A Long-term Retrospective Analysis of Survival Rates of Implants in the Mandible

Thomas J. Balshi, DDS, PhD, FACP[1]/Glenn J. Wolfinger, DMD, FACP[2]/
Brett E. Stein[3]/Stephen F. Balshi, MBE[4]

Purpose: *To retrospectively analyze the survival rate of endosseous dental implants placed in the edentulous or partially edentulous mandible over a long-term follow-up period of 10 years or more.* ***Materials and Methods:*** *The charts of patients who underwent mandibular implant placement at a private prosthodontic practice and received follow-up care for 10 years or more were included in this study. Implants were examined according to the following study variables: patient sex, patient age, degree of edentulism (fully vs partially edentulous), implant location, time of loading (delayed vs immediate), implant size and type, bone quality, prosthesis type, and the presence of other implants during placement.* ***Results:*** *The study sample was composed of 2,394 implants placed in 470 patients with 10 to 27 years of follow-up. Of these 2,394 implants, 176 failed, resulting in an overall cumulative survival rate (CSR) of 92.6%. A total of 1,482 implants were placed in edentulous mandibles, and 912 implants were placed in partially edentulous mandibles, with CSRs of 92.6% and 92.7%, respectively. Comparisons of the study variables with respect to CSR were largely nonsignificant. However, there were significant differences in CSRs between anterior vs posterior locations and rough- vs smooth-surfaced implants in addition to some prosthesis types, ages, and bone qualities. The overall CSR of 92.6% in the present study is high and comparable to survival rates observed in previous long-term analyses of mandibular implants. The significant differences observed between implant locations, patient age groups, bone qualities, and prostheses were not suggestive of any remarkable trends.* ***Conclusion:*** *Patient sex, age, degree of edentulism, implant location, time of loading, implant size and type, bone quality, prosthesis type, and the presence of multiple implants did not result in any significant effect on long-term implant survival. The CSR observed after 10 to 27 years of follow-up in a single private prosthodontic center was high (92.6%) and supports the use of endosseous dental implants as a long-term treatment option for the rehabilitation of the edentulous and partially edentulous mandible.*
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Key words: *dental implants, life-history analysis, long-term study, mandibular rehabilitation, osseointegration, survival rates*

Since the creation of the titanium implant by Brånemark et al[1] over 45 years ago, it has been used and advanced as an effective restorative approach in the rehabilitation of the partially edentulous and edentulous jaw.[2,3] In addition to the effective support of removable and fixed dental prostheses, implants that achieve osseointegration are also beneficial in slowing and possibly halting residual ridge resorption after tooth extraction.[4] The latter benefit has stimulated focus on the efficacy of implants placed in the partially and fully edentulous mandible because it has been shown that rates of residual ridge resorption can be up to four times faster in the mandible relative to the maxilla.[5]

The use of titanium implants in rehabilitation has primarily been successful over several decades. However, osseointegration has occasionally been subject to late failure. In 1982, the Conference on Osseointegration in Clinical Dentistry proposed that a given type of implant must have a survival rate of 95% in a 5-year follow-up and 90% in a 10-year follow-up.[6,7] Although the causes of failure are not fully understood, failures are most commonly the result of advanced age, systemic

[1]Founder and Prosthodontist, Pi Dental Center, Institute for Facial Esthetics, Fort Washington, Pennsylvania, USA.
[2]Prosthodontist, Pi Dental Center, Institute for Facial Esthetics, Fort Washington, Pennsylvania, USA.
[3]Student, School of Dental Medicine, University of Pennsylvania, Philadelphia, Pennsylvania, USA.
[4]President, CM Prosthetics; Director of Research, Pi Dental Center, Institute for Facial Esthetics, Fort Washington, Pennsylvania, USA.

