Long-Term Results After Placement of Dental Implants: Longitudinal Study of 1,964 Implants over 16 Years

Nicole Noack, MD*/Jürgen Willer, DMD**/Jürgen Hoffmann, MD, DMD***

In a retrospective study, Kaplan-Meier implant survival analyses were conducted on 883 patients with 1,964 implants of various systems placed, followed up, documented, and statistically evaluated at an oral surgery and dentistry practice between January 1981 and January 1997. The goal of this study was to evaluate the success of osseointegrated implants of the Brånemark, Frialit-1 (Tübinger Implant), Frialit-2, and IMZ systems and Linkow blade implants. For all systems, mandibular implants were generally more successful than maxillary implants. The preprosthetic loss rate was 1.9%, and 4.3% of implants were lost after prosthetic treatment. The lowest loss rates were seen with implants in intermediate and distal extension spaces and with single-tooth replacements using IMZ, Frialit-2, and Brånemark implants. In edentulous arches, implants of the IMZ and Brånemark systems had the lowest failure rates.
(Int J Oral Maxillofac Implants 1999;14:748–755)

Key words: dental implants, longitudinal study, long-term results

The evaluation of long-term treatment results for dental implants and the analysis of related success rates has been accomplished through clinical observation studies, either at single university-associated institutions or multiple treatment centers. Since reliable and usable data from independently practicing dentists employing implant technology is not readily available, it was deemed important to conduct a comparable survey based on the results of the longitudinal study of a patient population treated by colleagues in private practice.

The objective of the study was to determine the success of treatment with various implant systems and to develop long-term prognoses for these systems, taking diverse parameters into account. Further goals were to recognize possible factors that could have a direct influence on survival rates and to help answer the question of whether the positive results achieved at university clinics can also be attained under the conditions prevailing at practicing dentists' offices.

There has been a very significant increase in the interest shown by patients in receiving implant treatment, and the high rate of success with implant treatment is a major reason for this.[1–3] In addition, a marked widening of the indication spectrum has become possible because of the adjuvant surgical procedures and augmentative methods that can be employed, such as guided bone regeneration and sinus augmentation. The ability to determine nearly ideal implant positions has led to better functional and esthetic results.[4–11] Moreover, improved radiographic techniques have facilitated not only the planning but also the performance of implant surgeries.[12,13]

The fact that there is a series of statistically verified findings now available that is based on large-scale clinical studies of the use of various implant

*Research Associate, Department of Prosthodontic Dentistry, Dental School, University of Hannover, Hannover, Germany.
**Private Practice, Reutlingen, Germany.
***Research Associate, Department of Oral and Maxillofacial Surgery, University of Tübingen, Tübingen, Germany.

Reprint requests: Dr Jürgen Hoffmann, Department of Oral and Maxillofacial Surgery, University of Tübingen, Osianderstraße 2-8, 72076 Tübingen, Germany. E-mail: juergen.hoffman@uni-tuebingen.de

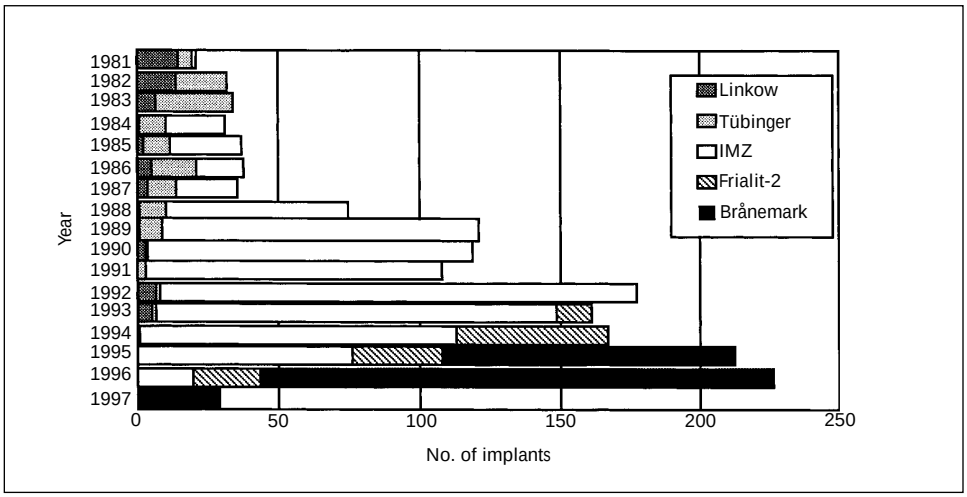

Fig 1 Implantation period. The systems evaluated have been used since 1982 (Frialit-1, Linkow), 1984 (IMZ), 1993 (Frialit-2), and 1995 (Brånemark).

