 patients had had a previous total knee replacement of the ipsilateral knee and all the replaced knees had a satisfactory alignment.

Statistics

Our aim was to identify prognostic factors from the radiographical anatomy of the hip for the location and type of primary OA. Some patients had bilateral OA and therefore contributed data on two hips.

Table 1. Kellgren and Lawrence classification of hip osteoarthrosis (1957)

Grade 1	Possible joint space narrowing medially and possible osteophytes around femoral head
Grade 2	Definite joint space narrowing inferiorly, definite osteophytes and slight sclerosis
Grade 3	Marked joint space narrowing, slight osteophytes, some sclerosis and cyst formation, and deformity of femoral head and acetabulum
Grade 4	Gross loss of joint space with sclerosis and cysts, marked deformity of the femoral head

Data provided on two hips from the same patient cannot be considered to be independent and therefore a fixed effects approach was not appropriate. Mixed models analyses using the general strategy for variable selection described by Collett (1993) were therefore used (assuming a compound symmetry covariance pattern for the residual matrix) to identify prognostic factors for the location and type of OA. Mixed models were fitted using the GLIMMIX macro in SAS (SAS Institute Inc., SAS Campus Drive, Cary, NC 27513, USA).

F-tests based on corrected Pearson's χ^2 statistics, applying the Rao and Scott second order correction, were calculated to test for associations between pairs of categorical variables, treating patient as a clustering factor (Rao and Scott 1981, 1984). These analyses were performed in Stata (Stata Corporation, 702 University Drive East, College Station, TX 77840, USA).

24 radiographs were randomly selected for inclusion in the assessment of inter-observer and intra-observer agreement. Two observers (ICV and IAK) independently assessed each of the 24 radiographs with respect to the anatomical indices studied. Observer ICV re-assessed the same 24 radiographs 1 year later to allow an assessment of intra-observer agreement. Both inter- and intra-observer agreement were assessed using limits of agreement plots (Bland and Altman 1986, Portney and Watkins 1993). All plots were generated using Stata (Stata Corporation, 702 University Drive East, College Station, TX 77840, USA).

Table 2. Summary of inter- and intra-observer agreement results. Mean difference with lower and upper 95% limits of agreement

Variable	N	Mean difference	95% limit lower	upper
Inter-observer				
Depth/width ratio	24	0.01	–0.05	0.07
Neck shaft angle	24	0.69	–5.62	6.99
Peak edge distance	22	0.30	–4.22	4.81
Spherical sector	24	–0.48	–11.5	10.6
WBS inclination angle	24	–1.00	–6.42	4.42
Intra-observer				
Depth/width ratio	22	–0.01	–0.04	0.02
Neck shaft angle	24	–0.17	–2.72	2.38
Peak edge distance	22	0.05	–1.46	1.55
Spherical sector	24	–0.58	–2.53	1.36
WBS inclination angle	24	0.15	–1.43	1.72

Results

Intra- and inter-observer agreement

Acceptable differences in measurement were defined a priori (±2 mm for distances, ±3° for angles and 0.05 for the DW index). For each of the five indices there was much better agreement between repeated assessments by the same observer than between different observers. There was acceptable intra-observer agreement for neck shaft angle, peak edge distance, spherical sector, DW index and WBS angle. However, there was an unacceptable level of agreement for the inter-observer agreement for these indices (Table 2).

