

THE CHARNLEY VERSUS THE CHRISTIANSEN TOTAL HIP ARTHROPLASTY

A Comparative Clinical Study

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Charnley total hip arthroplasties (THA) and Christiansen THA were carried out in two concurrent groups of patients, consisting of 113 hips in 87 patients and 90 hips in 81 patients respectively. The mean age of the patients was about 65 years, two thirds had idiopathic arthrosis, and only two had rheumatic hip disease. The two groups of patients were similar with regard to sex, age, weight, etiology of arthrosis, and standard laboratory tests, but different with regard to the surgeons who operated on them. Postoperative films showed that the stems of the prostheses were in the neutral and the varus position in the Christiansen group, and in the valgus, neutral and varus position in the Charnley group.

Neither group had any deaths, or deep infections in the postoperative period. Only minor postoperative complications were noted. At follow-up, 5-8 years later, the failure (revision) rate of Charnley THA to Christiansen THA was 1 to 7.7 and 1 Charnley cup was revised as against 19 Christiansen cups. The methodological weaknesses in the comparative clinical trial did not explain the inferior long-term results of the Christiansen THA.

Key words: arthroplasty; coxarthrosis; hip joint; polyacetal; polyethylene

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During the last decade THA has become routine in Norway; in 1980, 2435 primary operations were performed in the 4.1 million population (Raugstad et al. 1982). The Charnley total hip, or modifications thereof, and the Christiansen total hip have been the most common types of prostheses used.

The Charnley and the Christiansen total hip prostheses are quite different, but both are designed to minimize frictional torque. To reduce the torque Charnley chose a small 22 mm head, while Christiansen introduced a trunnion bearing between a larger 37 mm head and the stem. The Charnley cup is made of ultra high molecular weight (UHMW) high density polyethylene, while the Christiansen cup and the sleeve of the

trunnion bearing are made of polyacetal (Delrin®, Dupont).

In order to examine which design gives the best long-term results a comparative clinical trial was started by Dr. Brinchmann-Hansen and his staff at this hospital in 1974. The results of this investigation are presented here.

PATIENTS AND METHODS

From September 1974 through December 1976 (period of clinical trial) 181 consecutive patients, 48 men aged 53-80 years (mean 65 years) and 133 women aged 29-84 years (mean 67 years) had THA.

Every other patient had a Charnley prosthesis inserted (Charnley group, 90 patients) and the others had

Table 1. Distribution of surgeons between 203 total hip arthroplasties

Group (No. of patients)	Surgeon				Sum
	A	B	C	D	
Charnley (87)	12	87	14	0	113
Christiansen (81)	56	4	26	4	90
Sum	68	91	40	4	203

The figures in the Table refer to the number of hips. There was a significant difference between the groups ($P = 10^{-10}$).

a Christiansen prosthesis inserted (Christiansen group, 91 patients), except during vacations, when the surgeons on duty chose the type of prosthesis according to their own preferences. Ten patients in the Christiansen group and three in the Charnley group had had a previous intra-articular hip operation (including four hip arthrodeses in the Christiansen group which were converted to a Christiansen THA). We have thus excluded all hips which had had an *intra-articular* hip operation prior to the THA done in the years 1974–76 unless otherwise stated, so that the Charnley group consisted of 113 hips in 87 patients and the Christiansen group of 90 hips in 81 patients. There was no significant difference between the groups with regard to sex and age.

Three orthopaedic surgeons performed most of the operations. Two of these preferred one of the two prostheses on trial. Thus, surgeon A operated on 62 per cent of the patients in the Christiansen group, while surgeon B operated on 77 per cent of the patients in the Charnley group (Table 1). For comparison of results we have therefore also studied the hospital records of all the 10 Charnley hips operated by surgeon A prior to September 1974 and during 1977.

Etiology of arthrosis

The reason for a THA was idiopathic arthrosis in 68 per cent, congenital dysplasia of the hip or Legg-Calvé-Perthes' disease in 23 per cent, and fracture of the neck of the femur in 5 per cent of the patients; only two patients had rheumatoid arthritis. There was no significant difference in etiology between the two groups of patients.