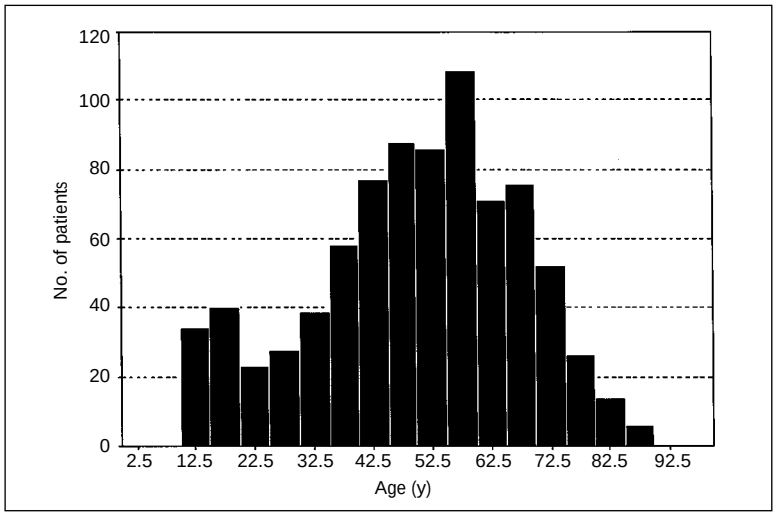

Fig 2 Age distribution among 883 patients examined.

systems in the edentulous jaw, in partially edentulous jaws, and for single-tooth replacement, has caused endosseous implants to be considered more frequently for prosthetic treatment measures, in academic and in private dental settings.[14–21]

Patient Material and Methods

Between January 1981 and January 1997, 1,964 implants from the Brånemark System (Nobel Biocare, Göteborg, Sweden); Frialit-1 (Tübinger Implant) and Frialit-2 Systems (Friatec, Mannheim, Germany); and IMZ System (Interpore International, Irvine, CA); as well as Linkow blade implants (Linkow, New York, NY) were placed in a total of 883 consecutive patients (Fig 1). The patients treated included 530 females and 353 males; their ages ranged from 15 to 86 years (Fig 2). Patients with a history of uncontrolled diabetes, ongoing chemotherapy, radiation therapy to the head and neck region, or psychologic instability were refused implant therapy. For this study, a statistical analysis was made on 1,250 IMZ implants in 527 patients, 349 Brånemark implants in 144 patients, 286 Frialit-1 and Frialit-2 implants in 151 patients, and 79 Linkow blade implants in 61 patients (Table 1).

The patients treated were not selected because of treatment indications or other criteria. All implants were placed by one surgeon, who also

Table 1 No. of Patients and Implants Distributed Among the Implant Systems Employed, According to Indication

Implant system	No. of implants	No. of patients	Patients lost to follow-up	Indication				Failures
				Single tooth	Intermediate space	Distal extension	Edentulous	
Brånemark	349	144	12	37	48	95	169	3
Frialit-1	146	83	6	72	19	25	30	49
Frialit-2	140	68	5	20	35	30	55	8
IMZ	1250	527	45	23	107	511	609	46
Linkow	79	61	6	3	6	59	11	16
Total	1964	883	74	155	215	720	874	122

planned and integrated the prosthodontic superstructures and performed the follow-up for the entire period.

When considering the sum total, it should be noted that some patients received more than one type of implant. The analysis included the type and rate of implant loss, as well as the results of regular clinical and radiographic examinations after placement. The findings of these examinations were recorded on survey sheets within the framework of a prospective study, to enable the patients treated to be recorded and monitored systematically.