Sourcil inclination (prior to OA onset)

49 of the 64 hips had a sourcil with craniolateral (CL) inclination. The degree of CL inclination ranged from 2° to 24° with a median of 10° (lower quartile (q1) = 7°, upper quartile (q3) = 12°). In 12 hips the sourcil was inclined craniomedially (CM). The degree of CM inclination ranged from –20° to –3.5° with a median of –5.5° (q1 = –9°, q3 = –4.5°). Only 3 hips had a horizontal (HOR) sourcil. Of the 22 men studied, 19 had craniolateral WBS and 3 craniomedial WBS. Of the 25 women studied, 17 had only craniolateral WBS, 4 had only craniomedial WBS and 2 had only horizontal WBS. The remaining 2 women had bilateral OA where the orientation of the sourcil differed between the two hips. In the other 15 patients with bilateral OA,

Table 3. Patients with asymmetric WBS orientation, OA location or OA type

Pt	Sourcil inclination (°)		OA location		OA type	
	Right	Left	Right	Left	Right	Left
1	HO (0)	CM (4)	M	M	A	H
2	CM (8)	CL (5)	M	L	N	D
3	CL (8)	CL (15)	L	M	N	N
4	CL (10)	CL (9)	L	L	H	D
5	CL (10)	CL (13)	L	M	N	A
6	CL (9)	CL (9)	L	L	H	N
7	CL (14)	CL (7)	L	M	N	N

HO Horizontal, CM Craniomedial, CL Craniolateral,
M Medial, L Lateral,
A Atrophic, N Normotrophic, H Hypertrophic, D Destructive

Table 4. OA type in relation to OA location

	Lateral (n 44)	Medial (n 18)	Global (n 2)	Total
Atrophic	7	6	0	13
Normotrophic	25	5	1	31
Hypertrophic	7	5	1	13
Destructive	5	2	0	7

the orientation of the sourcil was the same in both hips (Table 3).

OA location

Three patterns of OA were recognised: lateral, medial and global. 44 hips developed lateral OA, 18 medial OA and 2 global OA. 43 of 49 hips with a CL sourcil developed lateral OA and 11 of 12 hips with CM sourcil medial OA. 4 of the 17 patients with bilateral involvement, developed asymmetrically located OA-lateral on one side and medial on the other (Table 3).

OA type

In almost half of the hips (31/64), the coexistence of atrophic and hypertrophic features resulted in their classification as indeterminate or "normotrophic". In these hips, a definite reparative bone reaction (osteophytes of small or moderate size, ⁄ 5 mm) could be identified but not to a degree that would justify their characterisation as hypertrophic. Atrophic osteoarthrosis developed in 13 hips, while hypertrophic changes were noted in 13. The remaining 7 hips exhibited a rapid course of severe destruction and were classified as destructive OA. The type of OA in relation to its location is shown in Table 4. There was no evidence to suggest an association between OA type (atrophic/destructive vs. normotrophic/hypertrophic) and location (lateral vs. medial) ($p = 0.25$, 62 hips, 45 patients).

5 of the 17 patients with bilateral involvement developed different types of OA in each hip (Table 3).

Anatomic indices, OA location, OA type and OA grade (Table 5)

Location was categorised as lateral (44 hips), medial (18) or global (2). There were insufficient global hips to identify prognostic variables for this location. As it was not appropriate to group global hips with lateral or medial hips, these hips were excluded from the analysis to identify prognostic factors for the location of OA.

Due to the small number of study hips available it was only possible to consider three potential prognostic factors for location: WBS angle, spherical sector and neck shaft angle. These were selected because they are the ones considered in Bombelli's theory as determinants of OA location. WBS angle was the only variable found to be significantly associated with OA location ($p = 0.01$). Figure 6 illustrates the relationship between the ln(odds) of developing medial OA and the WBS angle. The

Table 5. Summary of data by OA location

Variable	N	Mean	SD	Median	Q1	Q3
Lateral OA						
Depth/width ratio	44			0.46	0.41	0.49
Neck shaft angle	44			129	126	134
Peak edge distance	42			18.3	16.5	21
Spherical sector	44	75	11			
WBS inclination angle	44	9.6	4.8			
Medial OA						
Depth/width ratio	18			0.50	0.44	0.54
Neck shaft angle	18			125	124	132
Peak edge distance	17			18	16	22
Spherical sector	18	73	16			
WBS inclination angle	18	–2.6	8.6			

