Single Implants in the Anterior Maxilla After 15 Years of Follow-up: Comparison with Central Implants in the Edentulous Maxilla

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Purpose: To present long-term clinical and radiographic data on single-implant treatment in the anterior maxilla and to compare these results with comparable data of central implants supporting fixed prostheses in the edentulous maxilla. ***Materials and Methods:*** A total of 38 patients consecutively restored with 47 single-implant crowns in the anterior maxilla were included in the single-implant (study) group. The implants in the edentulous group (control) were included by randomly selecting one of the central implants (closest to midline) from 76 consecutively treated edentulous patients. Mean age was 25.4 years (SD: 10.0) and 60.1 years (SD: 11.6) at inclusion ($P < .001$) for the study and control groups, respectively. Clinical and radiographic data were retrospectively retrieved from files holding up to 15 years of function in both groups. ***Results:*** No implants in the study group were lost (cumulative success rate: 100%), while 3 implants in the control group were lost (cumulative success rate: 95.4%). Ten single crowns were replaced (15-year cumulative survival rate: 77.0%), and the study group showed more mucosal problems and fistulas compared to the implants in the control group ($P < .05$). Loose screws were a common problem in the single-implant group during the first 5 years of function, but bone loss did not differ significantly between patients with stable and loose screws/fistulas ($P > .05$) or between study and control implants after 15 years ($P > .05$). ***Conclusions:*** There is an obvious difference between the survival of the implants (100%) and original implant crowns (77%) in the study group. The present early single-implant restorations showed significantly more mechanical/fistula problems compared to central implants in the edentulous maxilla ($P < .05$), but bone response was similar for both groups during 15 years of follow-up. Bone loss was not affected by the level of the implant head in relation to the cementoenamel junction of adjacent teeth, nor was it affected by mechanical or mucosal problems or persistent fistulas of the single implants during the entire follow-up period. *Int J Prosthodont 2008;21:400–408.*

Single-implant treatment in the anterior maxilla is predominantly performed in young patients due to partial anodontia or trauma. The technique using osseointegrated implants was first introduced more than 20 years ago.[1] One advantage of this treatment modality is that preparation and crown restoration of permanent teeth in the anterior region can be avoided in the early stage of life. However, with an average life expectancy of another 50 to 60 years in this group of patients, it must be expected that the crown restoration itself will be replaced several times during the lifetime of the patient. This can be due to mucosal recession,[2] adult facial growth, adjacent tooth movements,[3–9] etc, as well as porcelain fractures or changes of the shade of adjacent teeth by time. Thus, with a prosthetic protocol that allows for easy replacement of the crown restorations, the long-term prognosis for the implant itself is of a higher significance than the retrievable artificial crown restoration. In the perspective of this predominantly young patient group, short-term 5-year studies have shown encouraging clinical treatment results.[10–16] However, single implant crown restorations

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Table 1 Distribution of Patients and Single-Implant Crown Restorations in the Canine, Lateral Incisor, and Central Incisor Areas in the Study Group

	Patients		Single-implant restorations			
	No.	Mean age (SD) (y)	Canine	Lateral incisor	Central incisor	Total
Males	26	25.8 (11.0)	1	13	17	31
Females	12	24.8 (8.1)	6	5	5	16
Total	38	25.4 (10.2)	7	18	23	47

may present mucosal recession and implant crown infraposition after 10 to 15 years[2–9] in function. This jeopardizes the longevity of the individual implant crowns in the anterior maxilla, but the original implant can be used to support another crown restoration. Thus, more clinical and radiographic long-term documentation beyond 5 years of follow-up of this restorative alternative would be of interest, but is rare in the literature.

On the other hand, implant treatment in the edentulous maxilla is somewhat better documented for 10 to 15 years,[17–19] but is performed in much older age groups, and these patients generally have fewer years of remaining life expectancy compared to the average single-implant patient. Most of these edentulous patients have undergone extensive dental treatment during a long period of time, eventually loosing all of their remaining teeth mainly due to caries or periodontitis in a later stage of life. Since edentulous patients can be considered to be the complete failure of homecare and dental efforts in dentistry, it can be argued whether or not these patients can be expected to present the same prognosis of implant treatment compared with younger, healthier patients provided with single implants.