Information gathered included patients' data (age, sex), Plaque Index, time of implantation (immediate or late implant), prosthetic indication for implantation (subdivided into maxilla and mandible), type of dental prosthesis (attached or removable), implant length and diameter, and the amount of bone resorption as recorded radiographically by means of orthopantomograms.

All patients were evaluated at 3-month intervals for the first 2 years after implant placement. Thereafter, each patient was evaluated at least annually. If patients were not seen for more than 1 year, they were considered lost to follow-up. Radiographs were taken immediately after implant placement and at each follow-up examination.

In this study, the criteria of Buser et al[4] were used to determine success. If one of these criteria was observed to be clinically negative or if peri-implant bone resorption (according to Albrektsson[22]) exceeded 1 mm after the first year and 0.1 mm annually thereafter, the implant was regarded as a failure.

Survival analyses for the implant systems employed were carried out according to the Kaplan-Meier method.[3,23,24] When analyzing the statistics, a distinction was made between a preprosthetic and a postprosthetic function period. The preprosthetic phase comprises the period from implant placement to the potential premature loss or until the implant has become a part of the prosthesis provided. In the postprosthetic phase, the period from providing the prosthesis to its loss, or to the time the last observation was made, was analyzed.

Using the survival analysis after Kaplan and Meier, it was possible to determine the success of the implant. The influence of the extent of plaque, sex of the patient, time of implant placement (immediately after loss or extraction of the tooth [immediate implant] or after osseous regeneration [late implant]), indication, location (maxilla or mandible), prosthesis type (fixed or removable), extent of bone resorption, type of implant, and length and diameter of implant, were determined by the Log-Rank Test. For the purposes of survival analysis, only the first implant placed in each patient was considered, so as to eliminate any errors caused by reciprocal effects involving more than one implant.

By means of a Cox regression analysis with stepwise approach, it was possible to check the independent influence of the parameters as covariables on the prognosis for the implant (Table 2). For all statistical tests, a significance level of $P < .05$ was determined.

Results

Overall Ratings. In total, 96.6% of the implants were late implants, and 3.4% were immediate; 10.9% were classified as intermediate spaces, 7.9% as single teeth, 36.7% as distal extension situations, and 44.5% as edentulous arches. With respect to location, 25.6% of implants were in maxillae and 74.4% were in mandibles. The mean survival time was 3.96 years, with a maximum of 15.3 years. Thirty-seven implants failed before a

Table 2 Cox Hazard Model, Prognostic Factors

Factor		Relative risk*	*P* value
Plaque	Found vs no plaque found	4.2 [2.4 to 7.2]	< .0001
Bone resorption	No vs yes	4.2 [2.4 to 7.3]	< .0001
Type of implant	Frialit-1 vs IMZ	3.4 [1.9 to 5.9]	< .0001
	Linkow vs IMZ	2.1 [1.0 to 4.3]	.05

*95% confidence interval.

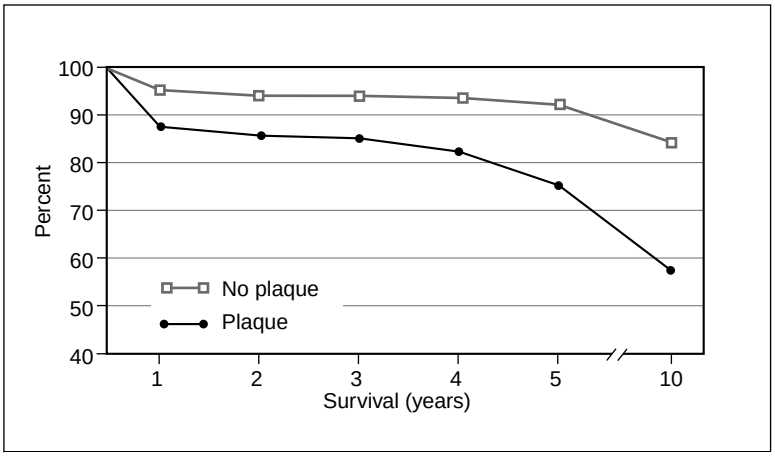

Fig 3 Survival analysis as a function of existing plaque (Plaque Index). *P* < .0001 (Log-Rank test).

