Is there a future for hinged prostheses in primary total knee arthroplasty?

A 20-YEAR SURVIVORSHIP ANALYSIS OF THE BLAUTH PROSTHESIS

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The Blauth prosthesis is a hinged total knee replacement. We have evaluated 422 consecutive primary total knee arthroplasties using this design in 330 patients with a maximum follow-up of 20 years (mean 6). The mean age of the patients at the time of operation was 70 years (29 to 87).

Using endpoints of infection, removal because of aseptic loosening, removal for any cause, and the worst case as definitions of failure, the cumulative rates of survival at 20 years were 93.6%, 96.0%, 94.4% and 86.8%, respectively. The cumulative rate of survival of the patients themselves was 14.4% (24% in patients with osteoarthritis and 9% in these with rheumatoid arthritis) after 20 years.

Our survivorship analysis shows that hinged knee prostheses, when they are biomechanically well designed, can yield a satisfactory long-term outcome, similar to those of the best prostheses of the resurfacing type. Hinged knee prostheses continue to be of value in patients with severe deformity or instability of the knee.

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Replacement of knees which have severe deformity or instability requires a prosthesis with some inherent stability,¹ and the use of a hinged design may be preferable to a resurfacing procedure. Some early hinged prostheses gave poor results, and are now rarely used.² Cemented condylar prostheses have become the most successful knee arthroplasties.³

The poor results of hinged prostheses were associated with designs such as those of Shiers,^{4,5} Walldius,⁶ Young^{7,8} and Guepar.^{9,10} Their main deficiencies were shown to be the non-anatomical position of the load-bearing axes, direct

metal-to-metal transmission of load and the need for massive resection of bone.¹¹ Blauth tried to eliminate these faults and designed a new hinged prosthesis¹¹⁻¹³ which was first implanted in 1972. The original design was slightly modified in 1984¹³ in order to allow resurfacing of the patella with a cemented, domed, polyethylene component. There are three sizes of this modified prosthesis. The tibial and femoral stems are shorter, there is a larger tibial plateau and valgus angulation of the femoral stem has been reduced from 8° to 6°.

The Blauth prosthesis (Aeskulap, Tuttlingen, Germany) has been implanted selectively since 1972 at the Tübingen University Clinic. We now report our results over a 20-year period.

Patients and Methods

A cemented Blauth prosthesis was used for 422 primary total knee arthroplasties in 330 patients between August 1972 and December 1994. All were followed up, including three patients who died postoperatively. The mean follow-up until removal of the prosthesis, the latest examination or death was six years (0 to 20).

Survival analysis to 1995 was undertaken defining failure in four modes: infection, removal for aseptic loosening, removal for any cause, and worst case. We used the life-table method^{14,15} (SAS/STAT and SAS/GRAPH software, version 6, 1991; SAS Institute Inc, Cary, USA) and present the survival curves with 95% confidence intervals^{16,17} (Tables I and II).

We gained our information chiefly from the medical records, but when these were not available the patients were examined by us or their local physician. For the 121 patients (160 knees) who had died we used the last radiographs, the medical records and, when necessary, information from their relatives. No recent clinical and radiological data were available for nine patients (9 knees). They were evaluated on the results of their last follow-up examination at a mean of 50 months (21 to 101), recorded as lost to follow-up, and included as failures in a worst-case survivorship curve.

The hinged Blauth prosthesis had been inserted in 207 left knees and 215 right knees by a total of 16 surgeons. Of the 330 patients, 92 (27.8%) had bilateral prostheses. There

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Table I. Survival analysis of the Blauth prosthesis in 422 primary total knee arthroplasties at 10 and 20 years with 95% confidence limits

Failure definition	Survival %	
	10-year	20-year
Infection	94.9 (92.2 to 97.7)	93.6 (89.8 to 97.4)
Removal because of aseptic loosening	98.4 (96.0 to 100)	96.0 (91.0 to 100)
Removal for any cause	96.7 (94.0 to 99.6)	94.4 (89.2 to 99.6)
Worst case (removal and/or infection and/or lost to follow-up)	90.2 (86.0 to 94.4)	86.8 (80.4 to 93.1)