The aim of this study was to present the long-term clinical and radiographic performance of single-implant treatment in the anterior maxilla (study group) and to compare these results with the long-term survival of randomly selected central implants placed to support fixed prostheses in the edentulous maxilla (control group).

Materials and Methods

Study Group

The present study covers 38 consecutively treated patients provided with standard turned Brånemark system implants (Nobel Biocare) supporting early single-implant crown restorations in the anterior maxilla (canine to canine) between December 1987 and June 1990. This material has also been accounted for in 2 previous studies.[8,9]

Twelve patients in the study group were females, and the mean age was 25.4 years (SD: 10.2) at the time of the first surgery (Table 1). All patients were healthy nonsmokers who were not taking any medications.

The patients received a total of 47 standard turned Brånemark implants according to a 2-stage surgical procedure.[20] Healing or standard abutments (Nobel Biocare) were connected after a period of 6 to 8 months.[21] Thereafter, permanent porcelain-fused-to-metal crowns were cemented to original single-implant abutments[1,21] or Cera-one abutment cylinders[11] (Nobel Biocare) by means of conventional zinc-phosphate cement outside the mouth (Table 2). Thereafter, the crowns were mounted onto the implants, abutment screws were tightened by hand, and the screw access holes were sealed using composite resin after about 4 to 6 weeks.[21] Occlusion was adjusted with light contacts in centric relation, considering the ankylotic character of the implant.

Data were retrieved from patients' files, including all problems encountered during the follow-up period. Intraoral apical radiographs were taken on a routine basis at the time of prosthesis insertion and after 1, 5, 10, and 15 years in function. Vertical distance between the implant-abutment junction (IAJ) of the single implant in relation to the cementoenamel junction (CEJ) of the adjacent tooth on the mesial side was measured (Fig 1). When 2 implants were placed next to each other (2 patients), the CEJ of the distal tooth was used as a reference instead. Bone loss was measured in relation to the threads of the implants to the closest 0.3 mm on the mesial and distal side of the implant. A mean value between the mesial and distal side was used for each implant. The reference for these measurements was the IAJ placed 0.8 mm coronal of the implant reference point used in the previous studies.[22]

Control Group

The central implants (1 from each patient) were randomly selected from a group of 76 edentulous patients, who were also accounted for in 2 previous studies.[19,23] These patients were consecutively provided with fixed

Table 2 Life Table Analysis of Single Implants, Original Single Crown Restorations, and Central Implants in the Edentulous Maxilla

	Single implants				Original single crowns				Central implants			
Time	Total	Lost	Failed	CSR (%)	Total	Lost	Failed	CSR (%)	Total	Lost	Failed	CSR (%)
Surgery	47			100					76			100
Abutment	47			100	47			100	76		1	98.7
1 y	47	1		100	47	1		100	75	3		98.7
2 y	46			100	46		3	93.5	72	2		98.7
3 y	46			100	43		1	91.3	70	3		98.7
4 y	46			100	42		3	84.8	67	4		98.7
5 y	46			100	39		2	80.5	63	2		98.7
6 y	46	6		100	37	6		80.5	61	4	1	97.2
7 y	40	3		100	31	3		80.5	56	5		97.2
8 y	37	3		100	28	3		80.5	51	1	1	95.4
9 y	34			100	25			80.5	49	1		95.4
10 y	34			100	25			80.5	48	5		95.4
11 y	34	2		100	25	2		80.5	43	6		95.4
12 y	32			100	23			80.5	37	1		95.4
13 y	32			100	23			80.5	36	5		95.4
14 y	32			100	23			80.5	31	3		95.4
15 y	32			100	23		1	77.0	28			95.4
Total	32	15	0	100	22	15	10	77.0	28	45	3	95.4

CSR = cumulative success rate.