prosthesis could be provided; 11 of these were single-tooth replacements, 1 was classified as intermediate space, 12 belonged to the category distal extension replacements, and 13 had been placed in edentulous arches. This showed an unloaded implant-oriented success rate of 98.1% according to the following criteria (based on Buser et al[4]):

- Absence of persistent subjective complaints, such as pain, foreign body sensation, and/or dysesthesia
- Absence of recurrent peri-implant infection with suppuration
- Absence of mobility
- Absence of a continuous radiolucency around the implant

In the postprosthetic phase, 85 implants were lost; 11 losses involved single-tooth replacements, 35 losses were recorded for distal extension replacements, and there were 31 losses among patients with edentulous arches. This resulted in a failure rate of 4.3% during the postprosthetic phase. Seventy-four patients with 153 implants were lost to follow-up because of various reasons (eg, refusal to follow-up, death).

To obtain a more accurate assessment of the influence of various factors on the survival rate, only the first implant placed in each patient was considered. When evaluating the influence of plaque, it was determined that in the group of patients with insufficient plaque removal, only 67% of the implants remained for 10 years, whereas the survival probability rate among patients without plaque was 90% for the same period (Fig 3).

Figures 4 to 6 show the influence of late or immediate placement, implant location, and bone resorption on implant survival. Implant placement in the mandible showed better results (survival rate: 83% after 10 years) than those in the maxilla (survival rate: 72% after 10 years). The diameter and length of the implants used showed no effect on the survival rate. In the multifactorial Cox

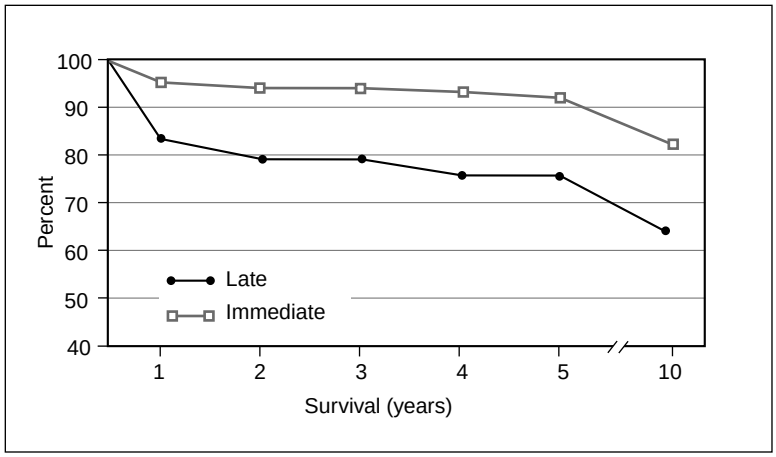

Fig 4 Survival analysis as a function of time of implant placement (late/immediate). $P < .001$ (Log-Rank test).

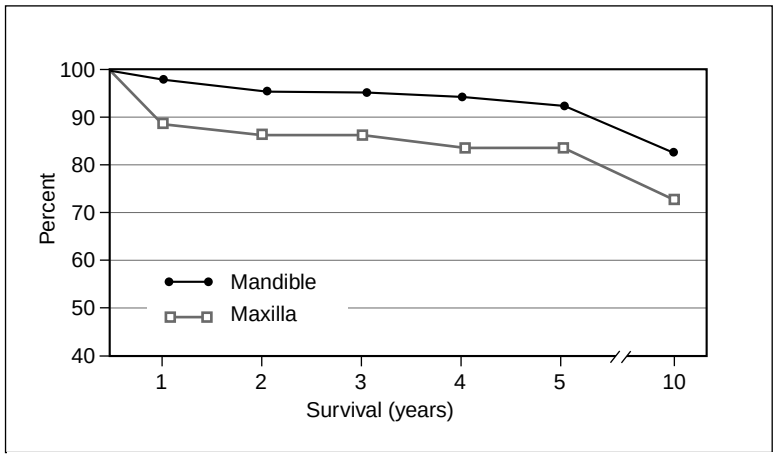

Fig 5 Survival analysis as a function of localization of placement (maxilla or mandible). $P < .01$ (Log-Rank test).