Table II. Life table and survival analysis of the Blauth prosthesis in 422 primary total knee arthroplasties. Failure was defined as removal for any cause

Years since operation	Number at start	Number withdrawn	Number at risk	Failure	Annual failure rate (%)	Annual success rate (%)	Cumulative success rate (%)
0 to 1	422	36	404.0	1	0.25	99.75	100
1 to 2	385	55	357.5	2	0.56	99.44	99.75
2 to 3	328	60	298.0	1	0.34	99.66	99.19
3 to 4	267	37	248.5	0	0.00	100.00	98.86
4 to 5	230	29	215.5	0	0.00	100.00	98.86
5 to 6	201	18	192.0	1	0.52	99.48	98.86
6 to 7	182	32	166.0	1	0.60	99.40	98.35
7 to 8	149	30	134.0	0	0.00	100.00	97.75
8 to 9	119	13	112.5	0	0.00	100.00	97.75
9 to 10	106	20	96.0	1	1.04	98.96	97.75
10 to 11	85	22	74.0	0	0.00	100.00	96.74
11 to 12	63	15	55.5	0	0.00	100.00	96.74
12 to 13	48	12	42.0	1	2.38	97.62	96.74
13 to 14	35	5	32.5	0	0.00	100.00	94.43
14 to 15	30	9	25.5	0	0.00	100.00	94.43
15 to 16	21	2	20.0	0	0.00	100.00	94.43
16 to 17	19	5	16.5	0	0.00	100.00	94.43
17 to 18	14	4	12.0	0	0.00	100.00	94.43
18 to 19	10	0	10.0	0	0.00	100.00	94.43
19 to 20	10	3	8.5	0	0.00	100.00	94.43
20 to 21	7	7	3.5	0	0.00	100.00	94.43

were 284 women (86%) and 46 men; 202 knees (48%) had a domed polyethylene patellar component. More than 60% of the patients were more than 10% heavier than normal for their height. A lateral release was performed in 46% of knees with patellar resurfacing and in 17% of the others. The underlying diagnosis was osteoarthritis (OA) in 208 patients (255 knees; post-traumatic in 9), and rheumatoid arthritis (RA) in 122 patients (167 knees).

The mean age at the time of operation was 70 years (29 to 87); for patients with OA, it was 72 years (46 to 87) and for those with RA 65.6 years (29 to 84). Forty-eight knees had had previous operations including high tibial osteotomy (17), synovectomy (13), meniscectomy and/or ligament repair (9), and other procedures (9).

Results

Survivorship analysis. The results of the survivorship analysis are presented in Tables I and II.

Medical complications. There were two postoperative deaths from pulmonary embolism and one from a stroke. Five patients with deep-venous thromboses recovered uneventfully after anticoagulation therapy. One patient had a convulsion, another developed pneumonia which was treated successfully with antibiotics, and cholestasis occur-

red in a patient with chronic hepatitis B who recovered spontaneously. A patient with paralytic ileus was successfully treated by parenteral nutrition and coloscopic decompression.

Surgical complications. There were six infractions of a femoral condyle and perforation of the femoral shaft occurred in four patients. In three the tibial tuberosity was avulsed and in one the patellar tendon was torn. In one case the stem of the tibial component had to be shortened because the medullary canal was too narrow.

Peroneal nerve palsy was encountered twice, once in a patient with a preoperative valgus deformity of 30° and once due to local pressure in a continuous passive motion machine. Both patients recovered within six months.

Infection. There was deep infection in 16 knees giving an overall incidence of 3.8% (3.1% for OA and 4.8% for RA). The life-table method showed that the cumulative rate of infection after 20 years was 6.4% (Table I), 6.3% for OA and 7.0% for RA. In five patients infection was seen within three months of operation, and another 11 had late infection at an average of 38 months (7 to 121) after surgery. In four with early and four with late infection, cure was achieved after synovectomy, irrigation, exchange of the polyethylene components and antibiotics, without removal of the whole prosthesis. Five patients required removal of the prosthesis

Fig. 1a

Figures 1a, b and c – Radiographs of a 74-year-old woman with OA who required revision arthroplasty reveal loosening of the femoral component with anterior perforation. Figure 1d – The removed prosthesis (original design) showed only minimal wear of the polyethylene menisci with polished surfaces. There was minimal wear of the polyethylene bush.

