SURVIVORSHIP OF CEMENTED KNEE REPLACEMENTS

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The survivorship method of analysis has been used to compare the failure rate and overall success of 1 430 cemented primary total knee arthroplasties performed at The Hospital for Special Surgery over a 15-year period. There were 224 total condylar prostheses with a polyethylene tibia, 289 of the posterior stabilised type with an all polyethylene tibia, and 917 posterior stabilised with a metal-backed tibial component.

There were 12 failures in the total condylar series, giving an average annual failure rate of 0.65% and a 15-year success rate of 90.56%. The posterior stabilised prosthesis with a polyethylene tibia showed an average annual failure rate of 0.27% and a 10-year success rate of 97.34%, and this prosthesis with a metal-backed tibial component gave an annual failure rate of 0.19% and a seven-year success rate of 98.75%.

The overall survival rate was not influenced by sex or age, diagnosis or the percentage of ideal body weight. No metal-backed tibial components have yet needed revision for loosening. It seems that infection will be the major cause of failure.

Total knee replacement has evolved to afford the orthopaedic surgeon the ability to correct deformity, maintain movement and relieve pain. Most current designs of implant are successful but many reports contain information based on limited follow-up periods (Insall, Scott and Ranawat 1979; Insall, Lachiewicz and Burstein 1982; Insall et al 1983; Insall and Kelly 1986; Vince, Kelly and Insall 1988). The variation in follow-up makes it difficult to interpret and compare results since failure rates are time-dependent. The ultimate concern is how long can total knee replacement be expected to last.

Survivorship analysis has been advocated as providing annual and overall failure rates, as well as the probabilities of implant survival (Dobbs 1980; Tew and Waugh 1982; Grimer, Karpinski and Edwards 1984; Lettin et al 1984; Lewallen, Bryan and Peterson 1984; Knutson, Tjörnstrand and Lidgren 1985; Tew, Waugh and Forster 1985; Knutson, Lindstrand and Lidgren 1986; Ritter and Campbell 1987; Vince et al 1988). Survivorship analysis is easy to apply since the end-point can be clear cut and will provide a conservative estimate

of failure over time. It also allows the inclusion of some data from patients with short follow-up, those lost to follow-up and those who have died. When the same definition of failure is used comparison between different prostheses is possible.

The total condylar prosthesis was first used in January 1974 and is still successful (Insall et al 1979; Insall et al 1983; Insall and Kelly 1986). Evolution led to the posterior stabilised modification in 1978; this was designed to improve the range of movement, making stair climbing easier, and to prevent posterior tibial subluxation (Insall et al 1982). At first, the posterior stabilised tibial component was made entirely of polyethylene, but it was later shown that metal-backed tibial trays transmit load better (Bartel et al 1982). In November 1980 we began to use metal-backed tibial components and in October 1981 made the last use of the all-polyethylene type.

We have now applied the survivorship method of analysis to our series of cemented primary knee replacements with these prostheses.

MATERIALS AND METHODS

From 1974 to 1986, 1 430 cemented primary total knee arthroplasties were performed by or under the direct supervision of the senior author (JNI) at The Hospital for Special Surgery and are available for analysis. The review includes 224 total condylar prostheses with a polyethylene tibial component (1974 to 1978), 289 posterior stabilised type with an all polyethylene tibial

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component (1978 to 1981), and 917 posterior stabilised with a metal-backed tibial component (1981 to 1986). There were 445 knees in men and 985 in women, with an average age of 67 years (range 20 to 87) and an average body weight 135% of the ideal (range 70.4% to 308.6%). There were 1 117 osteoarthritic knees, 193 rheumatoid knees, and 120 knees with other diagnoses including osteonecrosis, post-traumatic arthritis, psoriatic arthritis and haemophilia.

Survivorship analysis used the method described by Armitage (1971); life tables were constructed with each knee replacement entered only once and having one of three possible outcomes for a particular interval: success, failure, or withdrawal. Success was defined as a prosthesis still in situ at the end of the follow-up regardless of clinical score. Failure was defined as a prosthesis revised for any cause or one for which revision has been recommended but not yet performed. Patients who died or were lost to follow-up were withdrawn from the life table as from the date of their last evaluation. The implicit assumption is that lost and dead patients would otherwise be subject to the same probability of failure as the balance of the cohort. The length of follow-up for each patient was determined from routine clinic and office notes, but when a patient had not been seen for a prolonged period, the date of response to a mailed questionnaire was accepted. The latest reviews were in April 1988.

Fig. 1

Survival curves for three patterns of total knee prosthesis.