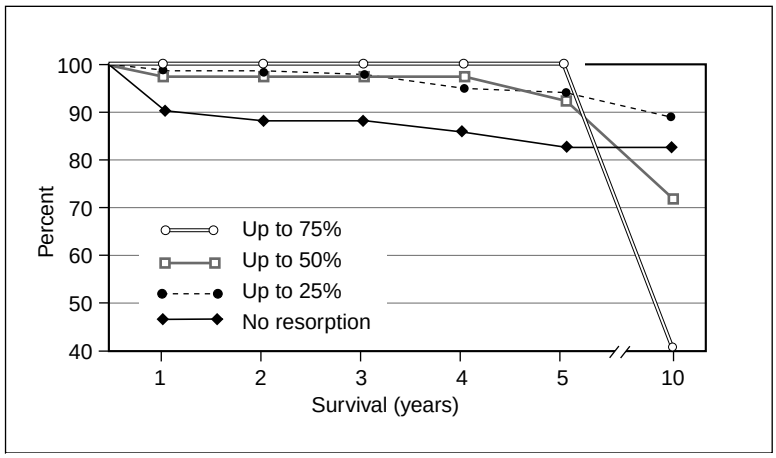

Fig 6 Survival analysis as a function of the extent of bone resorption. $P < .00001$ (Log-Rank test).

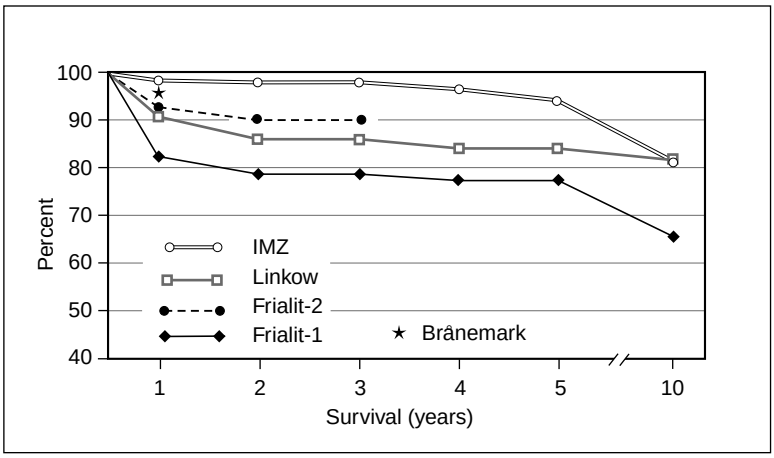

Fig 7 Comparison of the survival probability of the implants studied.

model, plaque and bone resorption were shown to be of independent prognostic effect on the survival rate of the implants. Figure 7 gives a direct comparison of the survival rate analyses of the 5 systems investigated.

Individual Ratings. *Brånemark.* The Brånemark implant has been routinely employed since March 1995. In 144 patients, 349 implants were used in the evaluation. Of these, 48.4% are in edentulous arches, 27.2% in distal extension situations, 13.8% in an intermediate space, and 10.6% in single-tooth spaces. Of the implants placed exclusively as late implants, 0.5% failed during the preprosthetic phase. Kaplan-Meier analysis showed a survival probability level of 96.2% for 1 year.

Frialit-1 (Tübinger Implant). The Tübinger implant, made of aluminum oxide ceramic, was used from January 1981 to June 1989. It was placed in 32.2% of the patients as an immediate implant and in 67.8% as a late implant. A total of 146 implants was placed in 83 patients; 49.3% of the implants were employed as single-tooth replacements, 13% to restore intermediate spaces, 17.1% in distal extension situations, and 20.6% in edentulous maxillae or mandibles. In 7 patients (4.8%) fractures of the implants were seen between 1.5 years and 3.2 years after placement. Of the total number of failures, 28.6% occurred during the preprosthetic phase and 71.4% took place in the postprosthetic phase. The survival analysis yielded a survival probability rate of 82.1% after 1 year and 69.6% after 10 years.

