WEAR CHARACTERISTICS OF THE CANINE ACETABULUM AGAINST DIFFERENT FEMORAL PROSTHESES

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We studied cartilage degeneration in 45 canine acetabula after implantation of prostheses with articulating surfaces of low-temperature isotropic (LTI) pyrolytic carbon, cobalt-chromium-molybdenum alloy and titanium alloy for periods ranging from two weeks to 18 months. Gross specimens and histological sections were compared with the nonoperated (control) acetabulum of the same animal.

Cartilage articulating with LTI pyrolytic carbon exhibited significantly lower levels of gross wear, fibrillation, eburnation, glycosaminoglycan loss, and subchondral bone change than with metallic surfaces. Survivorship analysis showed a 92% probability of survival for cartilage articulating with LTI pyrolytic carbon at 18 months, as compared to only a 20% probability of survival for cartilage articulating with either of the metallic alloys.

Erosion of acetabular articular cartilage with associated pain is a significant late complication of hemiarthroplasty. Many factors have been implicated, including incongruity between head and acetabulum, the use of cement, excessive neck length, impaction at the time of injury, a physiologically young and active patient, and abnormal shear forces between the device and the cartilage (Anderson, Hamsa and Waring 1964; Hinchey and Day 1964; Bateman 1974; Giliberty 1974, 1983; Salvati et al 1974; Carnesale and Anderson 1975; D'Arcy and Devas 1976; Beckenbaugh, Tressler and Johnson 1977; Gingras, Clarke and Evarts 1980; Radin 1980; Sisk 1980; Devas and Hinves 1983; Leyshon and Matthews 1984). There is still some controversy regarding the fixation of a hemiarthroplasty. The advantages of cement are reported to be an increased area for force distribution and a decreased period of immobilisation, while the advantages of cementless or interference fit fixation include less impaction forces on the cartilage, easier treatment of infection, elimination of complications due to cement and greater preservation of bone stock (Follacci and Charnley 1969; Wrighton and

Woodyard 1971; Mears and Cruess 1973; D'Arcy and Devas 1976; Beckenbaugh et al. 1977; Welch et al. 1977; Montgomery and Lawson 1978; Gingras et al. 1980; Sonne-Holm, Walter and Jensen 1982).

The principal goal of the design of the bipolar prosthesis was to reduce the shear and impact stresses on the cartilage by allowing two separate articulations (Bateman 1974; Giliberty 1974, 1983; Langan 1979; Bhuller 1982; Devas and Hinves 1983); another advantage is the ease of conversion to a total hip if significant complications arise. No clear long-term advantages have been found either clinically or histologically, and there is controversy about the use of bipolar prostheses for the treatment of fresh fractures (Hinchey and Day 1964; Johnston et al. 1982; DeLee 1984).

When reduction and fixation of a femoral neck fracture fails, it may be advisable to replace the femoral head with a prosthesis fabricated from a material having similar elastic properties. Although much has been written about high modulus femoral stems and bone stresses and remodelling, little is known about the effects of implant stiffness or surface composition on cartilage degeneration (Oh and Harris 1978; Lewis et al. 1984; Engh, Bobyn and Glassman 1987). Low-temperature isotropic (LTI) pyrolytic carbon is a material which has been used extensively in cardiovascular work because of its excellent biocompatibility and mechanical strength (Haubold, Shim and Bokros 1981). It has an elastic modulus of approximately 21 to 26 GPa which is in the range of that reported for cortical bone (Park 1979; Thomas et al. 1985).

The objective of our study in the dog was to compare

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Fig. 1

Canine femoral prostheses used in this investigation: on the left an implant with a Ti-6Al-4V articulating surface on a CP titanium porous-coated stabilising stem and undercap region; on the right an LTI pyrolytic carbon implant with a polished articulating surface and the "as-deposited" stem and undercap. The third implant we used had a Co-Cr-Mo articulating surface on a CP titanium porous-coated Ti-6Al-4V stem.

the acetabular cartilage degeneration produced by femoral prostheses made of LTI pyrolytic carbon with that produced by the commonly used cobalt-chromium-molybdenum (Co-Cr-Mo) and titanium (Ti-6Al-4V) alloys.