Survivorship tables were constructed using 12-month intervals and recording, for each interval after surgery, the total number of knee replacements entering the interval, the numbers of failures and withdrawals, the number at risk, the annual failure and success rates, and the cumulative success rate (Table I).

Variables such as pathological diagnosis, sex, age and weight were subjected to survivorship analysis to determine their significance for the longevity of total

knee replacement. Those with diagnoses of osteoarthritis, rheumatoid arthritis, post-traumatic arthritis, osteonecrosis and other diseases were assessed separately. Age at the time of surgery, was recorded as 55 years or younger or as over 55 years. The ideal body weight was calculated for each patient, and separate life tables were constructed for those patients at 110% or less of their ideal and those over 110%. The significance of the difference between the survival rates for each prosthesis was determined.

RESULTS

The data for the different prostheses are given in Tables I to IV and the survival curves which result are shown in Figure 1. There were 12 failures in the total condylar series with an average annual failure rate of 0.65% and a 15-year overall success rate of 90.56%. The posterior stabilised prosthesis with a polyethylene tibia gave six failures with an average annual failure rate of 0.27% and a 10-year overall success rate of 97.34%. The posterior stabilised prosthesis with a metal-backed tibia gave seven failures with an average annual failure rate of 0.19% and a seven year overall success rate of 98.75%.

Failure in the total condylar series included three cases of infection, four loose tibial components, two loose femoral and tibial components, two unstable arthroplasties and one femoral supracondylar fracture. There were no reported revisions later than nine years. For the posterior stabilised prosthesis with a polyethylene tibia, failures included two loose tibial components, three loose femoral components and one tibial stress fracture. The failures in the metal-backed posterior stabilised group were six infections and one loose femoral component. There were no revisions after five years with the posterior stabilised type with a polyethylene tibia or after four years with the metal-backed prosthesis. No metal-backed tibial components have yet been revised for loosening. The incidence of femoral loosening requiring revision was 0.89% in the total condylar group and 0.33% in the combined posterior stabilised group. The overall incidence of infection for all total knee replacements was 0.63%.

The survivorship curves were not significantly affected by diagnosis, sex, age or body weight (Tables IA, IIA, IIIA and IV).

DISCUSSION

The survivorship method of analysis makes it possible to compare the failure rate and the overall success rate of different knee replacements. Tew and Waugh (1982) suggested that survivorship analysis may be more accurate than the conventional method of measuring failure. Since the patient population in joint replacement is older, patients may have died, been incapacitated by serious illnesses or lost to follow-up. Survivorship analysis

Table I. Life table for the original total condylar prosthesis (TCP1)

Follow-up interval*	Number				Annual		
	Entering interval (1)	Failures (2)	Withdrawals (3)	At risk (4)	Failure† (5)	Success† (6)	Overall success† (7)
0 to 12	224	1	28	210	0.48	99.52	99.52
13 to 24	195	2	16	187	1.07	98.93	98.46
25 to 36	177	1	19	167.5	0.60	99.40	97.86
37 to 48	157	0	7	153.5	0	100	97.86
49 to 60	150	0	18	141	0	100	97.86
61 to 72	132	2	23	120.5	1.66	98.34	96.24
73 to 84	107	4	3	105.5	3.79	96.21	92.59
85 to 96	100	0	6	97	0	100	92.59
97 to 108	94	2	5	91.5	2.18	97.81	90.56
109 to 120	87	0	16	79	0	100	90.56
121 to 132	71	0	20	61	0	100	90.56
133 to 144	51	0	13	44.5	0	100	90.56
145 to 156	38	0	28	24	0	100	90.56
157 to 168	10	0	9	5.5	0	100	90.56
169 to 180	1	0	1	0.5	0	100	90.56

The number of surviving knee replacements at the start of each interval (Column 1) is obtained by subtracting the number of failures (Column 2) and number of withdrawals (Column 3) within the previous interval from the number of survivors at the start of the previous interval. For any given interval the number of implants at risk (Column 4) is obtained by subtracting half the number of withdrawals from the start of the interval. It is assumed for convenience that the withdrawals survived half the interval. The percentage of failures (Column 5) within any interval is obtained by dividing the number of failures by the number at risk and multiplying by 100. The percentage of successes (Column 6) is obtained by subtracting the probability of failure from 100. The overall success rate (Column 7) is obtained by the successive multiplication of the probability of success. From the life tables, survival curves are derived.