Correspondence to: Mr Stephen Balshi, Institute for Facial Esthetics, 467 Pennsylvania Avenue, Suite 201, Fort Washington, PA 19034, USA. Fax: 215-643-1149. Email: stephen.balshi@cmprosthetics.com

disease, compromised oral hygiene, and surgical complications.[7] Health complications of particular concern include osteoporosis, diabetes, smoking, and alcohol consumption.[8] In an early retrospective study, Adell et al[9] reported cumulative survival rates (CSRs) of 86% for implants in the mandible and 78% in the maxilla for observation periods of up to 15 years. Advances in surgical techniques and implant types have resulted in reports of higher long-term survival rates of 95% in the mandible and 87% in the maxilla.[10] In the mandible, there is also potential for varying success of posterior and anterior osseointegrated implants. Possible factors influencing success include an increased progression of residual ridge resorption in an inferior-anterior direction in the edentulous mandible[5] relative to the partially dentate mandible and prosthetic limitations of the posterior jaw.[11] Studies show similar survival rates for Brånemark system implants placed in fully edentulous[12] and partially edentulous mandibles[13]; anterior and posterior mandibular implants show survival rates above 95%.[11,14]

When considering the type and timing of an implant-supported prosthesis, it has also been shown that both immediate and delayed loading of endosseous implants have resulted in high success rates that are comparable.[15] Similarly, the type of prosthesis in fully edentulous[16] and partially edentulous[17] mandibles has not been shown to affect implant survival rates. However, in a study by Bryant et al[16] on the effect of prosthesis type on implant survival in the edentulous mandible, the authors suggest that prosthesis design, rather than type, might influence implant survival because of variations in prosthesis maintenance.

The promise of the osseointegrated implant in rehabilitating the partially and fully edentulous jaw is supported by numerous retrospective studies that have reported success rates above 90% in the mandible.[9,10,18–22] Although the successes of mandibular implants in 5-year and 10-year follow-up studies are numerous, reports of follow-up beyond 10 years are lacking in the literature.

The purpose of this retrospective study was to examine, after follow-up periods of 10 years or more, the survival of Brånemark system endosseous dental implants placed in the mandible to better understand trends in the long-term life history of the implant and to investigate potential factors that may contribute to implant failure.

MATERIALS AND METHODS

Study Design/Sample

The charts of patients who underwent mandibular implant placement at a prosthodontic private practice (PI Dental Center, Institute for Facial Esthetics, Fort Washington, Pennsylvania, USA) were examined. Patients with follow-up periods of 10 years or longer were selected for this study to examine the long-term outcomes of implant placement in partially or completely edentulous mandibles. Implants placed in patients who underwent 10 years of follow-up or more, but became inactive at some point after 10 years, were included in the study up to the year of their last appointment and excluded from CSR calculations in the years to follow. Excluded entirely from this study were implants placed in patients who did not return to the private practice for at least 10 years of follow-up. A patient's most recent appointment date was used to calculate follow-up time.

Table 1 Life History Analysis

Period	Implants	Failures	Inactive	Survival rate (%)	Cumulative survival rate (%)
0–3 mo	2,394	34	0	98.6	98.6
3–6 mo	2,360	64	0	97.3	95.9
6–9 mo	2,296	8	0	99.7	95.6
9–12 mo	2,288	3	0	99.9	95.4
1 y	2,285	4	0	99.8	95.3
2 y	2,281	10	0	99.6	94.9
3 y	2,271	9	0	99.6	94.5
4 y	2,262	4	0	99.8	94.3
5 y	2,258	5	0	99.8	94.1
6 y	2,253	4	0	99.8	93.9
7 y	2,249	4	0	99.8	93.8
8 y	2,245	1	0	100.0	93.7
9 y	2,244	3	0	99.9	93.6
10 y	2,241	3	333	99.9	93.5
11 y	1,905	3	271	99.8	93.4
12 y	1,631	1	225	99.9	93.3
13 y	1,405	4	207	99.7	93.1
14 y	1,194	1	129	99.9	93.1
15 y	1,064	2	147	99.8	93.0
16 y	915	1	120	99.9	93.0
17 y	794	4	110	99.5	92.8
18 y	680	2	117	99.7	92.7
19 y	561	0	157	100.0	92.7
20 y	404	0	86	100.0	92.7
21 y	318	2	85	99.4	92.6
22 y	231	0	63	100.0	92.6
23 y	168	0	96	100.0	92.6
24 y	72	0	23	100.0	92.6
≥ 25 y	49	0	49	100.0	92.6