MATERIALS

The prostheses had hemispherical heads with straight stabilising stems, and three types of implant with femoral heads of different materials were used. The *first implant* consisted of a Ti-6Al-4V alloy substrate with a sintered 0.5 mm thick porous coating of commercially pure (CP) titanium applied along the stabilising stem and under the cap; the articulating surface was highly polished Ti-6Al-4V alloy (Fig. 1). The porous coating had an extremely irregular morphology with a mean pore size of approximately 250 μm and a pore volume of approximately 55% (Anderson et al. 1984; Cook et al. 1985). The *second implant* also had a Ti-6Al-4V alloy stem with porous coating, but had a Co-Cr-Mo alloy articulating surface. These two devices were considered "high modulus" systems, since the elastic modulus was approximately 110 GPa for the Ti-6Al-4V alloy and 250 GPa for the Co-Cr-Mo alloy (Park 1979).

The *third implant* was fabricated by the deposition of a 0.5 mm thick LTI pyrolytic carbon layer onto an appropriately shaped graphite substrate. The deposition process results in a highly biocompatible material having a slightly roughened (microporous) surface. The "as-deposited" material has a surface porosity of approximately 5 to 10 μm with no interconnecting porosity, and the material may be finished to a highly polished surface. The stem and undercap regions of the LTI

Fig. 2

Postoperative radiograph showing a Ti-6Al-4V implant in neutral position with excellent congruence with the acetabulum.

Table I. Number of implants investigated at various intervals

Implantation period (months)	LTI pyrolytic carbon	Cp-Cr-Mo alloy	Ti-6Al-4V alloy
0.5	1	0	1
1	3	0	2
2	5	1	3
3	0	1	0
4.5	4	1	2
9	3	2	2
12	3	2	4
18	3	0	2
Total	22	7	16

Table II. Criteria for grading results, all as compared to the contralateral control acetabulum

Gross appearance of the acetabulum

- 0 No difference from control
- 2 Minimal wear, no surface irregularities, slight colour change
- 5 Obvious cartilage thinning, limited regions of fibrillation, obvious colour changes
- 7 Areas of eburnation, severe fibrillation, and obvious colour change
- 10 Complete eburnation

Histological microradiographic sections

- A Eburnation (per cent of surface)

- B Bony changes
 - 0 None to mild
 - 1 Moderate
 - 2 Severe

Microtome sections

- A Fibrillation
 - 0 None to mild
 - 1 Moderate
 - 2 Severe
- B Loculation
 - 0 None to mild
 - 1 Moderate
 - 2 Severe
- C GAG stain uptake
 - 0 No difference to mildly decreased uptake
 - 1 Moderately decreased uptake
 - 2 Severely decreased uptake

carbon devices had the as-deposited surface, while the articulating surface was highly polished. Additional details and further descriptions of the manufacture of the LTI pyrolytic carbon can be found in the literature (Bokros 1969, 1977; Bokros, LaGrange and Schoen 1972; Haubold 1977).

The implant design, similar to that of Judet and Judet (1950), was chosen to accommodate the mechanical properties of LTI carbon, which is relatively weak in bending (Park 1979). An LTI carbon prosthetic head on a metallic stem could provide a clinically more acceptable design (Cook et al. 1985). The articulating surfaces of all the devices, regardless of material, were polished to a surface finish to approximately 3 to 5 micro-inches, as evaluated by surface profilometry. Three sizes of head were available, 19 mm, 20.5 mm and 22 mm in diameter.

METHODS

The implants were placed unilaterally in skeletally mature dogs, after radiographic screening had ensured normal bone morphology and hip structure, and that the animals had the appropriate acetabular size for the implants. Aseptic surgical techniques were used with either a direct lateral approach (nine animals) with

osteotomy of the greater trochanter, or a medial (ventral) approach (36 animals) similar to that described by Hohn (Piermattei and Greeley 1979). The medial approach was used in most cases because the abductor muscles remain intact and no trochanteric osteotomy is required. Specially designed instrumentation was used to insure a precise fit. All implants were placed in a neutral or slightly valgus position, and the nonoperated side served as a control.

Radiographs were taken to check femoral head congruency, so as to exclude undue contact stresses (Fig. 2). The implanted side was compared with the control side for surgical fit by measuring the diameter of the bony labrum of both acetabula on a standard anteroposterior radiograph, and determining the maximum diameters of both femoral heads. Congruency ratios were calculated from the ratio of the diameter of the operated acetabulum to the diameters of the normal control head, the experimentally excised head, and the diameter of the device. In most animals, devices with a 20.5 mm diameter articulating surface were used.