Preoperative assessment

Standard laboratory tests including microscopy of urinary sediment were carried out for all the patients. Patients with anemia and/or frank urinary tract infection

were specifically treated before surgery. As regards body weight, sedimentation rate, and leukocyte count there was no significant difference between the groups.

Operative procedure

The total hip arthroplasties were done with the original instruments, implants and techniques described by their designers (Christiansen 1969, Goldie & Raner 1979, Christiansen 1974, Sundal et al. 1974, Charnley 1979). However, the special subcutaneous sutures anchored to pressure pads recommended by Charnley (1979) were not used. Subfascial suction drainage was always used. Usually ordinary Simplex surgical bone cement was used, but gentamicin-impregnated cement was used in nine patients in the Charnley group and in one patient in the Christiansen group. The operating theaters were equipped with vertical downflow of filtered air (Allander system); no body exhaust system (Charnley 1979) was used.

An attempt was made to insert all the stems in either a neutral or a valgus position relative to the femur. In the Christiansen group 20 prosthetic heads (22 per cent) had short necks, 28 heads (31 per cent) had medium necks and 42 heads (47 per cent) had long necks.

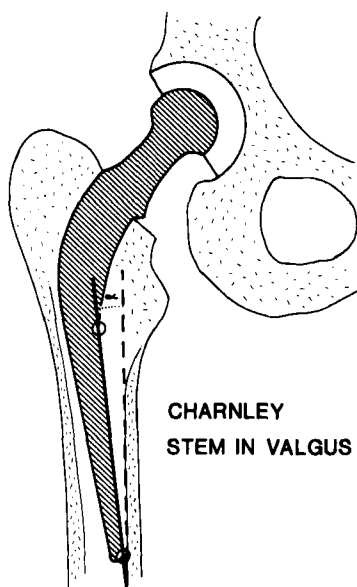
In bilateral THA the same make of prosthesis was usually inserted, but patients in the Christiansen group needing a contralateral total hip after October 1977 had a Charnley and not a Christiansen hip inserted.

From the day of operation 8 g cloxacillin and 8 g ampicillin (Ekvacillin® and Doctacillin®, Astra, Södertelje, Sweden) a day were given intravenously for 3–6 days as prophylaxis against infection; doxycycline (Vibramycin®, Pfizer) was used in those allergic to penicillin. High molecular weight dextran (Macrodex®, Pharmacia, Uppsala, Sweden) and warfarin sodium were used as prophylaxis against thromboembolism. To reduce postoperative inflammation most patients were given indomethacin postoperatively, usually for 3 days. All operations except two were done under general anesthesia.

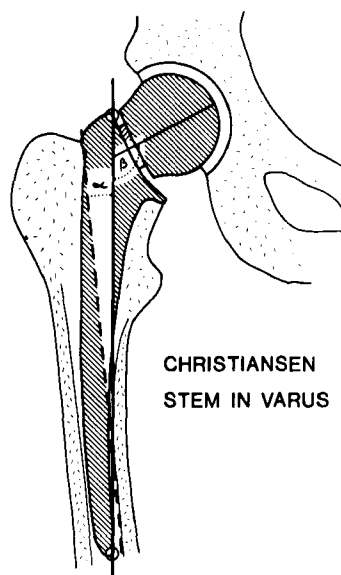
Revisional arthroplasties

In principle a loose prosthesis was replaced by the appropriate component of the same type. However, since no Christiansen prosthesis was used for a *primary* THA after October 1977, many patients in the Christiansen group had a Charnley prosthesis inserted in one or both hips later. Thus, at follow-up several Charnley (standard and revisional) prostheses were found in the Christiansen group. At follow-up patients with pain in the hip and a radiographically loose total hip were advised to have a revisional arthroplasty.

At revisional arthroplasty the joint cavity was aspirated for aerobic and anaerobic bacteriological cultures before the capsule was opened and further cultures were taken after opening it.



CHARNLEY
STEM IN VALGUS



CHRISTIANSEN
STEM IN VARUS

Figure 1

Figures 1–2. Schematic drawing of radiographs. Charnley stem in the valgus position (Figure 1); the valgus (and varus) angle (α) is the angle between the medial endosteal cortex of the diaphysis of the femur and the straight medial contour of the stem. Christiansen stem in the varus position (Figure 2); the varus (and valgus) angle is the angle between the medial endosteal cortex and a line drawn between the medial distal end and the proximal end of the stem proper. This line forms an angle (β) of about 117 degrees with the trunnion axis.