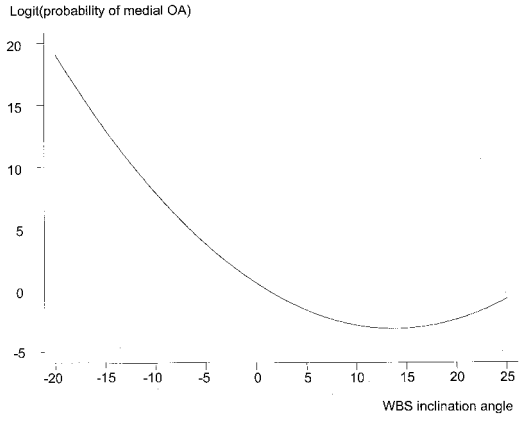

Figure 6. Modelling hip OA. Relationship between logit(p) and WBS angle where p = probability of medial OA.

figure shows that the ln(odds) of medial OA are highest for negative WBS (CM) and increase with increasing negativity. The more negative the WBS angle, the more likely the patient is to have medial rather than lateral OA. For the values of WBS angle observed (< 25°), patients with positive WBS angles (CL) are more likely to have lateral OA. See Table 6 for the parameter estimates of this model.

OA type was categorised as atrophic (13), hypertrophic (13), normotrophic (31) or destructive (7). There were insufficient hips to identify prognostic factors for a four-category classification of OA type. OA type was therefore dichotomised (atrophic/destructive (20) vs. normotrophic / hypertrophic (44)), since atrophic and destructive both show absence of bone formation in contrast to normotrophic and hypertrophic that exhibit varying degrees of reactive bone formation. Three potential prognostic factors for OA type were considered: WBS angle, spherical sector and neck shaft angle. None of these variables were found to be significant predictors of OA type (p = 0.9, p = 0.1, p = 0.8, respectively for univariate models). Finally, there was no evidence to suggest an association between OA type (atrophic/destructive vs. normotrophic / hypertrophic) and grade (1 and 2 vs. 3 and 4) (p = 0.3, n 64 hips, 47 patients).

Discussion

We attempted to provide information about local predisposing factors and their association with the location of the arthrotic changes within the acetabulum as well as the type of bone reaction. We recognise the difficulty encountered in objectively quantifying these changes as a limitation of our study.

Table 6. Parameter estimates for OA location model

Effect	Estimate	Standard error
Intercept	0.59	0.76
WBS inclination angle	–0.54	0.18
(WBS inclination angle)^2	0.02	0.01
Outcome = medial OA		

The most interesting finding was that the anatomy of the hip joint seems to influence the location of the developing arthrotic changes. We found the orientation of the acetabular sourcil to be a significant predictor of OA location. Craniolateral sourcils were more likely to develop lateral rather than medial OA (Figure 7) and craniomedial sourcils were more likely to develop medial OA (Figure 8). These findings are in agreement with Bombelli's theory.

An association of a varus neck with medial OA has been also suggested by Bombelli and reported by others (Cameron and Macnab 1975, Hayward et al. 1988). In a univariate model for OA location, neck shaft angle was significant at the 10% level, however, it was not a significant predictor of OA location in the presence of the WBS angle. A larger study would be needed to examine this relationship in further detail.

Murphy et al. (1995) suggested that a low D/W index is an index of hip dysplasia. These authors found that normal hips have a D/W index of 0.48 while the values for dysplastic hips were significantly lower (0.31). In our study, hips with medial OA had a higher median D/W index than those with lateral OA, but our small numbers restricted the number of prognostic factors for location that could be investigated.