Prophylactic antibiotics were given for four days postoperatively and animals were permitted immediate, unrestricted weight-bearing, for the first four to five days in a cage, and then in a standard dog-run for unlimited periods. Radiographic evaluation and gait analysis using force plates were performed monthly. Table I gives the implant and time period for each of the 45 dogs.

After killing the animal both acetabula were removed en bloc and immediately fixed by immersion in 10% formalin solution. After fixation, colour macrophotographs were made for later grading as described below. The specimens were then embedded in methylmethacrylate (Jowsey et al. 1965; Klawitter and Hulbert 1971) and undecalcified histological sections were cut from the principal load-bearing region of each acetabulum, ground to 100 µm and microradiographed, then further ground to 50 µm and stained with basic fuchsin and toluidine blue (Cook et al. 1988). From the same embedded blocks undecalcified 5 µm microtome sections were also prepared for histochemical analysis of cell and matrix viability. The stains used for this assessment were PAS/alcan blue, safranin O/fast green, and toluidine blue (Mankin and Lippiello 1970; Rosenberg 1971; McLeod 1980).

The colour macrophotographs of the acetabula were graded according to the criteria shown in Table II. The 50 µm ground sections and corresponding microradiographs were used to evaluate morphological changes such as eburnation (Table II). The 5 µm microtome sections were graded for fibrillation, chondrocyte loculation, and glycosaminoglycan (GAG) content based on comparison with the control acetabulum (Table II). All ground sections, microtome sections and gross macrophotographs were graded independently by three observers who were not appraised of the implant type or length of implantation.

Table III. Gross appearance and histological evaluation

	T-6Al-4V (n = 16)	Co-Cr-Mo implants (n = 7)	LTI Carbon implants (n = 22)	All implants (n = 45)
Gross appearance (Scale: 0-10)				
Mean	5.84	6.43	3.82	4.94
Median	5.75	6.5	4.0	5.0
Maximum	9.0	8.0	6.0	9.0
Minimum	1.0	5.0	1.0	1.0
Fibrillation (Scale: 0,1,2)				
Mean	1.47	1.21	0.66	1.03
Median	2.0	1.0	1.0	1.0
Maximum	2.0	2.0	2.0	2.0
Minimum	0.0	0.0	0.0	0.0
Eburnation (per cent of surface)				
Mean	8.75	29.29	0.68	8.0
Median	0.0	10.0	0.0	0.0
Maximum	7.5	95.0	15.0	95.0
Minimum	0.0	0.0	0.0	0.0
Loculation (Scale: 0,1,2)				
Mean	1.03	1.07	0.98	1.01
Median	1.0	1.0	1.0	1.0
Maximum	2.0	2.0	2.0	2.0
Minimum	0.0	0.5	0.0	0.0
Bony changes (Scale: 0,1,2)				
Mean	0.84	1.0	0.34	0.62
Median	1.0	0.5	0.25	0.5
Maximum	2.0	2.0	1.5	2.0
Minimum	0.0	0.5	0.0	0.0
GAG stain uptake (Scale: 0,1,2)				
Mean	1.16	0.93	0.70	0.90
Median	1.0	1.0	0.5	1.0
Maximum	2.0	2.0	1.5	2.0
Minimum	0.0	0.0	0.0	0.0

The data from grading the gross specimen macrophotographs and histological sections were grouped by implant type and analysed using Kruskal-Wallis nonparametric analysis of variance, and specific paired differences were determined post hoc (Hollander and Wolfe 1973; Rosner 1982). To examine relationships between grades for gross appearance, for histological evaluation, and the period of implantation, Spearman rank correlation coefficients were calculated separately for each implant group and evaluated for statistical significance (Rosner 1982; Dixon 1983).

Two methods were used to assess the effect of the period of implantation on cartilage viability, which was evaluated by assessment of eburation. Cartilage was considered to survive only if there was no eburation at all; in terms of survivorship analysis, eburation was considered as an end point. Product-limit (Kaplan-Meier) survival function was estimated for each of the implant groups and differences evaluated for significance (Kaplan and Meier 1958).