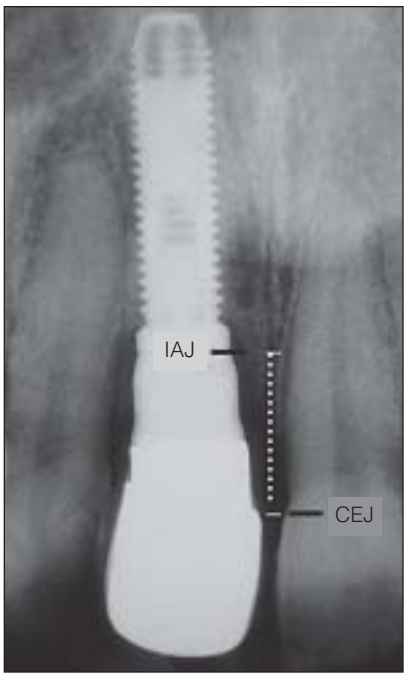

Fig 1 Vertical distance between the implant-abutment junction (IAJ) and the cementoenamel junction (CEJ) at the adjacent mesial tooth was measured.

prostheses supported by implants in the edentulous maxilla at a single clinic (Brånemark Clinic) from January 1986 to December 1987. Data for this group are shown in detail in the previous publications.[19,23]

In brief, the group comprised 76 patients, 48 of which were men. The mean age at implant surgery was 60.1 years (SD: 11.6 years), with a range of 32 to 75 years. Fourteen of the patients reported no general health problems (18.4%). Smoking habits were recorded for 34 patients (44.7%), and 21 patients (61.8%) were smokers.

Details on the time of edentulism before treatment, dentition in the opposite arch at the time of implant placement, and bone quality and bone resorption of the treated jaws at the time of first surgery are presented in previous papers.[19,23]

In total, 76 of 450 turned titanium Brånemark implants placed closest to the midline were randomly (right or left side) included in the present study. These implants were placed in the central incisor position, or when the incisor canal was wide, in the position between the central and lateral incisors. All implants were placed according to a 2-stage standard surgical protocol[20] and allowed to heal for 6 to 8 months before abutment connection. Thereafter, fixed prostheses designed with a cast type III gold alloy framework supporting conventional acrylic resin teeth were connected to the implants using bridge-locking screws.[19,23]

Only annual check-ups were scheduled after insertion and final tightening of the bridge-locking screws, but all patients were encouraged to contact the clinic whenever they had problems with their prostheses.[19,23]

For the edentulous patients, intraoral apical radiographs were taken on a routine basis at the Radiological Specialist Clinic, Public Dental Health Service, Göteborg, Sweden, at the same time intervals as the single-implant patients. Measurements included bone levels in relation to the IAJ and bone loss in relation to the threads of the implants to the closest 0.3 mm on the mesial and distal side of the implant in the same way as the single implants.

Data regarding problems and complications during the follow-up period in relation to the central implants were retrieved from patients' files.

Success Criteria

Criteria for implant success according to Albrektsson and Isidor[24] were used to identify implant performance for both single-implant patients as well as the central implants in the edentulous patients. These criteria for success allowed for a less than 1.5 mm bone loss during the first year of function and less than 0.2 mm of bone loss annually thereafter. Accordingly, bone loss at individual implants of a magnitude of < 2.3 mm, < 3.3 mm, and < 4.3 mm was considered acceptable after 5, 10, and 15 years of follow-up according to these criteria, respectively. Regarding the single crown patients, survival rates were calculated both for the original crown restorations as well as for the single implants still in function after 15 years.

Statistical Analysis

Descriptive statistics and conventional life table analysis with regard to cumulative success rates (CSRs) for implants and original crown restorations were used in the present study. Distributions between the study and control groups were tested by means of chi-square tests, and the Student *t* test for unpaired samples was used to assess differences between the 2 groups. Statistical analysis was only performed on the patient level, and significance was set at 5%.

Results

Patients Lost to Follow-up

Eleven patients (28.9%) provided with 15 single-implant restorations (31.9%) were lost to follow-up during the 15-year period (Table 2). One of these patients was deceased, and 6 patients had moved from Göteburg.

In the edentulous control group, 45 patients (59.2%) were lost to follow-up during the study period (Table 2). With exclusion of 21 deceased patients, the dropout rate was 31.6% for 15 years. Other than deceased patients, most withdrawals were because patients had moved or could not attend annual check-ups due to general health problems (12 patients).