Figure 2

Postoperative regimen

The patients were usually allowed out of bed on the third postoperative day, and partial weightbearing was encouraged. Full weightbearing was not allowed until 3 months later, when the patients were being regularly seen in the outpatient clinic. Most patients were also seen after 1 year, but thereafter irregularly.

Follow-up

All patients were asked to attend the outpatient clinic between December 1981 and May 1982 except two, who lived in other parts of the country and were evaluated by local orthopaedic surgeons. Thus, the mean observation period was 6 years.

At follow-up an anteroposterior radiograph was taken of all the patients with the central X-ray centered over the symphysis pubis and both hips were included on the same film. Preoperative and postoperative films were available of all the patients for comparison.

In the radiographs, when the medial straight part of the Charnley stem, and correspondingly the longitudinal axis of the Christiansen stem, was parallel to the medial endosteal cortex of the diaphysis of the femur the stem was defined as being in a neutral position

with zero degrees of valgus/varus (Figures 1–2). The longitudinal axis of the Christiansen stem was defined as a line drawn from the medial distal end of the stem to the most proximal part of the stem proper. This line forms an angle with the trunnion axis of about 117 degrees (Figure 2). According to Christiansen (1969) the angle between the longitudinal (principal) axis of the stem (shaft) and the trunnion axis is 65 degrees, i.e. 115 degrees. Since we have not made any corrections for this slight difference the varus angles in the Christiansen group below were slightly overestimated.

Radiographically a loose implant was defined as having a radiolucent zone of ≥ 2 mm between the bone and most of the implant and/or a change in the position of the implant. Subsidence of a cup without any radiolucency was classified as loose, but subsidence of the stem was not.

In radiographs loss of thickness of the cup (creep/wear) was measured with an electric digital engineer's micrometer (Charnley 1979); in our hands these measurements could usually be reproduced to only within 0.5 mm.

In THA revised before follow-up, the radiographic data were recorded from a radiograph taken just before the (first) revisional arthroplasty.

Data processing and statistics

All data were stored and processed by means of an 8-bit microcomputer with a CP/M file oriented statistics microcomputer program (type FOSS, Arvid Amundsen, Oslo, Norway). Differences between the two groups of patients were tested by the Wilcoxon rank sum test for unpaired data and the chi square test. Subdivision of the Charnley group and the Christiansen group according to laterality did not alter the statistical results. The cases in each group of patients were therefore pooled. The *P* values were found by two-tailed tests and differences were considered significant when $P < 0.05$.

RESULTS

The mean operation time was 2 h, and the mean quantity of blood transfused during and after the operations was 1.4 liters in both groups.

In the postoperative radiographs the Christiansen stems were significantly more often in the varus position than the Charnley stems (Table 2).

Peroperative and postoperative complications

No patients died. Postoperative wound hemorrhage was noted in one patient in the Charnley group and in one patient in the Christiansen group, leg thrombosis in one and hematemesis in another patient in the Charnley group. Three patients in the Christiansen group needed closed repositioning of a luxated total hip prosthesis postoperatively.

No deep infection was noted in any patient with a primary THA. One revisional arthroplasty done during the period of clinical trial contracted a deep infection, but the (Christiansen) prosthesis was not removed until 5 years later.

Clinical data at follow-up

During the 10-year period 1972 through 1981 the 181 consecutive patients admitted during the period of clinical trial (1974–76) had had one or more major operations on 218 hips in all, and in unilateral cases the right hip was operated on about twice as often as the left one. Twenty per cent of the cases had a bilateral hip operation. The categories of patients (Charnley 1979) did not differ significantly (Table 3), but there was a significant difference in laterality between the two groups.

In 1981/82, seven out of 87 patients in the Charnley group and 13 out of 81 patients in the Christiansen group had died (without a revisional arthroplasty). Five and seven patients respectively were unfit and unable to attend for causes other than the hip arthrosis.