The second approach also used the eburation gradings, but a different method was used to estimate survival. Eburation is not strictly survivorship data, since the exact time of the response of eburation is not known, and specimens which showed eburation may have suffered this at an earlier time. Further, specimens which exhibited no eburation on examination may have suffered this later. To address this concern, the proportions of devices surviving at a particular time were calculated as follows:

$$P = \frac{(\text{number surviving at time} > t)}{(\text{number surviving at time} > t) + (\text{number not surviving at time} < t)},$$

where P is the proportion of acetabula with surviving cartilage at time t. The numerator is the number of acetabula with viable cartilage at time periods longer than or equal to the time of interest; cartilage which

survived for a time period of longer than the time of interest necessarily had to have survived at shorter time periods. The denominator differs from standard survivorship analysis to account for the cartilage which has failed at periods less than the period of interest. Proportions of cartilage survival were computed for the LTI carbon devices and for the two types of metallic device together; any differences in these proportions were evaluated for significance by Fisher's exact test (Snedecor and Cochran 1980). The data were analysed by BMDP statistical programs (Dixon 1983) and for all statistical tests significance was defined as $p < 0.05$ (one-tail values).

RESULTS

Force-plate gait analysis confirmed that loading of the operated hips was from 85% to 100% of that of the control side; no differences between the implant groups or due to the surgical approach were found. No infections, dislocations or clinical complications occurred in any of the 45 animals. Congruency measurements indicated no significant differences in size between implant and control femoral heads.

Post-mortem radiographs demonstrated excellent bone maintenance under the cap and along the stem of the LTI carbon devices. The metallic porous-coated implants showed hypertrophy distal to the stem tip and slight to moderate proximal remodelling. The porous titanium stem and undercap regions were well ingrown with new bone by four weeks, and sections at greater periods demonstrated consistent bone ingrowth and maintenance within the porous structure. Sections from the stem and undercap regions of the LTI carbon implants showed direct bone-implant apposition over approximately two-thirds of the interface with no evidence of a fibrous interpositional layer.

Fig. 3a

Fig. 3b

Macrophotographs of acetabular specimens comparing the gross appearance of cartilage degeneration after nine months implantation. Figure 3a LTI carbon implant (Grade 3.0). Figure 3b - Ti-6Al-4V implant (Grade 5.5). Magnification $\times 2.5$.

Fig. 4a

Fig. 4b

Macrophotographs of acetabular specimens comparing the gross appearance of cartilage degeneration after 18 months implantation. Figure 4a - LTI carbon implant (Grade 5.0), Figure 4b - Ti-6Al-4V implant (Grade 9.0). Magnification $\times 2.5$.

Fig. 5a

Fig. 5b

Microradiographs prepared from histological ground sections showing increased bone density in an acetabulum which had articulated for two months with a Ti-6Al-4V implant. Figure 5a - Control side. Figure 5b - Operated side. Magnification $\times 10$.

All prosthetic hips were enveloped by a thickened fibrous capsule containing normal colourless synovial fluid. There were reddish-brown central acetabular areas in animals with Ti-6Al-4V and Co-Cr-Mo alloy devices. These areas, suggestive of wear, were much less extensive in animals with the LTI carbon devices, and in none of these animals did the gross appearance of the cartilage show more than moderate changes. The gross appearance of all the operated acetabula exhibited progressive degeneration with time but more severe changes were noted for the metallic surfaces (Figs 3 and 4). Bony changes in the acetabula were also much more pronounced for the metallic devices, appearing as early as two months postoperatively (Fig. 5).

Representative examples of the sections used to

assess cartilage degeneration are shown in Figures 6 and 7, and the results for gross rating, fibrillation, eburnation, loculation, bony changes and GAG stain uptake are shown in Table III. The average gross appearance grade as a function of time comparing the LTI carbon and metallic devices is shown in Figure 8. The average grade for fibrillation, loculation, bony changes and GAG stain uptake as a function of time is shown in Figure 9.

The data in Table III were analysed for differences between implant groups and significant differences were found for gross appearance, fibrillation, eburnation, and for bony changes (all $p < 0.0075$), as well as for GAG stain uptake ($p < 0.05$). Loculation scores did not differ significantly among the implant groups ($p = 0.95$). Post hoc pair-wise comparisons (Dunn's procedure) revealed

Fig. 6a

Fig. 6b

Histological sections showing severe fibrillation (Grade 2) in an acetabulum which had articulated for two months with a Ti-6Al-4V implant. Figure 6a - Control side. Figure 6b - Operated side. (Basic fuchsin and toluidine blue, polarised light, $\times 50$).