Study Variables

The following nine study variables were chosen in the present study: *(1)* patient sex, *(2)* patient age at the time of implant placement, *(3)* edentulous vs partially edentulous mandibles, *(4)* implant location (anterior vs posterior), *(5)* loading protocol (immediate vs delayed), *(6)* implant size and type, *(7)* bone quality, *(8)* prosthesis type, and *(9)* multiple vs single implant placement procedure. Study variables were recorded for each implant at the time of implant placement or prosthesis delivery. Patient ages were grouped in cohorts spanning 10-year intervals. Bone quality was classified as types 1 through 4, following the Lekholm and Zarb criteria.[21] Anterior teeth included those spanning canine to canine, and posterior teeth included premolars and molars. Mandibular edentulism was defined irrespective of patients' maxillary dentition. Prostheses included in this study were single crowns, fixed partial dentures, acrylic or porcelain full-arch prostheses, and overdentures. The study sample was also divided in two groups: implants that were placed in the presence of multiple implants in the same mandible and implants placed alone to control for the possible confounding factor of the presence of multiple implants in each patient.

Outcome Variable

The outcome variable was implant CSR. Early failures, defined as those occurring earlier than 10 years from the time of placement, were noted and calculated into CSRs. Failures were recorded at 3-month intervals for the first year after implant placement and at yearly intervals thereafter.

Data Analyses

Statistical analyses were performed using the Kruskal-Wallis nonparametric test with a 95% confidence level ($P < .05$). The database was maintained using an Excel spreadsheet (Microsoft), and study variables were analyzed using the XLSTAT add-on statistical package.

RESULTS

A total of 470 patients (5.1 implants per patient; 153 men, 317 women; mean age, 56.62 years; age range, 11 to 86 years) underwent mandibular implant placement between August 1986 and July 2003. A total of 2,394 implants were placed for an overall implant survival rate of 92.6%. Table 1 shows the number of functioning implants and CSRs for each recorded length of time. The majority (55.7%) of failures occurred within the first 6 months of placement.

Of 837 implants placed in men, 67 failed, and of 1,557 implants placed in women, 109 failed, which resulted in CSRs of 92.0% and 94.5%, respectively (Table 2). No significant differences were found between men and women ($P > .05$). The differences in CSRs for implants placed in patients aged 60 to 69 years (94.6%) and both 40 to 49 years (91.2%) and 50 to 59 years (91.9%) were statistically significant ($P < .05$); however, CSRs for implants in the other patient age groups were similar ($P > .05$) (Table 2). Implants placed in fully and partially edentulous mandibles accounted for 1,482 (61.9% of total) and 912 (38.1% of total), respectively, with CSRs equaling 92.6% and 92.7%, respectively. There were 1,504 (62.8% of total) and 890 (37.2% of total) implants placed in the posterior and anterior aspects of the mandible, respectively. Implants placed posteriorly resulted in a 91.4% CSR while implants placed anteriorly resulted in a 94.7% CSR (Table 2). There was a statistically significant difference ($P < .05$) between CSRs of anterior and posterior implants. Of the 365 (CSR = 94.0%) implants that were immediately loaded with a screw-retained prosthesis, 343 survived, whereas 1,884 of the 2,029 (CSR = 92.4%) implants in delayed-loading cases survived (Table 2). Differences in loading protocol did not result in statistically significant differences with respect to implant CSRs ($P > .05$). With respect to bone quality, however, there was a significant difference ($P < .05$) in the survival rates of implants placed in type 3 bone (93.5%) vs both type 1 (86.2%) and type 4 bone (87.9%). Bone quality was only recorded for 1,173 of the 2,394 (49%) implants placed. This smaller sample size is a result of the lack of data on bone quality during the earlier years of this study (Table 2).

In the current study, 1,385 (57.9% of total) implants supported a full-arch acrylic prosthesis with a CSR of 96.6%. This CSR, in addition to those of implants supporting single crowns (CSR = 94.0%) and fixed partial dentures (CSR = 95.6%) were significantly different ($P < .05$) from the 81.5% CSR seen in the 27 implants (1.1% of total) that supported full-arch porcelain prostheses in seven patients (Table 2). No statistically significant difference was seen between any two CSRs of implants supporting single crowns, fixed partial dentures, full-arch acrylic prostheses, overdentures, or implants that were not loaded. Of all of the implants placed, 82 (46.6%) of the 176 failures did not survive long enough for prosthetic loading. Of the implants placed in this study, 2,326 (97.1% of total) were placed in addition to other implants during the same procedure. The CSRs of implants placed in the presence of other implants (92.8%) and implants placed alone (88.2%) were similar ($P > .05$) (Table 2).