Study Group

None of the standard implants were lost during the follow-up period (CSR: 100%; Table 2).

Fourteen crowns (36.8%) were followed-up without any problems reported. Ten of these crowns were followed-up for 15 years, 1 for 10 years, and 4 for less than 10 years.

Altogether, 11 original single crown restorations were replaced during the follow-up period (15-year CSR: 77.0%; Table 2). Ten of these crowns were replaced during the first 5 years in function. Seven of these crowns were replaced due to problems with shade and form of the crowns, and 1 crown each was replaced due to porcelain fracture after trauma, recurrent unstable screw joint, or infraposition of the implant crown in relation to adjacent teeth (after 5 years). The remaining crown was replaced during the 15th year of function, also due to infraposition. Both crowns remade due to infraposition were in female patients and were originally placed when the patients were at the age of 33 or 24 years.

Vertical distance between the implant head (IAJ) and the CEJ of the adjacent tooth ranged from 1.5 to 14.5 mm, with a mean distance of 6.9 mm (SD: 2.3). Five of the implants were placed 4 mm or less below the CEJ, 11 were placed 4.5 to 6 mm below the CEJ, and 21 were placed 6.5 to 8 mm below the CEJ. The remaining 10 implants were placed more than 8 mm below the CEJ (Table 3).

Mechanical problems and fistulas were reported in relation to 33 (70.2%) single crowns during the follow-up period (Table 4). Twenty of the crowns were reported with only loose screws, and 5 other patients presented only buccal fistulas at the single-implant crowns (Table 4). Buccal fistulas in association with loose crowns were observed in 8 patients. The majority of screw stability and fistula problems were reported during the first 5 years in function, but 9 crowns (28.1%) still showed buccal fistulas at the implant crowns at the termination of the study (Table 4). Fifteen titanium abutment screws (31.9%) were replaced by gold alloy screws during the follow-up period due to mechanical problems.

Mean marginal bone levels and mean marginal bone loss at the single implants are shown in Tables 5a and 5b. The corresponding mean marginal bone loss in relation to the distance between the IAJ and CEJ is presented in Table 3. It can be noted that the number of implants with longer distances from the IAJ to the marginal bone level increased over time (Table 5a). Overall, mean marginal bone loss was 0.66 mm (SD: 0.78)

Table 3 Mean Marginal Bone Loss at Implants with Regard to Placement of the Implant Head (IAJ) in Relation to the Cementoenamel Junction (CEJ) in the Study Group

Distance (IAJ-CEJ)	Bone loss (mm)			
	0 to 5 y		0 to 15 y	
	No.	Mean (SD)	No.	Mean (SD)
≤ 4.0 mm	5	0.72 (0.55)	1	–
> 4.0–6.0 mm	11	0.85 (0.84)	6	0.87 (0.93)
> 6.0–8.0 mm	21	0.52 (0.61)	17	0.49 (0.61)
> 8.0 mm	10	0.80 (0.55)	8	1.00 (0.90)

Table 4 Distribution of Single Crown Restorations with Regard to Reported Technical and Biological Problems During Different Periods of Follow-up

Complication	No. of crowns	No. of reported complications		
		0–5 y	6–10 y	11–15 y
Loose screw only	20	32	4	2
Loose screw and fistula	8	13	2	6
Fistula only	5	9	2	3

Table 5a Mean Marginal Bone Level in Relation to the Implant-Abutment Junction (IAJ) and Distribution of Single Implants with Regard to Bone Level During Different Periods of Follow-up in the Study Group

	Placement	Time			
		1 y	5 y	10 y	15 y
Follow-up (n)					
Patients	38	37	36	20	28
Implants	47	46	45	23	32
Bone level in relation to IAJ (mm)					
Mean	1.29	1.85	1.96	1.94	1.92
SD	0.46	0.64	0.72	0.75	0.91
Bone level to IAJ (no. of implants)					
0.0–0.8 mm	14 (29.8%)	3 (6.5%)	6 (13.3%)	4 (17.4%)	7 (21.9%)
0.9–1.9 mm	28 (59.6%)	24 (52.2%)	16 (35.6%)	8 (34.8%)	11 (34.4%)
2.0–2.5 mm	5 (10.6%)	14 (30.4%)	15 (33.3%)	8 (34.8%)	8 (25.0%)
2.6–3.1 mm	0	4 (8.7%)	5 (11.1%)	2 (8.7%)	4 (12.5%)
3.2–3.7 mm	0	1 (2.2%)	3 (6.7%)	1 (4.3%)	1 (3.1%)
> 3.7 mm	0	0	0	0	1 (3.1%)