Table IA. Overall success rates for TCP1 broken down for diagnosis, sex, age and body weight

Follow-up interval*	Diagnosis		Sex		Age		Ideal body weight	
	OA	RA	Male	Female	<55 years	>55 years	<110%	>110%
0 to 12	99.36	100	97.75	100	100	99.49	97.40	100
13 to 24	98.65	100	97.75	98.67	95.35	98.89	97.40	98.72
25 to 36	97.86	100	94.95	98.67	95.35	98.22	97.40	98.02
37 to 48	97.86	100	94.95	98.67	95.35	98.22	97.40	98.02
49 to 60	97.86	100	94.95	98.67	95.35	98.22	97.40	98.02
61 to 72	95.43	100	94.95	96.60	85.31	98.22	91.50	97.08
73 to 84	95.43	94.74	94.95	92.03	79.98	94.93	84.18	93.91
85 to 96	94.07	94.74	94.95	92.03	79.98	94.93	84.18	93.91
97 to 108	94.07	89.17	90.21	90.74	79.98	92.50	84.18	91.61
109 to 120	94.07	89.17	90.21	90.74	79.98	92.50	84.18	91.61
121 to 132	94.07	89.17	90.21	90.74	79.98	92.50	84.18	91.61
133 to 144	94.07	89.17	90.21	90.74	79.98	92.50	84.18	91.61
145 to 156	94.07	89.17	90.21	90.74	79.98	92.50	84.18	91.61
157 to 168	94.07	89.17	90.21	90.74	79.98	92.50	84.18	91.61

* months † per cent

Table II. Life table for posterior stabilised TCP with an all-polyethylene tibial component

Follow-up interval*	Number				Annual		
	Entering interval	Failures	Withdrawals	At risk	Failure†	Success†	Overall success†
0 to 12	289	1	41	268.5	0.37	99.63	99.63
13 to 24	247	3	18	238	1.26	98.74	98.37
25 to 36	226	1	25	213.5	0.47	99.53	97.91
37 to 48	200	0	19	192	0	100	97.91
49 to 60	181	1	15	173.5	0.58	99.42	97.34
61 to 72	165	0	45	142.5	0	100	97.34
73 to 84	120	0	26	107	0	100	97.34
85 to 96	94	0	39	74.5	0	100	97.34
97 to 108	55	0	48	31	0	100	97.34
109 to 120	7	0	7	3.5	0	100	97.34

* months † per cent

Table IIA. Overall success rates for posterior stabilised TCP with an all-polyethylene tibial component broken down for diagnosis, sex, age and body weight

Follow-up interval*	Diagnosis		Sex		Age		Ideal body weight	
	OA	RA	Male	Female	< 55 years	> 55 years	< 110%	> 110%
0 to 12	100	97.37	100	99.50	97.37	100	97.78	100
13 to 24	98.36	97.37	98.40	98.37	97.37	98.53	97.78	98.48
25 to 36	97.76	97.37	98.40	97.75	97.37	97.98	97.78	97.95
37 to 48	97.76	97.37	98.40	97.75	97.37	97.98	97.78	97.95
49 to 60	97.07	97.37	96.08	97.75	97.37	97.31	94.90	97.95
61 to 72	97.07	97.37	96.08	97.75	97.37	97.31	94.90	97.95
73 to 84	97.07	97.37	96.08	97.75	97.37	97.31	94.90	97.95
85 to 96	97.07	97.37	96.08	97.75	97.37	97.31	94.90	97.95
97 to 108	97.07	97.37	96.08	97.75	97.37	97.31	94.90	97.95
109 to 120	97.07	97.37	96.08	97.75	97.37	97.31	94.90	97.95

* months

Table III. Life table for posterior stabilised TCP with a metal-backed tibial component

Follow-up interval*	Number				Annual		
	Entering interval (1)	Failures (2)	Withdrawals (3)	At risk (4)	Failure† (5)	Success† (6)	Overall success† (7)
0 to 12	917	3	89	872.5	0.34	99.66	99.66
13 to 24	825	2	322	664	0.30	99.70	99.36
25 to 36	501	1	169	416.5	0.24	99.76	99.12
37 to 48	331	1	127	267.5	0.37	99.63	98.75
49 to 60	203	0	92	157	0	100	98.75
61 to 72	111	0	84	69	0	100	98.75
73 to 84	27	0	27	13.5	0	100	98.75

* months † per cent

Table IIIA. Overall success rates for posterior stabilised TCP with a metal-backed tibial component broken down for diagnosis, sex, age and body weight

Follow-up interval*	Diagnosis		Sex		Age		Ideal body weight	
	OA	RA	Male	Female	< 55 years	> 55 years	< 110%	> 110%
0 to 12	99.55	100	99.32	99.81	100	99.61	100	99.73
13 to 24	99.13	100	98.85	99.55	100	99.24	100	99.16
25 to 36	98.80	100	98.85	99.14	100	98.95	100	98.86
37 to 48	98.29	100	97.69	99.14	100	98.51	100	98.41
49 to 60	98.29	100	97.69	99.14	100	98.51	100	98.41
61 to 72	98.29	100	97.69	99.14	100	98.51	100	98.41
73 to 84	98.29	100	97.69	99.14	100	98.51	100	98.41