The most common implant size used was the 3.75 × 10-mm machine-surfaced Brånemark system implant (24.9%). A total of 2,115 (88.3% of total) machine-surfaced and 279 (11.7% of total) rough-surfaced

Table 2 Cumulative Survival Rates for Study Variables

Variable	Implants placed	Failures	Cumulative survival rate (%)
Sex			
Male	837	67	92.0
Female	1,557	109	94.5
Age (y)			
10–19	16	1	93.8
20–29	57	7	87.7
30–39	167	12	92.8
40–49	407	36	91.2*
50–59	708	57	91.9†
60–69	753	41	94.6*†
70–79	266	19	92.9
80–89	20	3	85.0
Edentulism			
Partially edentulous	912	67	92.7
Fully edentulous	1,482	109	92.6
Location (tooth no.)[a]			
Anterior (31–33; 41–43)	890	47	94.7‡
Posterior (34–38; 44–48)	1,504	129	91.4‡
Time of loading			
Immediate	365	22	94.0
Delayed	2,029	154	92.4
Bone quality			
Type 1	65	9	86.2§
Type 2	363	28	92.3
Type 3	604	39	93.5§‖
Type 4	141	17	87.9‖
Prosthesis			
Single crown	218	13	94.0¶
Fixed partial	662	29	95.6**
Full arch: acrylic	1,385	47	96.6††
Full arch: porcelain	27	5	81.5¶**††
Overdenture	12	0	100
Not loaded	8	0	100
Failed before loading	82	82	0
Multiple implants			
Yes	2,326	168	92.8
No	68	8	88.2

*P < .05 for patients aged 40–49 years vs 60–69 years.
†P < .05 for patients aged 50–59 years vs 60–69 years.
‡P < .05 for anterior vs posterior mandibular implants.
§P < .05 for implants in type 1 vs type 3 bone.
‖P < .05 for implants in type 3 vs type 4 bone.
¶P < .05 for single-crown vs full-arch porcelain prostheses.
**P < .05 for fixed partial dentures vs full-arch porcelain prostheses.
††P < .05 for full-arch acrylic vs full-arch porcelain prostheses.
[a]FDI tooth-numbering system.

Table 3 Survival Rates of Brånemark System Implants Based on Size and Type

Implant size and type	Sample (%)	No. of implants	No. of failures	Survival rate (%)
3.75 unknown*	1.9	45	0	100
3.3 × 13 Mk II	0.1	2	0	100
3.75 × 10	24.9	597	40	93.3
3.75 × 10 MK III	0.3	8	0	100.0
3.75 × 10 MK III TiURP	1.3	32	2	93.8
3.75 × 13	10.4	250	20	92.0
3.75 × 13 MK III	0.5	11	0	100
3.75 × 13 MK III TiURP	1.1	27	0	100
3.75 × 15	16.2	388	33	91.5
3.75 × 15 MK III TiURP	2.1	51	3	94.1
3.75 × 18	9.6	229	11	95.2
3.75 × 18 MK III	0.0	1	0	100
3.75 × 18 MK III TiURP	1.6	38	1	97.4
3.75 × 20	3.6	87	6	93.1
3.75 × 7	2.8	67	8	88.1
3.75 × 8.5	3.5	84	11	86.9
3.75 × 8.5 MK III TiURP	0.2	5	0	100
4 × 15	1.4	33	0	100
4 × 15 MK IV TiURP	0.6	14	0	100
4 × 10	4.4	106	18	83.0
4 × 10 Ebon	0.6	15	0	100
4 × 10 MK III TiURP	0.2	5	0	100
4 × 10 MK IV	0.2	5	0	100
4 × 10 MK IV TiURP	2.3	54	3	94.4
4 × 11.5 Ebon	0.0	1	0	100
4 × 13	1.6	38	5	86.8
4 × 13 MK III	0.1	2	0	100
4 × 13 MK III TiURP	0.2	4	0	100
4 × 13 MK IV	0.2	4	0	100
4 × 13 MK IV TiURP	0.3	6	0	100
4 × 13 RP Ebon	0.1	2	0	100
4 × 15 Ebon	0.1	2	1	50.0
4 × 15 MK III TiURP	0.3	7	0	100
4 × 18	1.0	23	1	95.7
4 × 18 Ebon	0.1	2	2	0
4 × 18 MK III TiURP	0.3	6	0	100
4 × 18 MK IV TiURP	0.5	12	0	100
4 × 7	0.3	6	1	83.3
4 × 7 MK IV TiURP	0.1	2	0	100
4 × 7 RP Ebon	0.1	2	0	100
4 × 8.5	0.3	8	0	100
4 × 8.5 MK III TiURP	0.2	5	0	100
4 × 8.5 MK IV TiURP	0.5	11	0	100