Frialit-2. Since June 1989, 140 of these implants, which are made of pure titanium and developed as a modification of the Frialit-1 implants, have been placed in 68 patients; 14.3% were used for single-tooth replacements, 25% for intermediate spaces, 39.3% in edentulous arches, and 21.4% in distal extension situations. Altogether, 5.7% of the implants failed; 75% of these losses took place during the preprosthetic period and 25% occurred during the postprosthetic period. The survival probability rate for 1 year was 92.7%.

IMZ. Since March 1984, 1,250 IMZ implants have been placed in 527 patients. They were subdivided into 1.8% single-tooth replacements, 8.6% intermediate spaces, 40.9% distal extension situations, and 48.7% edentulous arches. Forty-six failures occurred; 23.9% took place during the preprosthetic phase and 76.1% occurred during the postprosthetic phase. Kaplan-Meier analysis yielded a survival probability level of 98.2% for 1 year and 81% after 10 years.

Linkow Blade Implants. Of the 79 extension blade implants placed in 61 patients since January 1981, 13.9% were placed in edentulous mandibles, 3.8% in single-tooth spaces, 7.6% in intermediate spaces, and 74.7% in distal-extension situations. The survival rate was 90.1% for 1 year and 81.4% after 10 years. Sixteen implant failures were recorded, 25% in the preprosthetic period and 75% in the postprosthetic period. Forty-two implants are still in situ, and 21 implants have been lost to follow-up because of patient deaths.

Discussion

In this study, the definition of successful implant placement was based on the criteria published by Buser et al.[4] The implantation results presented are

Table 3 Postoperative Observation Period and Failure Rates

Implant system	Follow-up (mo.)	Total	Indication			
			Single tooth	Intermediate space	Distal extension	Edentulous arch
Brånemark	10	2/53 (4%)	1/5 (20%)	1/1 (100%)	0/15 (0%)	0/32 (0%)
Frialit-1	94.5	26/78 (33%)	17/57 (30%)	3/8 (37%)	3/6 (50%)	3/7 (43%)
Frialit-2	23	4/42 (9%)	0/15 (0%)	0/11 (0%)	0/6 (0%)	4/10 (40%)
IMZ	49	32/500 (6%)	1/45 (2%)	1/45 (2%)	19/205 (9%)	11/232 (5%)
Linkow	112	13/53 (24%)	—	1/3 (33%)	8/42 (19%)	4/6 (66%)

based on an evaluation of the Brånemark, Frialit-1 (Tübinger), Frialit-2, IMZ, and Linkow implant systems, with a total of 1,964 implants placed in 883 patients (Table 3). In spite of the low failure rates experienced up to 1995, the IMZ system was replaced by Brånemark implants because of the IMZ system's elastic intramobile elements, which are made of plastic and have been regarded as problematic. Nevertheless, because the 349 Brånemark implants placed have as yet undergone only a short median observation period of 10 months, further internal investigations will have to be made before it is possible to directly compare Brånemark implants with the much larger group of patients (n = 527) with IMZ implants.

The assumption that the edentulous arch, especially the mandible, should be regarded as the classically indicated site for osseointegrated implants, was also confirmed in this study; 772 implants were placed in edentulous mandibles and 102 were placed in edentulous maxillae. IMZ implants were used most frequently (609), but the number of Brånemark implants is increasing rapidly (169 thus far). Because of the considerable expense of implant placement surgery the number of patients with removable denture prostheses supported by 2 or 4 implants per arch is significantly greater than the number of those with 6 or more implants.

In patients with single-tooth loss, most were treated with Tübinger implants (72 were placed). At 37 implants thus far, Brånemark implants are also being used more frequently for this indication. In patients with distal extension and intermediate spaces, 511 and 107 IMZ implants, plus 95 and 48 Brånemark implants, were placed respectively. Because the Frialit-1, IMZ, and Linkow systems had been in use longer, it was possible to compile success probability rates in patient-related statistical analyses beyond 10 years. At 69.6% for Frialit-1, 81% for IMZ, and 81% for Linkow blade implants, they are generally lower than comparable levels reported by other authors for Brånemark implants.[14,17,18,25–27]