* months

allows some of the data from these patients to be included in long-term studies. It is assumed that patients who die or are lost to follow-up are subject to the same failure rate as the balance of the cohort. Although this assumption may not always be correct, any bias should affect all reporting equally in comparative series of knee arthroplasties. However, we believe that survivorship analysis becomes more valid when accompanied by a detailed analysis of a subset of the whole series. Hence we also present in this issue a paper reporting a 10 to 12 year study of the total condylar prosthesis (Vince, Insall and Kelly 1989 see pages 793 to 797).

For survivorship analysis the end-point and definition of failure must be clearly defined and reproducible. No standard clinical or radiographic grading system has been universally accepted; but the use of more sensitive end-points will obviously result in a higher failure rate. The quality of each result could not be considered in the survivorship analysis because of this difficulty of defining a precise and standard end-point. Pain is a nonspecific criterion because it is not objective, has a physician and patient bias and may not be related to the implant. Using revision or recommended revision provides an easily reproducible end-point and enables comparison with other prosthetic designs studied in a similar manner.

Our overall success rates indicate that changes in prosthetic design have improved the longevity of knee replacement, with seven year success in 92.6% of the total condylar prostheses, 97.3% of the posterior stabilised type with a polyethylene tibia and 98.8% for the posterior stabilised type with a metal-backed tibia. Since we have been using the metal-backed tibial component not one tibial component has been revised for loosening. The femoral loosening rate is also lower with the posterior stabilised component (0.3%) when compared to the total condylar (0.9%). This improvement may be partly due to better surgical technique in the posterior stabilised group. Infection has been the major cause of failure (0.65%) in the posterior stabilised prosthesis with the metal-backed tibia.

Comparing our survivorship data with those from recent studies using the same definition of failure revealed similar results. Knutson et al (1985) reported a five-year overall survival rate of 100% for tricompartmental prostheses (total condylar, kinematic and porous coated anatomic) and in a nationwide multicentre study of 8 000 knees Knutson et al (1986), report a six-year overall survival rate of 90% for similar prostheses.

Table IV. Overall success rates for the three types of prosthesis

	7 years	10 years	15 years
Original TCP	92.59	90.56	90.56
<i>Posterior stabilised</i>			
Polythene tibial	97.34	97.34	—
Metal-backed tibial	98.75	—	—

Our results do appear to be better than those for some earlier designs. Though some of these prostheses are now outdated, the results do provide long-term experience against which newer designs can be judged. Tew et al (1985) reported a six year survival of 72% in 365 replacements using the Freeman, Sheehan and Manchester prostheses and Lewallen et al (1984) reported a 10 year survival of 66% with the polycentric total knee. The longevity of our three prostheses is much better than that of the hinged arthroplasties. Grimer et al (1984) reported a seven year survival of 80% and Lettin et al (1984) an eight year survival of 83% for the Stanmore hinged prosthesis. Knutson et al (1986) reported a six year survival of 75% with the Guepar prosthesis.

Our overall success was comparable between knees with diagnoses of osteoarthritis and rheumatoid arthritis, and this has been shown in other studies (Lewallen et al 1984; Knutson et al 1986).

Survivorship analysis of total hip replacement using

the same end-point of failure allows comparison with our series of total knee replacement. Dobbs (1980) in reviewing 173 metal on metal Stanmore total hip replacements reported an 11-year overall survival of 53% and with 248 metal on plastic Stanmore total hip replacements an eight-year overall survival of 88%. Ritter and Campbell (1987) reported a 15-year overall survival of 65.4% with the Charnley total hip prosthesis, a 14-year overall survival of 55.8% with the Muller hip prosthesis and an 11-year overall survival of 82.8% with the Trapezoidal-28 hip prosthesis. The overall survival with total knees in our study appears better. Women and older patients had a significantly higher success rate as reported by Ritter and Campbell (1987), but this was not found in our total knee series.

In conclusion, cemented total knee replacement has

been a reliable procedure which so far has withstood the test of time. The overall success does not appear to be influenced by diagnosis, sex, age or percentage of ideal body weight. At present, the posterior stabilised prosthesis with a metal-backed tibial component is our prosthesis of choice for primary total knee replacement.

Good surgical technique, in particular component positioning, knee alignment, soft-tissue balance and minimal tibial resection, remains essential in obtaining a long lasting arthroplasty.

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