*Length unknown for diameter indicated.

Table 3 *Continued* **Survival Rates of Brånemark System Implants Based on Size and Type**

Implant size and type	Sample (%)	No. of implants	No. of failures	Survival rate (%)
5.5 × 10 MK II	0.1	2	0	100
5.5 × 13 MK II WP	0.1	2	0	100
5 × 10	1.5	35	5	85.7
5 × 10 Ebon WP	0.1	2	1	50
5 × 10 MK II WP	0.3	7	1	85.7
5 × 12	1.1	27	1	96.3
5 × 12 RP	0.3	6	0	100
5 × 13	0.1	2	0	100
5 × 13 Ebon WP	0.1	2	0	100
5 × 13 MK II WP	0.1	2	0	100
5 × 6	0.2	4	1	75
5 × 8	0.3	6	1	83.3

*Length unknown for diameter indicated.

(TiUnite anodized) implants were placed, with CSRs of 92.1% and 96.8%, respectively. This difference in CSRs was statistically significant ($P < .05$). Table 3 contains a distribution of the implants placed and data related to implant survival. Figure 1 displays a fully edentulous patient who was followed for 25 years, and Figs 2 and 3 are examples of two partially edentulous patients who were followed for 22 years.

DISCUSSION

The Brånemark system implant CSRs of 94.1% after 5 years and 93.5% after 10 years observed in the current report were similar to the survival rates observed in previous retrospective studies over similar lifespans.[9,10,18–22] In addition, the survival rate after 10 or more years of follow-up for the Brånemark system implants used in this study were all above 90%, exceeding the benchmark for success established by the 1982 Conference on Osseointegration in Clinical Dentistry.[6] Nevertheless, the 5-year CSR for Brånemark system implants (94.1%) was 0.9% below the Conference's standard of a 95% survival rate after 5 years of follow-up. For all implants placed in this study, the CSR of 95.9% after 6 months of follow-up dropped to 92.6% at 25 or more years of follow-up. This small change in survival rate over 25 years is suggestive of a very successful prognosis after a critical 6-month period, which may endure decades of function. These observations are consistent with early studies on osseointegration that showed that a healing period of 3 to 6 months is necessary for successful osseointegration and that the majority of failures occur during this time.[1,2]

The long-term follow-up data after 10 to 25 or more years in this study were also consistent with data from previous retrospective studies showing no significant correlation between implant failure and sex,[21] age,[22] loading time,[15,23] and degree of edentulism.[12,13] Conversely, the present study found a significant difference between CSRs with respect to implant location. Although the survival rates of implants in the anterior and posterior mandible were high (94.7% and 91.4%, respectively), in concurrence with previous studies,[11,14,24] the present study findings are also consistent with those of Tolstunov[25] that proposed an approximately 4% difference between survival rates in the anterior and posterior mandible. It is suggested that this difference may be the result of increased susceptibility to ischemia in the posterior mandible relative to the anterior mandible. However, Balshe et al[26] suggested that although there are differences in anterior and posterior survival rates with smooth-surfaced implants, the data do not support a correlation between anatomical location and implant failure with rough-surfaced implants. The correlation found in the present study between location and failure is supported by the disproportionate amount of smooth-surfaced implants placed (Table 3). Likewise, the present data support increased performance of rough-surfaced implants (CSR = 96.8%) relative to smooth-surfaced implants (CSR = 92.1%).