At follow-up two THA had been successfully revised in the Charnley group; one was due to breakage of the stem in a very active and stout woman and one to loosening of the cup. Two additional patients (two hips) were advised to have revisional arthroplasty because the stem was working loose (Table 4). Thus, four total hip prostheses out of 99 total hips seen at follow-up were failures in the Charnley group.

In contrast, 21 total hip prostheses out of 68

Table 2. Postoperative position of 203 stems

Group (No. of patients)	Position of stem*			Sum (per cent)
	Valgus	Neutral	Varus	
Charnley (87)	29 (26%)	39 (35%)	45** (40%)	113 (100%)
Christiansen (81)	0 (0%)	23 (26%)	67+ (74%)	90 (100%)

The values in the Table refer to the number of stems.

* Definition of valgus/varus see Figure 1 and text.

** Range 1–12 degrees (mean \approx 6 degrees).

+ Range 1–10 degrees (mean \approx 5 degrees).

There was a significant difference between the two groups ($P = 10^{-6}$).

Table 3. Patient categories at follow-up

Group	Category*					Sum
	A	B	BB	C	D	
Charnley	26	9	30	8	2	75
Christiansen	24	9	18	6	4	61
Sum	50	18	48	14	6	136

The figures in the Table refer to the number of patients.

* Categories:

- A = unilateral hip arthrosis;
 - B = bilateral hip arthrosis, unilateral THA;
 - BB = bilateral hip arthrosis, bilateral THA;
 - C = function of walking impaired, not due to THA;
 - D = arthrodesis/endoprosthesis in contralateral hip.
- There was no significant difference between the groups.

(30.9 per cent) seen at follow-up had been revised or needed a revisional arthroplasty, one or more times, in the Christiansen group (Table 4). This gave a failure rate Charnley to Christiansen of 1 to 7.7 (Table 4).

Neither of the two revisional arthroplasties done in the Charnley group have failed so far. In contrast, five out of seven revisional arthroplasties done in the years 1974–81 in the Christiansen group failed when the loose component(s) were replaced by the appropriate *Christiansen* component(s), whereas none out of 14 failed when *both* the components were removed and a *Charnley* revisional total hip prosthesis was inserted (Table 5). At revisional arthroplasty wear on the Christiansen cups and the sleeve of the trunnion bearings was observed. In the Charnley

group no late infections were noted, while one was noted in the Christiansen group. There was no Girdlestone excision pseudarthrosis in the Charnley group compared to two in the Christiansen group (six in all in the Christiansen group when revisional arthroplasties were included). In 7 per cent of the THA in the Charnley group the wires had been removed due to local tenderness over the greater trochanter.

Surgeon A, who did the largest number of the Christiansen arthroplasties, had 26 per cent failures in 42 hips seen at follow-up (Table 6), whereas none of his Charnley arthroplasties failed in a cumulated group of 22 patients.

In the Charnley group 90 per cent of the hips had a pain index (d'Aubigné & Postel 1954, Charnley 1979) of 6 and the lowest index was 3 (mean 5.8). In contrast, in the Christiansen group only 60 per cent of the hips had a pain index of 6 and the lowest index was 2 (mean 5.3) ($P = 0.000007$). When the patients unfit for reasons

Table 5. Revisional arthroplasties in the Christiansen group 1974 through 1981

From a Christiansen THA to a:	No failure	Failure	Sum
- Christiansen THA	2	4*	6
- Charnley THA	13	0	13
- Christiansen, then to Charnley THA	1	0	1

* Two prostheses loose, two Girdlestone pseudarthroses.

There was a significant difference between the groups ($P = 0.00006$).

Table 4. Failures of THA at follow-up*

Group (No. of patients)	No failure (per cent)	No. of loosened (failed) (per cent)			Sum hips
		Cups	Stems**	Both	
Charnley (75)	95 (96%)	1 (1%)	3 (3%)	0	99
Christiansen (61)	47 (69%)	13 (19%)	3 (4%)	5 (7%)	68

* Failure = Revised/revision advised for the patient with THA done during 1974–1976 (later THA not included here).

** One Charnley stem broke.

There was a significant difference between the groups ($P = 0.000007$).