Fig. 7a

Fig. 7b

Histological sections showing chondrocyte loculation, cloning, and decreased GAG stain uptake in an acetabulum which had articulated for nine months with an LTI carbon implant. Figure 7a - Control side. Figure 7b - Operated side. Grades: loculation 2, GAG 0.5. (Toluidine blue, $\times 125$)

no significant differences between the Ti-6Al-4V and Co-Cr-Mo alloy devices for any parameter. Significant differences were found between the LTI pyrolytic carbon and the Co-Cr-Mo alloy devices for gross appearance, fibrillation, eburnation and bony changes; similarly there were differences between the LTI pyrolytic carbon and Ti-6Al-4V alloy devices for the bony changes and GAG stain uptake ratings (all $p < 0.05$). The LTI pyrolytic carbon implants had the lowest scores (mean or average rank sums) for each of the parameters evaluated, with the Co-Cr-Mo alloy devices having the highest scores for gross appearance, eburnation, loculation, and bony changes.

Spearman rank correlation coefficients for each implant group showed that for the Ti-6Al-4V alloy implants, there were significant relationships observed between gross appearance and time, loculation and fibrillation, GAG and time, GAG and gross appearance, GAG and eburnation, and between GAG and bony

changes. For the Co-Cr-Mo implants the only significant correlations were between bony changes and loculation, and between GAG and loculation grades. For the LTI pyrolytic carbon devices significant relationships were observed between gross appearance and time, loculation and time, loculation and gross appearance, loculation and fibrillation, bony changes and time, bony changes and gross appearance, bony changes and loculation, between GAG and gross appearance, and between GAG and fibrillation.

In analysis of cartilage survivorship both the methods described revealed a significantly greater survival of cartilage articulating with the LTI pyrolytic carbon devices. Using the product-limit estimates, the LTI carbon implants gave a probability of survival of 0.92 (92%) at 4.5 to 18 months, whereas the Ti-6Al-4V implants gave a probability of survival of only 0.75 (75%) at nine months, and 0.50 (50%) at 12 or 18 months. Similarly the Co-Cr-Mo implants gave a probability of

Fig. 8

Histogram comparing average scores for gross appearance as a function of implantation time for LTI carbon and metallic implants. No carbon implants were evaluated at three months.

Fig. 9a

Fig. 9b

Histograms comparing average histological grades as functions of implantation time. Figure 9a - LTI carbon implants. Figure 9b - Metallic implants. FIB, fibrillation; LOC, loculation; BONY, bony changes; GAG, glycosaminoglycan stain uptake.

survival of 0.41 (41%) at nine months, and of only 0.21 (21%) at 12 months. Kaplan-Meier survivorship analysis showed a significant difference between the survival of cartilage articulating with the LTI carbon implants and that with metallic implants ($p < 0.05$, Mantel-Cox test).

Using the second approach to evaluate survival, at nine months the proportion of cartilage surviving in

association with the LTI carbon was 6/7, and the proportion surviving with the metallic implants was 5/10; this difference was not significant. At 12 months the proportion surviving with LTI carbon was 6/7, and with the metallic implants 5/13; this difference was significant ($p < 0.025$). At 18 months, the proportion surviving with LTI carbon was 3/4, while that with the metallic implants was 2/10; this difference was also significant ($p < 0.05$).

DISCUSSION

This study was not undertaken to question the use of hemiarthroplasty, nor should the results be interpreted as indicting the use of such implants. It does appear that every attempt should be made to preserve the natural femoral head, but where a prosthesis is indicated, a better choice for the articulating surface would seem to be a material such as LTI pyrolytic carbon. Although the exact mechanism remains unclear, cartilage articulating with LTI carbon has a potential for longer term survival than that with Co-Cr-Mo or Ti-6Al-4V alloys.

Both metallic and carbon implants showed histological evidence of bony fixation of the stabilising stem and undercap region. Extensive bone ingrowth was observed with the metallic devices, and consequently a larger degree of implant loading might be transferred to the acetabulum as compared to that with carbon implants where fixation was limited to direct bone apposition. However evaluation of the stiffness of the implant-tissue interface where bone has grown into a porous metal surface by treating it as a two-phase composite material yields a result very similar to that for a bone apposition interface (Moyle, Klawitter and Hulbert 1973). The implant-tissue interface shear stiffness for porous titanium implants has been found to be slightly greater than that of LTI carbon when similar testing procedures were used (Thomas and Cook 1985, unpublished data; Thomas, Cook and Haddad 1988, submitted Clin Materials). The differing interface mechanics may have contributed to the increased wear and degeneration of cartilage articulating with the metallic implants. Increased articular cartilage wear has been reported when comparing cemented prostheses to press-fit devices, although others have not observed this effect (Follacci and Charnley 1969; Wrighton and Woodyard 1971; Beckenbaugh et al. 1977; Cabanela and VanDemark 1984).