Fig. 1b

Fig. 1c

Fig. 1d

and subsequent arthrodesis. A 68-year-old woman with RA and diabetes mellitus refused to have her prosthesis removed and died from septic encephalitis 35 months after the original implantation and 26 months after infection had been confirmed by microbiology. In two patients with multiple medical problems, chronic deep infection was treated with antibiotics because of the high risk of operation. One died from cardiac insufficiency and the other, with a chronic fistula, from ascending arterial occlusion of the other leg.

Aseptic loosening. The prosthesis was removed for aseptic loosening in three patients at 76, 119, and 150 months after insertion, respectively. Both the femoral and tibial components became loose in a young woman with RA who was aged 29 years at the time of her original operation. An arthrodesis was performed. In another patient the femoral component (Fig. 1) and in a third, the tibial component loosened; a special Blauth prosthesis with a longer stem was implanted.

Patellar complications. There was a fracture of the patella 25 months after operation in one woman who had not had patellar resurfacing. Lateral subluxation occurred but no treatment was necessary. In three patients with satisfactory patellar resurfacing, fractures occurred at 5, 8 and 15 months postoperatively. Only one of these patients had problems and patellectomy was performed. In three cases a lateral release was performed because of a lateralisation of the patella. Subluxation of the patella was seen in two patients who had not had the bone resurfaced, but no treatment was necessary.

Discussion

From the 1950s to the 1970s replacement of the knee joint commonly used a hinged prosthesis.^{4,6,7,9,18-20} None of these was particularly successful, and after the introduction of the total condylar prosthesis in 1974,²¹ resurfacing became the standard in most centres.

In 1969 the St Georg hinged total knee prosthesis was introduced in the Endo-Klinik at Hamburg,²² and three years later, the first Blauth prosthesis was implanted in Tübingen.¹² Both of these designs are based on the principles of low-friction arthroplasty, originally developed for hip replacement,²² and have proved successful. After slight modifications in 1975²³ and 1986,¹³ respectively, their use has continued.

When discussing the quality of a specific design of prosthesis, we should judge it by some essential criteria:

1. Excellent long-term survivorship.
2. Standard (simple) operating technique.
3. Easy correction of severe axial deformities and/or distinct contractures.
4. Good stabilisation.
5. Good preconditions for revisions: a) easy removal of the prosthesis and b) good bone stock for exchange arthroplasty or arthrodesis.

The most important criterion for evaluation is an excellent long-term survivorship of the prosthesis with clearly defined and reproducible definitions of failure.²¹ Recently, a large number of survivorship analyses have been published (Table III). Twenty-three of these 24 studies include

Table III. Survival analysis of knee arthroplasty. Failure is defined as removal for any cause