Table 6. Results for different surgeons in 68 Christiansen THA at follow-up

Surgeon	No failure	Failure	Sum
A	31	11	42
B + C + D	16	10	26

The figures in the Table refer to the number of hips.

other than the hip arthrosis were excluded the walking index varied from 2 to 6 (mean 5.3) in the Charnley group and from 2 to 6 (mean 4.5) in the Christiansen group ($P = 0.00002$). The cumulative range of motion varied from 0 degrees to 280 degrees (mean 205 degrees) and from 110 degrees to 360 degrees (mean about 185 degrees) in the Charnley and Christiansen groups respectively ($P > 0.8$).

Radiographic data at follow-up

Heterotopic para-articular ossifications were seen in 12 (11 per cent) out of 106 THA in the

Charnley group, and in 31 (36 per cent) out of 86 THA in the Christiansen group ($P = 0.00004$). A radiolucent zone adjacent to the cup measured from 0 mm to 2 mm and from 0 mm to 10 mm in the Charnley and Christiansen groups respectively ($P > 0.7$).

Loosening of one or both components of the prosthesis was found in 10 out of 99 in the Charnley group, and in 35 out of 68 in the Christiansen group (Table 7). In the Christiansen group fewer loose cups – and more stems – were seen when the stem was in the varus position than in the neutral position, but this was not statistically significant (Table 8). Four out of 10 patients and 21 out of 35 patients with a radiographically loose prosthesis had painful hips needing revision in the Charnley and Christiansen groups respectively.

Diminution of measurable acetabular cup thickness (creep/wear) during the observation period was seen in 28 out of 102 cups in the Charnley group; it varied from <0.5 mm to 3.3 mm (mean about 1.3 mm). In the Christiansen group only 5 cups were technically measureable.

Table 7. Radiographic loosening in 167 THA at follow-up

Group	No loosening (per cent)	Loose			Sum (per cent)
		Cups (per cent)	Stems (per cent)	Both (per cent)	
Charnley	89 (90%)	2 (2%)	7* (7%)	1 (1%)	99 (100%)
Christiansen	33 (49%)	23 (34%)	6 (9%)	6 (9%)	68 (100%)

The numbers in the Table refer to the number of total hip prostheses.

* One fractured stem included.

There was a significant difference between the groups ($P = 3 \times 10^{-9}$).

Table 8. Position of stem correlated with loosening in radiographs in Christiansen group at follow-up

Position of stem	No loosening (per cent)	Loosening of			Sum (per cent)
		Cup (per cent)	Stem (per cent)	Both (per cent)	
Valgus	0	0	0	0	0
Neutral	8 (42%)	8 (42%)	0	3 (16%)	19 (100%)
Varus	25 (51%)	15 (31%)	6 (12%)	3 (6%)	49 (100%)

The figures in the Table refer to number of total hip prostheses.

There was no significant difference between the groups.

The wear varied from 1.1 mm to 3.1 mm. At revisional arthroplasty considerable wear of the polyacetal components was seen.

In the Charnley group pseudarthrosis of the reattached greater trochanter was seen in eight out of 96 hips.

DISCUSSION

During an observation period of 5–8 years the Christiansen THA failed about 8 times as often in one group of patients as the Charnley THA in another concurrent group of patients. In retrospect these two groups of patients appear to be unmatched in several respects, but can these inequalities explain this marked difference in the failure rate between the two prostheses, or is the design and/or the choice of materials in the Christiansen prosthesis to blame?

Revisional arthroplasties were not initially excluded from the material. These technically more difficult arthroplasties were done by one of the most experienced surgeons, who also did the largest number of the Christiansen arthroplasties. These data may suggest a biased selection of the patients, but this was not statistically significant.

There was a marked difference in the distribution of the surgeons between the two groups of patients (Table 1). Thus, one of the surgeons (B) did 77 per cent of the Charnley THA, with a long-term failure rate of 4 per cent. The other surgeons had no failures in the Charnley group. Another surgeon (A) did 62 per cent of the Christiansen THA, with a failure rate of 26 per cent (Table 6). This is a methodological weakness of the clinical trial, and these results may suggest that here the dexterity of the different surgeons has been tested and not the two types of prostheses in question. But the more Christiansen prostheses the individual surgeon inserted, the fewer the failures; surgeon A had the lowest failure rate (26 per cent) while the other surgeons had more failures in the Christiansen group (Table 6). Further, surgeon A had no long-term failures at all, either among the Charnley prostheses he inserted as part of the clinical trial, or among patients with a Charnley THA operated on before and after the period of clinical trial.