Statistically significant differences were also found in CSRs of type 3 and type 1 bone as well as type 3 and type 4 bone. These data are partially consistent with the link between type 4 bone and lower success rates,[22,27] but do not support findings in the literature of similar survival rates for implants placed in types 1, 2, and 3 bone.[22,28] Likewise, the significantly higher CSR of the implants placed supporting single crowns, fixed bridges, and full-arch acrylic prostheses relative to the 27 implants that supported full-arch porcelain prostheses (1.1% of total) may not be suggestive of any major trend because these 27 units supported only seven patients in this study.

Factors such as surgical complications, osteoporosis, poor oral hygiene, tobacco use, and diabetes are among some additional variables that may lead to failure. However, these variables were not included in the present study because the records for these variables 10 to 25 years ago were not as categorically charted as they are today; therefore, the data were insufficient to provide meaningful results. Nevertheless, it is unlikely that any one factor might play an overriding role in predicting the success of an implant. Rather, myriad host-specific and environmental factors likely contribute, in various combinations, to osseointegration failure. Future studies might focus on identifying distinct combinations of such factors.

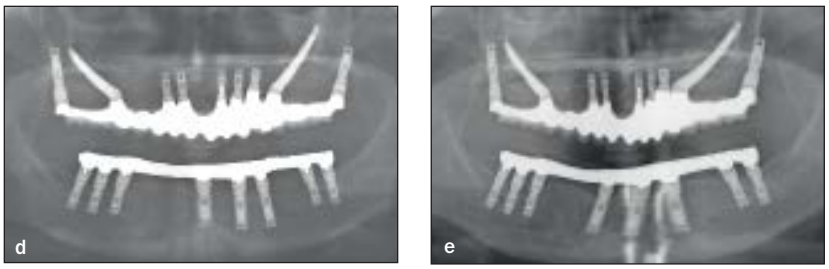

Fig 1 Panoramic radiographs of a patient who underwent mandibular complete arch rehabilitation with Brånemark system implants in 1987. The radiographs were taken at *(a)* implant placement, *(b)* abutment connection, *(c)* definitive prosthesis delivery, *(d)* 19-year follow-up, and *(e)* 25-year follow-up.

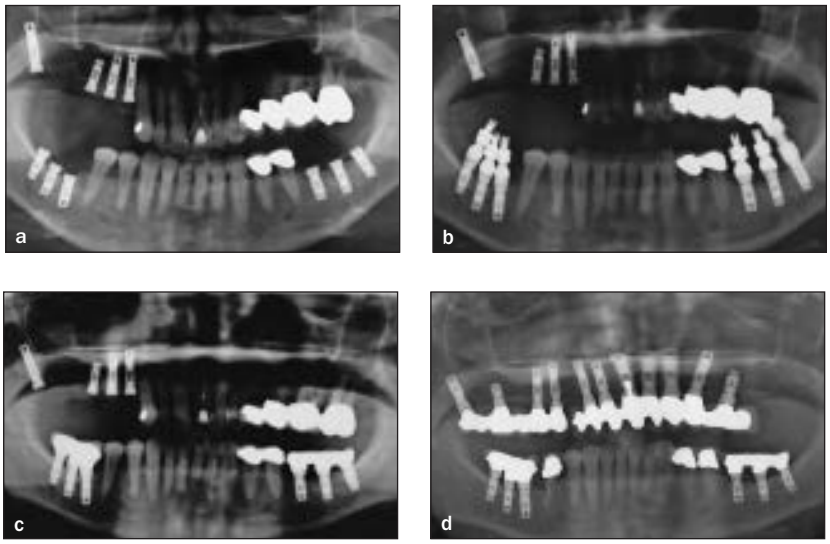

Fig 2 Panoramic radiographs of a patient who underwent bilateral mandibular posterior rehabilitation with Brånemark system implants in 1991. The radiographs were taken at *(a)* implant placement, *(b)* definitive impression, *(c)* definitive prosthesis delivery, and *(d)* 22-year follow-up.