Construction	Type of prosthesis	Author(s)	Remarks	Year	Cases	Survival (yr)				
						5	10	15	20	
Hinged	Various types	Knutson et al ²⁶	OA RA	1986	140	67				
	Stannore	Grimer et al ²⁵		1984	270	84				
	St Georg 2nd generation	Heiner and Engelbrecht ²³	Infection excluded	1988	103	85	19.1 (9 years)			
	Blauth	Blauth and Hasselpflug ¹¹		1990	824	≈96	≈94			
	Blauth	Böhm and Holy*	All cases Infection excluded Worst case	1998	497	≈97	96	94.4	94.4	
					422	98.9	96.7	96	96	
						100	98.4	96	96	
						94.5	90.2	86.8	86.8	
Older constrained	Various types	Rand and Ilstrup ³⁸		1991	356	90	86			
Newer constrained	Various types	Rand and Ilstrup ³⁸		1991	114	65				
Semiconstrained	Attenborough	Gallanaugh ¹		1992	505	70.1 (7 years)	≈56	44.9 (14 years)		
	Gallanaugh	Gallanaugh ¹		1992	149	98.4 (7 years)				
	GSB I-III	Gschwend and Siegrist ³³		1991	776	89	70	63 (12 years)		
	GSB III	Gschwend and Siegrist ³³		1991	638	94.1	86			
Bi- and tri-compartmental	Various types	Knutson et al ²⁶	OA RA OA RA	1986	1642	88				
	Various types	Knutson et al ²		1994	1962	91	≈84			
	Various types	Gill and Mills ³⁹		1991	1000	≈88 to 96	≈86			
	Older resurfacing	Rand and Ilstrup ³⁸		1991	3159	≈92 to 97.5	≈96	94.2 (13 years)		
	Condylar resurfacing	Rand and Ilstrup ³⁸		1991	3907	89	78			
	(metal-backed tibial component)					98	91			
	Total Condylar (TC)	Scuderi et al ²¹		1989	224	97.9	90.6	90.6		
	TC	Laskin ⁴⁰	RA	1990	117	93	80.6 (9 years)			
	TC	Ranawat et al ⁴¹		1993	112	100	99	94.1		
	TC	Rimnapoli et al ⁴²		1994	76	≈96	92	86		
	TC	Ritter et al ⁴³	Infection excluded	1994	418	99.7	98.4	95.4 (14 years)		
	TC	Falavyn et al ³		1995	151	97	97			
	TC	Abernethy et al ⁴⁴		1996	550	96.7	92.1			
	TC	Rodriguez et al ⁴⁵		1996	145					
	TC posterior stabilised (TCPS)	Stern and Insall ⁴⁶		1992	289	97	94.5	91		
	TCPS (polyethylene tibia)	Scuderi et al ²¹		1989	289	97.3	97.3			
	(metal-backed tibia)				917	98.8				
	Insall-Burstein	Nafei et al ³²		1996	348	98	92 (12 years)			
	Kinematic	Malikani et al ⁴⁷		1995	168	98	96			
	Kinematic	Abernethy et al ⁴⁴		1996	1017	93.8	87.9	86.9 (14 years)		
	Kinematic Stabiliser	Emmerson et al ³⁵		1996	109	98	95.3	≈83 (14 years)		
						≈95	≈91			
						98.1	94.1			
						94	89	85		
Unicompartmental	Ortholoc I	Whiteside ⁴⁸	Worst case	1994	163					
	Townley	Parto et al ⁴⁹		1994	360	94				
	Various types	Knutson et al ²⁶	OA (medial compartment) RA (medial compartment)	1986	2051	92				
	Various types	Knutson et al ²		1994	114	75	≈86.5			
	St Georg	Heiner and Engelbrecht ²³	Infection excluded	1988	505	≈93	≈77			
					24587	≈90				