Implant use can be differentiated according to the location of the implants, mainly in the mandible or maxilla. Brånemark implants were used in the mandible (77.1%) in greater numbers than in the maxilla (22.9%). The Tübinger implants (Frialit-1), which were often used as immediate implants (32.2%), and the Frialit-2 implants were placed mainly in the maxilla (86.3% and 69.9%, respectively). In contrast, IMZ implants and Linkow blade implants were placed mainly in the mandible (86.8% and 82.2%, respectively). The results of this study showed a higher survival probability for osseointegrated implants in the mandible than for those in the maxilla. The reason for this is the lower mechanical stress that the maxilla will withstand because of its thinner cortical layer, as well as the lower density of the maxillary spongiosa.[11,27–29]

For single-tooth and intermediate space indications, the lowest failure rates demonstrated in the analyses, reduced to 1 implant per patient, were seen in the IMZ and Frialit-2 implants. Implants placed in unilateral or bilateral distal extension situations yielded similar results, and Brånemark implants showed no failures for this indication. In edentulous arches, the best results were achieved using IMZ and Brånemark implants.

In the multifactorial Cox model, it was possible to demonstrate that among those factors that could have an influence on the survival rate, plaque and bone resorption proved to be independent prognostic factors. Moreover, it was confirmed that the prognosis for late implants and mandibular implants was more favorable than that for immediate implants and maxillary implants. The sex of the patient, indication, type of prosthesis, and length and diameter of implants proved to be insignificant in determining implant success.

Conclusions

This retrospective study of a large number of implants placed over a period of 16 years shows that plaque, time of placement, location of implants, and the extent of peri-implant bone resorption have primary influence on the long-term survival of the implants. High failure rates were found with the older systems, Frialit-1 and Linkow blades. Dental implants may have some limitations, but they are now an indispensable adjunct in prosthodontic rehabilitation.