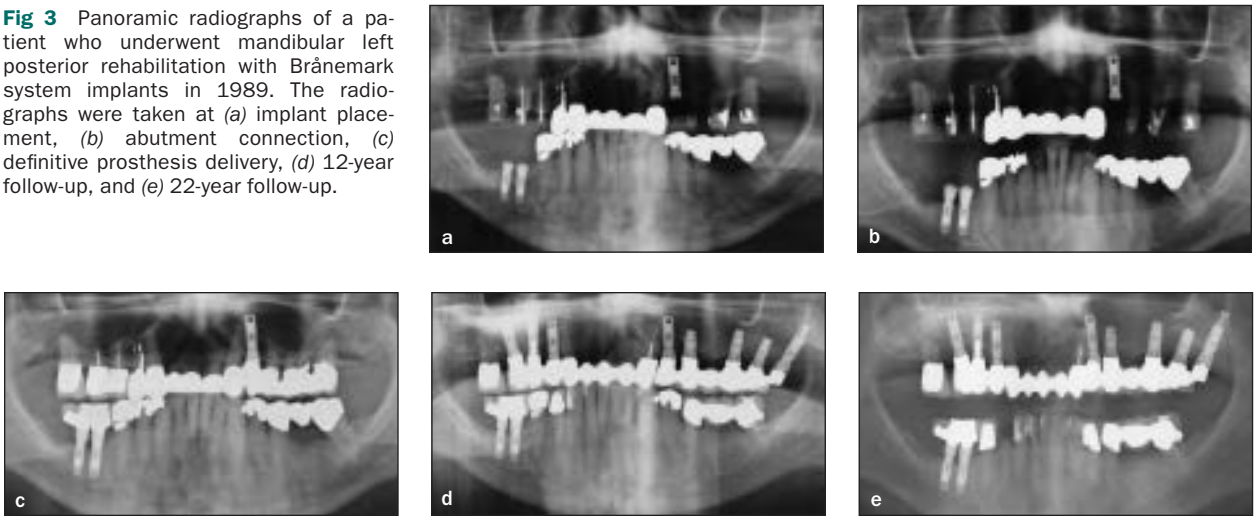

Fig 3 Panoramic radiographs of a patient who underwent mandibular left posterior rehabilitation with Brånemark system implants in 1989. The radiographs were taken at *(a)* implant placement, *(b)* abutment connection, *(c)* definitive prosthesis delivery, *(d)* 12-year follow-up, and *(e)* 22-year follow-up.

CONCLUSIONS

After more than 25 years of follow-up in a single private prosthodontic center, the cumulative survival rate of 2,394 endosseous dental implants placed in the mandible remained high (> 92%). Patient sex, patient age, degree of edentulism (fully vs partially edentulous), implant location, time of loading (delayed vs immediate), implant size and type, bone quality, prosthesis type, and the presence of other implants during placement did not significantly affect implant success in ways novel to the existing body of literature. The success observed in this study supports the use of endosseous dental implants as a long-term treatment option for the rehabilitation of the edentulous and partially edentulous mandible.