* this study

Table IV. Infection rate after arthroplasty of the knee

Construction	Type of prosthesis	Author(s)	Year	Cases	Follow-up (yr)	Infection incidence (%)	
						Overall	Cumulative
Hinged	Various types	Knutson et al ²⁶	1986	140 (OA) 270 (RA)	-6	12.1 7.4	16 at 6 yr 8 at 6 yr
		Shiers	1976	31	2 to 7	3.2	
		Watson et al ⁵	1983	43	No information	4.6	
		Duquenooy et al ⁵⁰	1983	80	-12	23	
		Arden ⁵¹	1984	90	-16	4.4	
		Oglesby and Wilson ⁵²	1971	91 (all cases)	-10	18.7	
		Young		38 (RA)		≈100	
		GUEPAR	1976	285	-2	6.6	
		Deburge and Guepar ⁹	1979	112	-3	11	
		Jones et al ¹⁰	1981	66	1-	9	
	St Georg 2nd generation	Schurman ⁵³	1983	100	No information	4	
		GUEPAR	1978	100	2.5	3	
		Lettin et al ²⁰	1984	103	-9	6.8	
		Stanmore	1988	824 (all cases)	-10	2.9	
		Grimer et al ²⁵		(RA)		3.5	
		Heinert and Engelbrecht ²³	1990	497	-14.9	3	
		Blauth	1998	422	-20	3.8	
		Blauth and Hassenpflug ¹¹					5.1 at 10 yr 6.4 (OA:6.3; RA:7.0) at 20 yr
		Böhm and Holy*					
Semiconstrained	Sheehan	Sheehan ⁵⁴	1978	157	-5.5	0.6	
		Arden ⁵¹	1983	60	-4	3.3	
		GSB	1991	638	-8	5	
		Gallannaugh ¹	1992	149	-7	2.7	
	Various types	Knutson et al ²	1994	(OA) (RA)	-10		≈2.9 at 10 yr ≈3.6 at 10 yr
		Wilson et al ³¹	1990	1857 (OA) 2076 (RA)	No information	0.9 2.2	
		Freeman-Swanson	1983	19	-7	16	
		Total Condylar (TC)	1984	39	-5	0	
		Scuderi et al ²¹	1989	224	-15	1.3	
		TC	1990	80 (RA)	-10	6.3	
Bi- and tri-compartmental	Various types	Laskin ⁴⁰	1993	112	-15	0.9	
		Ranawat et al ⁴¹	1994	76	-17	2.6	
		Rinonapoli et al ⁴²	1994	418	-18	1.4	
		TC	1995	151	-16	0.7	
		Ritter et al ⁴³	1996	145	-18	4.1	
		Falatin et al ³					
		Rodriguez et al ⁴⁵					
		TC posterior stabilised (TCPS)	1992	289	-12	1.7	
		TCPS (polyethylene tibia)	1989	289	-10	0	
		Scuderi et al ²¹		917	-7	0.7	
	Insall-Burstein	Nafei et al ³²	1996	184 (OA) 164 (RA)	-12	1.1 3.0	
		Miller Galante	1991	73	-5	4.1	
		Ortholoc I	1994	163	-10	3.1	
		Townley	1994	360	-17	2.2	
		Kinematic	1995	168	-10	0.6	
		Malkani et al ⁴⁷	1996	109	-14	0.9	
		Emmerson et al ³⁵	1984	31	-9	6.5	
		Kinematic Stabiliser					
Unicompartmental	St Georg 1st generation	Heinert and Engelbrecht ²³	1988	505	-10	0.7	
	Several types	Knutson et al ²	1994	3292	-10		≈0.8

* this study

more than 24 000 knee arthroplasties. The 30 003 primary knee arthroplasties reported in the Swedish knee arthroplasty register are not listed with the number of each type of prosthesis.² Only studies with the same definition of failure can be compared, and in most reports failure was defined as removal for any cause, but in some failure was defined as revision of the prosthesis, which may lead to misunderstanding.²⁴ The technique of survivorship analysis was applied only in the 1980s and there are few such analyses involving hinged prostheses. Most of the older designs of hinged prostheses yielded unacceptably poor

results,^{25,26} but those of the second-generation St Georg and the Blauth prosthesis are equal to, or better than, the best outcomes of resurfacing prostheses.

We were able to examine the condylar surface, the polyethylene menisci and the polyethylene bush of a Blauth prosthesis which had been revised 150 months after insertion because of aseptic loosening. There was only minimal wear (Fig. 1) due to adhesion and abrasion with no evidence of any fatigue failure.²⁷ The large contact area allows the contact pressure to remain below the permitted flow stress of polyethylene.²⁸ For such large areas of contact optimal

Fig. 2a

Fig. 2b

Fig. 2c

Long-term follow-up of a 59-year-old woman with RA and marked thinning of the patella. Postoperative views of right and left Blauth prostheses (a), implanted within one month. After nearly 20 years, the results were good (b). The lateral and the patellar skyline (c) views show marked thinning of the patella. The patient had no complaints and no further operation was required.

congruence of the gliding surfaces is essential, but to achieve this we have to accept both an increased loading of the anchorage and a reduction of the degrees of freedom. In non-constrained prostheses there may not be an area of contact but a point, line or quasiline of loading which may result in local peak contact stresses almost ten times higher than that in area contact.²⁸ Analysis of explanted Blauth prostheses²⁹ has confirmed the experimental observations that the design concept of the Blauth prosthesis is correct from a tribological aspect.³⁰ We consider that the low contact pressure of the Blauth prosthesis is the main technical reason for the minimal wear; this may explain both the low rate of aseptic loosening and the relatively low rate of infection.