References

1. Adell R, Lekholm U, Rockler B, Brånemark P-I. A 15-year study of osseointegrated implants in the treatment of the edentulous jaw. Int J Oral Surg 1981;10(6):387–416.
2. D'Hoedt B, Handtmann S, Gomez-Roman G, Axmann D, Jahn M, Schulte W. Verweildaueranalysen nach Kaplan-Meier und Cutler-Ederer für enossale Implantate verschiedener Systeme. Z Zahnärztl Implantol 1996;12: 110–120.
3. Richter EJ, Jansen V, Spiekermann H, Jovanovic SA. Langzeitergebnisse von IMZ und TPS-Implantaten im interforaminalen Bereich des zahnlosen Unterkiefers. Dtsch Zahnärztl Z 1992;47:449–454.
4. Buser D, Brägger U, Lang NP, Nyman S. Regeneration and enlargement of jaw bone using guided tissue regeneration. Clin Oral Implants Res 1990;1(1):22–32.
5. Edel A. The use of a connective tissue graft for closure over an immediate implant covered with occlusive membrane. Clin Oral Implants Res 1995;6(1):60–65.
6. Hammerle CH, Fourmousis I, Winkler JR, Weigel C, Brägger U, Lang NP. Successful bone fill in late peri-implant defects using guided tissue regeneration. A short communication. J Periodontol 1995;66(4):303–308.
7. Lang NP, Brägger U, Hammerle CH, Sutter F. Immediate transmucosal implants using the principle of guided tissue regeneration. I. Rationale, clinical procedures and 30-month results. Clin Oral Implants Res 1994;5(3):154–163.
8. Lang NP, Hammerle CH, Brägger U, Lehmann B, Nyman SR. Guided tissue regeneration in jawbone defects prior to implant placement. Clin Oral Implants Res 1994;5(2): 92–97.
9. Lehmann B, Brägger U, Hammerle CH, Fourmousis I, Lang NP. Treatment of an early implant failure according to the principles of guided tissue regeneration (GTR). Clin Oral Implants Res 1992;3(1):42–48.
10. Nyman S, Lang NP, Buser D, Brägger U. Bone regeneration adjacent to titanium dental implants using guided tissue regeneration: A report of two cases. Int J Oral Maxillofac Implants 1990;5(1):9–14.
11. Olsson M, Gunne J, Åstrand P, Borg K. Bridges supported by free-standing implants versus bridges supported by tooth and implant. A five-year prospective study. Clin Oral Implants Res 1995;6(2):114–121.
12. Brägger U, Burgin W, Fourmousis I, Lang NP. Image processing for the evaluation of dental implants. Dentomaxillofac Radiol 1992;21(4):208–212.
13. Brägger U, Burgin W, Lang NP, Buser D. Digital subtraction radiography for the assessment of changes in peri-implant bone density. Int J Oral Maxillofac Implants 1991; 6(2):160–166.
14. Brånemark P-I, Svensson B, van Steenberghe D. Ten-year survival rates of fixed prostheses on four or six implants ad modum Brånemark in full edentulism. Clin Oral Implants Res 1995;6(4):227–231.
15. Buser D, Weber HP, Brägger U, Balsiger C. Tissue integration of one-stage ITI implants: 3-year results of a longitudinal study with hollow-cylinder and hollow-screw implants. Int J Oral Maxillofac Implants 1991;6(4):405–412.
16. Henry PJ, Laney WR, Jemt T, Harris D, Krogh PH, Polizzi G, et al. Osseointegrated implants for single-tooth replacement: A prospective 5-year multicenter study. Int J Oral Maxillofac Implants 1996;11(4):450–455.
17. Hutton JE, Heath MR, Chai JY, Harnett J, Jemt T, Johns RB, et al. Factors related to success and failure rates at 3-year follow-up in a multicenter study of overdentures supported by Brånemark implants. Int J Oral Maxillofac Implants 1995;10(1):33–42.
18. Jemt T, Chai J, Harnett J, Heath MR, Hutton JE, Johns RB, et al. A 5-year prospective multicenter follow-up report on overdentures supported by osseointegrated implants. Int J Oral Maxillofac Implants 1996;11(3): 291–298.
19. Jemt T, Lekholm U. Implant treatment in edentulous maxillae: A 5-year follow-up report on patients with different degrees of jaw resorption. Int J Oral Maxillofac Implants 1995;10(3):303–311.
20. Johns RB, Jemt T, Heath MR, Hutton JE, McKenna S, McNamara DC, et al. A multicenter study of overdentures supported by Brånemark implants. Int J Oral Maxillofac Implants 1992;7(4):513–522.
21. Naert I, Quirynen M, van Steenberghe D, Darius P. A six-year prosthodontic study of 509 consecutively inserted implants for the treatment of partial edentulism. J Prosthet Dent 1992;67(2):236–245.
22. Albrektsson T, Zarb G, Worthington P, Eriksson AR. The long-term efficacy of currently used dental implants: A review and proposed criteria of success. Int J Oral Maxillofac Implants 1986;1(1):11–25.
23. Quirynen M, Bollen CM, Eyssen H, van Steenberghe D. Microbial penetration along the implant components of the Brånemark system. An in vitro study. Clin Oral Implants Res 1994;5(4):239–244.
24. Quirynen M, Bollen CM, Papaioannou W, Van Eldere J, van Steenberghe D. The influence of titanium abutment surface roughness on plaque accumulation and gingivitis: Short-term observations. Int J Oral Maxillofac Implants 1996;11(2):169–178.
25. Kaplan EL, Meier P. Nonparametric estimation from incomplete observations. J Am Statist Assoc 1958;53: 457–469.
26. Jahn M, d'Hoedt B. Zur Definition des Erfolges bei dentalen Implantaten. Zahnärztl Implantol 1992;8:221–222.
27. Kirsch A, Ackermann KL. Le systeme d'implants IMZ. Methode-clinique-resultats. Dent News 1987;9(61):17–18.
28. Kirsch A, Mentag PJ. The IMZ endosseous two phase implant system: A complete oral rehabilitation treatment concept. J Oral Implantol 1986;12(4):576–589.
29. Dietrich U, Lippold R, Dirmeier T, Behneke N, Wagner W. Statistische Ergebnisse zur Implantatprognose am Beispiel von 2017 IMZ- Implantaten unterschiedlicher Indikation der letzten 13 Jahre. Z Zahnärtzl Implantol 1993;9:9–18.