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REFERENCES

1. Brånemark PI, Breine U, Adell R, et al. Intra-osseous anchorage of dental prostheses. I. Experimental studies. Scand J Plast Reconstr Surg 1969;3:81–100.
2. Brånemark PI, Hansson BO, Adell R. Osseointegrated implants in the treatment of the edentulous jaw: Experience from a 10-year period. Scand J Plast Reconstr Surg 1977;16:1–132.
3. Schroeder A, van der Zypen E, Stich H, Sutter F. The reaction of bone, connective tissue and epithelium to endosteal implants with sprayed titanium surfaces. J Maxillofac Surg 1981;9:15–25.
4. Tallgren A. The continuing reduction of the residual alveolar ridges in complete denture wearers: A mixed-longitudinal study covering 25 years. J Prosthet Dent 1972;27:120–132.
5. D'Souza D. Residual ridge resorption – revisited. In: Virdi, M (ed) Oral Health Care - Prosthodontics, Periodontology, Biology, Research and Systemic Conditions. Rijeka: InTech, 2012:15–24.
6. Zarb G (ed). Toronto Conference on Osseointegration in Clinical Dentistry [Proceedings of the 1982 Toronto Conference]. St Louis: Mosby, 1983:1–165.
7. Salonen MA, Oikarinen K, Virtanen K, Pernu H. Failures in the osseointegration of endosseous implants. Int J Oral Maxillofac Implants 1993;8:92–97.
8. Kribbs PJ. Comparison of mandibular bone in normal and osteoporotic women. J Prosthet Dent 1990;63:218–222.
9. Adell R, Eriksson B, Lekholm U, Brånemark PI, Jemt T. Long-term follow-up study of osseointegrated implants in the treatment of totally edentulous jaws. Int J Oral Maxillofac Implants 1990;5:347–359.
10. Buser D, Mericske-Stern R, Bernard JP, et al. Long-term evaluation of non-submerged ITI implants. Part 1: 8-year life table analysis of a prospective multi-center study with 2359 implants Clin Oral Implants Res 1997;8:161–172.
11. Nevins M, Langer B. The successful application of osseointegrated implants to the posterior jaw: A long-term retrospective study. Int J Oral Maxillofac Implants 1993;8:428–432.
12. Friberg B, Gröndahl K, Lekholm U, Brånemark PI. Long-term follow-up of severely atrophic edentulous mandibles reconstructed with short Brånemark implants. Clin Implant Dent Relat Res 2000;2:184–189.
13. Lekholm U, Gunne J, Henry P, et al. Survival of the Brånemark implant in partially edentulous jaws: A 10-year prospective multicenter study. Int J Oral Maxillofac Implants 1999;14:639–645.
14. Doundoulakis JH, Eckert SE, Lindquist CC, Jeffcoat MK. The implant-supported overdenture as an alternative to the complete mandibular denture. J Am Dent Assoc 2003;134:1455–1458.
15. Meloni SM, De Riu G, Pisano M, De Riu N, Tullio A. Immediate versus delayed loading of single mandibular molars. One-year results from a randomized controlled trial. Eur J Oral Implantol 2012;5:345–353.
16. Bryant SR, MacDonald-Jankowski D, Kim K. Does the type of implant prosthesis affect outcomes for the completely edentulous arch? Int J Oral Maxillofac Implants 2007;22:117–139.
17. Pjetursson BE, Brägger U, Lang NP, Zwahlen M. Comparison of survival and complication rates of tooth-supported fixed dental prostheses (FDPs) and implant-supported FDPs and single crowns (SCs). Clin Oral Implants Res 2007;18:97–113.
18. Ekfeldt A, Carlson GE, Börjesson G. Clinical evaluation of single-tooth restorations supported by osseointegrated implants: A retrospective study. Int J Oral Maxillofac Implants 1994;9:179–183.
19. Engquist B, Nilson H, Astrand P. Single-tooth replacement by osseointegrated Brånemark implants. A retrospective study of 82 implants. Clin Oral Implants Res 1995;6:238–245.
20. Lemmerman KJ, Lemmerman NE. Osseointegrated dental implants in private practice: A long-term case series study. J Periodontol 2005;76:310–319.
21. Lekholm U, Zarb G. Patient selection and preparation. In: Brånemark P-I, Zarb G, Albrektsson T (eds). Tissue-Integrated Prostheses: Osseointegration in Clinical Density. Chicago: Quintessence, 1985:199–220.
22. Bryant SR. The effects of age, jaw site, and bone condition on oral implant outcomes. Int J Prosthodont 1998;11:470–490.
23. Wang IC, Reddy MS, Geurs NC, Jeffcoat MK. Risk factors in dental implant failure. J Long Term Eff Med Implants 1996;6:103–117.
24. Eckert SE, Wollan PC. Retrospective review of 1170 endosseous implants placed in partially edentulous jaws. J Prosthet Dent 1998;79:415–421.
25. Tolstunov L. Implant zones of the jaws: Implant location and related success rate. J Oral Implantol 2007;33:211–220.
26. Balshe AA, Assad DA, Eckert SE, Koka S, Weaver AL. A retrospective study of the survival of smooth- and rough-surfaced dental implants. Int J Oral Maxillofac Implants 2009;24:1113–1118.
27. Sakka S, Coulthard P. Bone quality: A reality for the process of osseointegration. Implant Dent 2009;18:480–485.
28. Fugazzotto PA, Wheeler SL, Lindsay JA. Success and failure rates of cylinder implants in type IV bone. J Periodontol 1993;64:1085–1087.