During the operations the stem of the prosthesis was deliberately inserted as far as possible in a neutral or in a valgus position. As shown above there were more stems in the varus position in the Christiansen group than in the Charnley group (Table 2). Thus, the Christiansen stem seems to have been more difficult to insert as intended than the Charnley stem, but the mean *varus* angles were only 5–6 degrees, and the maximum angles were 10–12 degrees in the two groups respectively (Table 2). More cups worked loose in the Christiansen group when the stem was in the neutral than in the varus position, but this was statistically not significant (Table 8). These data suggest, however, that there might be important factors other than the position of the stem that affect the failure rate. Since there were no Christiansen stems in valgus there was nothing to indicate whether or not the number of failures can be reduced if the stem is in valgus. However, the more pronounced the valgus position, the less the trunnion bearing of the Christiansen prosthesis will function as intended. A Christiansen stem in 15 degrees of valgus will have an angle of about 130 degrees between the trunnion axis and the femur, which is the same trunnion-to-femur angle as a Weber prosthesis inserted in a neutral position. According to Charnley (1979), the Weber prosthesis performed badly in the pendulum comparator and he suggested that it might work better with a smaller trunnion to stem angle. These laboratory data seem to support our findings concerning the Christiansen prosthesis in patients.

Since both the groups of patients and their treatment were unmatched, we cannot exclude that these inequalities had a bearing on the results of the treatment. However, once a Christiansen THA failed, it failed again in five out of seven cases when revised with a new *Christiansen* prosthesis/component. In contrast, when at revision (or rerevision) the Christiansen prosthesis (both components) were removed and a *Charnley* revisional prosthesis inserted, the revision did not fail (Table 5). The encouraging short-term results obtained by the Charnley revisional prosthesis in this study have been reproduced in a larger series of patients with loose Christiansen THA who were sent to us from other hospitals (unpublished

data). Since these patients served as their own controls, these short-term results suggest that the failures may be caused by the Christiansen prosthesis itself. A recent Scandinavian multicenter study (Josefsson et al. 1981), reporting a 2-year follow-up failure rate of one (0.9 per cent) out of 112 patients with the Charnley THA and 68 (9 per cent) out of 759 patients with the Christiansen THA, supports this contention.

Both the Charnley and the Christiansen prosthesis were designed to minimize frictional torque. To obtain this Charnley chose a small 22 mm stainless steel head bearing against UHMW high density polyethylene, while Christiansen chose a small diameter trunnion bearing between a larger 37 mm cobalt-chrome-molybdenum (Francobal) head and the stem. Both the cup and the sleeve of the trunnion bearing in the Christiansen prosthesis are made of polyacetal. In laboratory tests polyacetal (Delrin 150) seems to have up to twice the coefficient of friction and up to 60 times more rapid wear against *stainless steel* than UHMW high density polyethylene has (Clarke & McKellop 1980). In these respects UHMW high density polyethylene is therefore the better of the two. Since the Christiansen cups failed 19 times as often as the Charnley cups in this study, our clinical data support this contention (Table 4). Further, in two Christiansen THA revised during the last few years in this hospital, the wear extended right through the cups. In addition, some of the polyacetal cylindrical sleeves (of the trunnion bearings) were so worn that the metal of the neck bore directly on the stem proper (unpublished data). Finally, polyacetal wear particles may form a pronounced foreign body reaction around the joint, possibly contributing to the loosening of the cup (Mathiesen et al. 1983).

In radiographs taken 1 year after operation no Charnley prostheses and 5 per cent of the Christiansen prostheses were loose (Brinchmann-Hansen et al., unpublished). Our 5–8 year follow-up results show the same trend. As a consequence of their 1-year results Brinchmann-Hansen and coworkers decided to stop using of the Christiansen prosthesis in this hospital in 1977. This decision was based on preliminary

results from two groups of patients which appear to be unmatched in several respects (Tables 1–2). Nevertheless, with a rate of revision (failure) Charnley to Christiansen of about 1 to 8, and a rate of cup failure of 1 to 19 (Table 4), this decision seems warranted.

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