Infection is the most important complication, and in our study the highest annual risk for infection was 1.7% within the first year. In the following ten years this fell to 0.5% and from years 11 to 20 no further cases of infection were seen. The cumulative incidence was 3.7% after five years, 5.1% after ten years, and 6.4% after 20 years. There are, however, only few reports in the literature using survivorship for analysing the incidence of infection (Table IV) and in most papers, only the overall incidence is indicated; this cannot be directly compared with a cumulative rate. Life-table analysis is much more precise. In our study the overall incidence of infection was 3.8%.

When assessing various prostheses (Table IV), there is a clear reverse correlation between the degree of constraint and the overall rate of infection, but the real risk factor may be the amount of implanted foreign material. The mean overall incidence of infection of hinged prostheses (3254 cases) is 5.7% (2.9 to 23) compared with 3.9% (0.6 to 5) for semiconstrained designs (1004 cases). The lowest rate after total knee replacement is in bi- or tricompartmental implants with a mean of 1.6% (0 to 6.3) in 7944 cases. In the Swedish knee arthroplasty register, the cumulative rates of revision for infection increased after ten years to 3.5% in tricompartmental knees.² In this context the infection rates of the hinged St Georg and Blauth prostheses seem to be acceptable.

In most studies in which RA and OA have been analysed separately the rate of infection is higher for RA^{2,8,23,31,32} and in the study of Young⁸ it was eventually 100%. In our study the cumulative incidence after 20 years was nearly equal for OA (6.3%) and RA (7.0%).

Gschwend and Siegrist³³ found a relatively high rate of late infections with the semiconstrained GSB prosthesis, but in our study the annual rate of infection gradually decreased to zero after the eleventh year. The small amount of wear may have been a factor.

The worst-case survivorship curve,³⁴ including loss to follow-up as failure, is a powerful tool for the correct assessment of the validity of analyses of arthroplasties. Unfortunately, it is seldom published and we can therefore compare the results of the Blauth prosthesis only with those of the Kinematic knee.³⁵ In most studies, a number of patients are excluded from the analysis for various reasons:

some of the excellent published results may appear to be less successful if they were exposed to worst-case analysis. Our study shows a nearly linear annual drop in the worst-case survival of about 1.3% for each of the first 13 years. Between 13 and 20 years the result remained constant at 86.8%, which is similar to the 83% of the 14-year assessment of the Kinematic prosthesis in the study of Emmerson et al.³⁵

Apart from the survivorship curves of the prostheses, the survival of the patients themselves is of interest. We found a nearly linear reduction in survival, and after 20 years only 14.4% were still alive. Although the mean age at the time of operation was lower in our patients with RA, their survival after 20 years was only 9% as compared with 24% for patients with OA.

Radiological analysis and the use of such observations as defined endpoints may be useful in survivorship analyses of prostheses with a high incidence of aseptic loosening and a short follow-up, but was of little use in our study. Progressive radiolucencies were detected only in the four cases of aseptic loosening. There had been a reduction of the thickness of the patella in the knees in which it had not been resurfaced, on the lateral films of patients followed for more than 15 years (Fig. 2).

The technique of implanting the Blauth prosthesis is simple and it is easy to correct severe deformity, contracture or instability. A detailed clinical analysis of a prospective multicentre study of the Blauth prosthesis yielded good results.³⁶ About 6% of patients without patellar resurfacing suffered retropatellar pain while climbing stairs, raising from a chair or beginning to walk.³⁶ Resurfacing prostheses can be removed more easily than stemmed designs. When implanting a Blauth prosthesis, however, the amount of bone resected is quite small, even when compared with condylar prostheses.³⁷

We tend to prefer the use of hinged knee prostheses for patients with angular deformities of more than 20°, flexion contractures of more than 25°, massively unstable knees, and for revision arthroplasty. The relatively high percentage of patients with RA in our study may indicate that severe deformities, contractures and instabilities are more common in RA than in OA. In our department we implant about 150 primary total knee prostheses per year of which two-thirds are of a condylar design and one-third the Blauth prosthesis.

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