The effects of the reduced material elastic modulus of LTI carbon as against the metallic implants has been examined using a contact stress model (Shigley and Mitchell 1983). The maximum pressures between the natural acetabulum and the articulating surface of the implant were estimated as a function of elastic modulus. Assuming the same degree of congruity for all implant types, the maximum pressure for an LTI carbon device would be approximately 24% lower than for a Ti-6Al-4V

alloy device, and approximately 27% lower than for a Co-Cr-Mo device (Cook, Thomas and Kester 1987, unpublished data). The lower stiffness of the LTI carbon-tissue interface may enhance the cushioning effect of the modulus difference and further lower the contact pressures. The effect of modulus in lowering contact pressures may also explain the significant differences in bony remodelling observed when comparing the metallic and LTI carbon devices (Fig. 9). Although acetabular bony changes were manifested as early as one month postoperatively with the metallic implants, these changes were most dramatic when eburation had also occurred.

Both the LTI pyrolytic carbon and the metallic implants produced early changes in the GAG content of the matrix (Fig. 9). Weiss (1982) has described this phenomenon as part of the cartilage degeneration cycle. With the loss of matrix GAG, the cartilage loses resiliency, which in turn leads to subchondral bone damage and remodelling. The subchondral bone stiffens, producing even higher stresses, which result in further cartilage damage. As anticipated, the loss of glycosaminoglycan was associated with bony changes (Fig. 9). Neither the GAG loss nor the bony changes showed a strong correlation with time, suggesting that an equilibrium was eventually established between the processes of cartilage degeneration and repair for all implant types. Another possible explanation is the variability of the disease process (Mankin and Lippiello 1970; Mankin et al. 1971). The cartilage associated with the metallic implants, however, had GAG loss and bony changes which were consistently greater after each time period than the grades recorded for the cartilage articulating with LTI carbon implants.

No evidence of fibrillation was observed in 12 of the 45 specimens (26.7%); three of these specimens articulated with metallic implants, while nine articulated with LTI carbon implants. Fibrillation appeared as early as two weeks postoperatively and failed to exhibit a correlation with time; it appears that initially fibrillation occurs quickly and is subsequently slowed by reparative processes in the matrix. There was also no apparent relationship between gross rating and fibrillation or between eburation and fibrillation, indicating that the gross appearance of articular cartilage may not be a good indicator of fibrillation. The LTI carbon implants elicited significantly less fibrillation than did the metallic implants; since there were no differences in congruence and since all implants were polished to an identical finish, it appears likely that the improved performance of the LTI carbon devices resulted from the greater biocompatibility and reduced elastic modulus of the material. Another possible explanation is that the low surface energy and nonadhesive nature of the LTI carbon surface, which allow its use in cardiovascular applications, may have also played some role in reducing cartilage degeneration (Haubold et al. 1981).

The probability of cartilage survival, as evaluated by eburation, was one of the primary differences between the metallic and carbon implants. Kaplan-Meier survivorship analysis revealed a 92% probability that cartilage articulating with LTI carbon would survive up to 18 months (the longest time period investigated), as compared to only a 20% probability for cartilage articulating with a metallic implant; this difference was statistically significant. We also found that significantly greater proportions of acetabula articulating with the carbon survived at 12 and 18 months, and this difference could be a further manifestation of the combination of lower material modulus, surface chemistry and surface energy characteristics of LTI carbon.

Cruess et al. (1984) reported on the response of articular cartilage to a Co-Cr-Mo alloy prostheses in a canine model. Using the histologic grading scheme of Mankin et al. (1971), they reported little articular cartilage remaining after 24 weeks, with two animals having no evidence of any cartilage remaining, and five animals having a grade of 14 (the worst possible on Mankin's scale). Their study of 26 dogs used a traditional femoral device (with a collar), employed a different surgical technique than ours, and all devices were cemented in place. Although Cruess et al. reported a much higher rate of severe cartilage degeneration than we saw in our study, with no hip showing normal cartilage after six months, they also reported a failure of the animal's functional ability (normal gait and jumping) to reflect the ongoing cartilage degeneration. In addition, Cruess et al. reported that in preliminary studies, they found no correlation between too large or too small a prosthetic head and cartilage degeneration. In our study congruency between the prosthetic head and the natural acetabulum was a critically controlled factor. In spite of these differences, the similarity of the ultimate cartilage response to articulation with a metallic implant is noteworthy.

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