Although hips with a positive WBS angle (CL) were more likely to have lateral rather than medial OA, not all CL hips developed lateral OA. 48 hips with a CL sourcil were included in the analysis, 5 of which developed medial OA. A varus neck has been reported as a potential cause (Cameron and Macnab 1975, Hayward et al. 1988) and could be

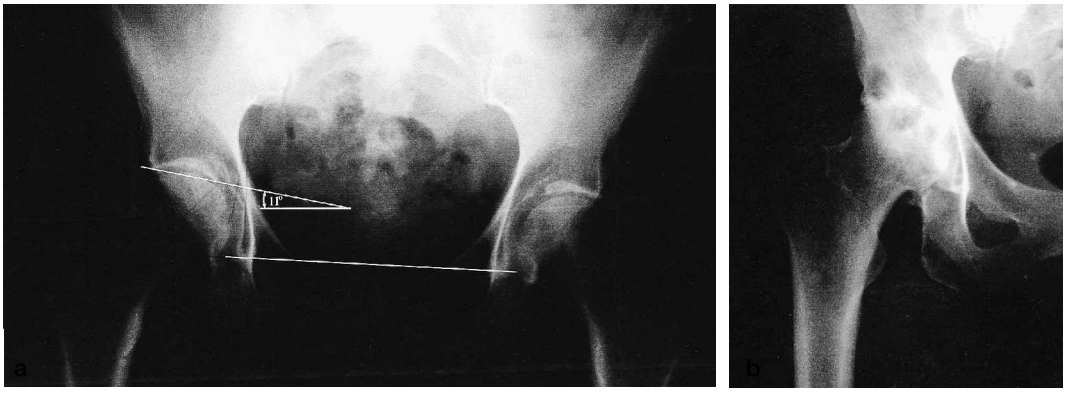

Figure 7. Right hip with craniolateral sourcil (a) developing lateral OA (b).

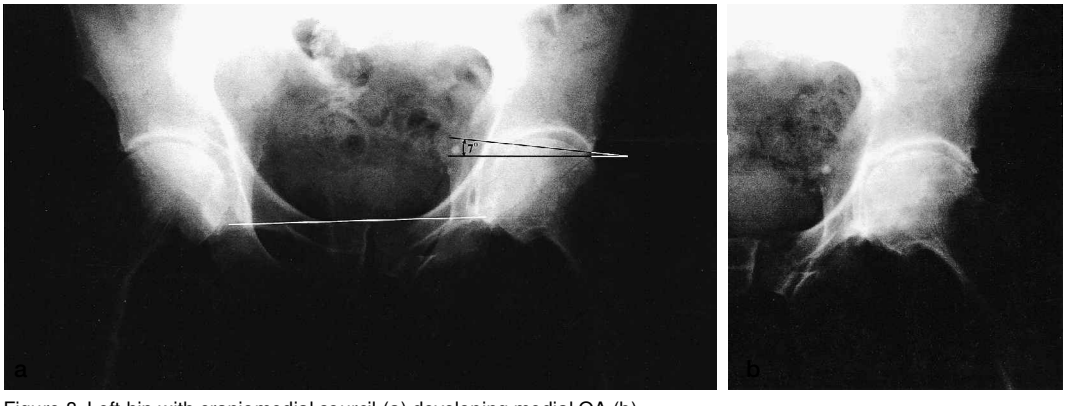

Figure 8. Left hip with craniomedial sourcil (a) developing medial OA (b).

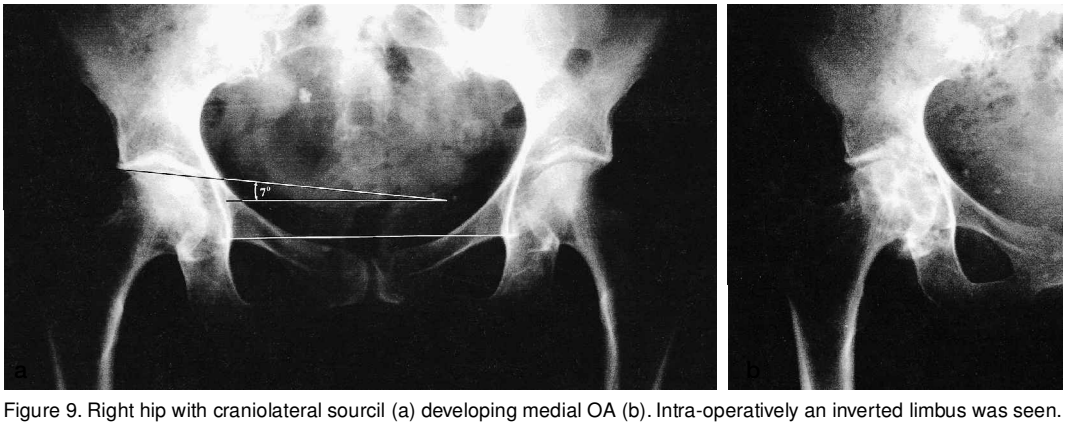

Figure 9. Right hip with craniolateral sourcil (a) developing medial OA (b). Intra-operatively an inverted limbus was seen.

implicated in 3 of these cases (124°, 124°, 126°, respectively). We found no obvious explanation for the other 2, which could be ascribed to the presence of a tight capsule (Cameron and Macnab 1975) or an inverted limbus. The latter was an intraoperative finding in one patient (Figure 9). None of the 11 hips with a CM sourcil developed lateral OA.

In 3 patients, despite the symmetrical sourcil orientation of the 2 hips, the location of OA was asymmetrical. Such cases have been previously reported in the literature (Resnick 1975).

The sourcil orientation was asymmetrical in 2 patients. It is tempting to ascribe this to secondary adaptive changes, but the measurements were per-

formed on radiographs showing no evidence of osteoarthrosis. However, even where the orientation of the sourcil was symmetrical in both hips, the degree of inclination often differed. It is well known that some degree of asymmetry exists between the left and the right side of the body, and this seems to extend to the hips as well.

Some asymmetry was also observed with respect to the type of OA in 5 patients as shown in Table 3. In the 2 cases who had a difference of only one category between the 2 hips this could reflect both the lack of objective criteria for this classification and differences in the quality of radiographs.

There were too few hips with global involvement to include them in any of the analyses. These perhaps represent an, as yet, unclassified inflammatory arthropathy.

The same difficulties reported by others (Ledingham et al. 1992) in classifying OA as atrophic and hypertrophic were encountered in our study. Almost half of the hips showed mixed radiographical patterns with mild or moderate osteophytosis. This was labelled "normotrophic" OA. It has been suggested that the two types of OA—atrophic and hypertrophic—might represent different diseases (Solomon et al. 1982, Bitounis 1985), or different responses to the same disease (Solomon et al. 1982). A histological study revealed that the rate of bone repair is increased in hypertrophic OA, although this was not quantified (Bitounis 1985). In the same study, the hips with atrophic OA showed some heterogeneity with 60% having decreased and 40% increased bone formation. Bombelli, alternatively, suggested that local mechanical factors influence the type of bone response (Bombelli 1983, Bombelli et al. 1983). He speculated that, for example, the "roof" osteophyte represented an attempt to improve the orientation of the WBS while the "capital drop" aimed at increasing the congruence of the hip. We failed to identify any association between the type of bone reaction and the location of OA. Considering destructive OA, there were not enough cases to allow any analysis. In addition, this type of arthritis has been linked with extensive bone necrosis in histology specimens (Bitounis 1985, Hasegawa et al. 1997), may be related to osteoporosis, and should probably be considered separately.

Although much larger studies are needed to explore the role of hip anatomy in the development of OA, we believe that at least the orientation of the sourcil is a prognostic factor for the location of the arthrotic changes. Regarding the type of bone reaction, however, no obvious conclusions are yet possible. A reasonable assumption might be that while the term "normotrophic" describes the equilibrium between bone destruction and regeneration in many osteoarthrotic hips, atrophic and hypertrophic types represent the states of reduced or exaggerated bone reaction, governed by local or idiosyncratic factors. The answers may lie with the future characterisation of the aetiology of what we currently refer to as "primary" hip osteoarthrosis.

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