Table 5b Mean Marginal Bone Loss and Distribution of Single Implants with Regard to Bone Resorption During Different Periods of Follow-up in the Study Group

	Time					
	0–1 y	1–5 years	1–10 years	1–15 years	5–10 years	10–15 years
Follow-up (n)						
Patients	37	36	20	28	20	20
Implants	46	45	23	32	23	23
Bone loss (mm)						
Mean	0.57	0.11	0.07	0.13	-0.03	-0.05
SD	0.48	0.56	0.56	0.67	0.32	0.53
Bone loss (no. of implants)						
0.0 mm	8 (17.4%)	21 (46.7%)	13 (56.5%)	16 (50.0%)	18 (78.3%)	17 (73.9%)
0.1–0.6 mm	19 (41.3%)	18 (40.0%)	6 (26.1%)	10 (31.3%)	5 (21.7%)	5 (21.7%)
0.7–1.2 mm	14 (30.4%)	5 (11.1%)	4 (17.4%)	4 (12.5%)	0	1 (4.3%)
1.3–1.8 mm	5 (10.9%)	1 (2.2%)	0	2 (6.3%)	0	0
1.9–2.4 mm	0	0	0	0	0	0
> 2.4 mm	0	0	0	0	0	0

during 15 years of follow-up. Bone loss was most pronounced during the first year of follow-up, followed by very small changes of mean marginal bone loss during the later years, with no trend of increased bone loss in later periods of follow-up (Table 5b).

Mean marginal bone loss for implants with no mechanical/fistula problems (n = 14) and implants with fistulas and loose screws (n = 31) was 0.69 mm (SD: 0.61) and 0.68 mm (SD: 0.64) during first 5 years in function, respectively. The corresponding bone loss during 15 years in function was 0.39 mm (SD: 0.56) and 0.78 mm (SD: 0.84) for implants with problems (n = 10) and without problem (n = 22), respectively ($P > .05$).

Mean values for bone loss in the group of implants with reported fistulas at termination of the study (n = 9) were 0.34 mm (SD: 0.64) up to 5 years and 0.58 mm

Table 6a Mean Marginal Bone Level in Relation to the Implant-Abutment Junction (IAJ) and Distribution of Central Implants with Regard to Bone Level During Different Periods of Follow-up in the Control Group

		Time			
	Placement	1 y	5 y	10 y	15 y
Follow-up (n)					
Implants	75	70	62	40	25
Bone level in relation to IAJ (mm)					
Mean	1.57	1.96	2.00	2.07	2.20
SD	0.82	0.90	0.88	0.90	0.98
Bone level to IAJ (no. of implants)					
0.0–0.8 mm	25 (33.3%)	9 (12.8%)	8 (12.9%)	6 (15.0%)	3 (12.0%)
0.9–1.9 mm	31 (41.3%)	32 (45.7%)	28 (45.2%)	13 (32.5%)	9 (36.0%)
2.0–2.5 mm	12 (16.0%)	19 (27.1%)	13 (21.0%)	10 (25.0%)	5 (20.0%)
2.6–3.1 mm	3 (4.0%)	3 (4.3%)	9 (14.5%)	9 (22.5%)	4 (16.0%)
3.2–3.7 mm	2 (2.7%)	4 (5.7%)	2 (3.2%)	1 (2.5%)	3 (12.0%)
> 3.7 mm	2 (2.7%)	3 (4.3%)	2 (3.2%)	1 (2.5%)	1(4.0%)

Table 6b Mean Marginal Bone Loss and Distribution of Central Implants with Regard to Bone Resorption During Different Periods of Follow-up in the Control Group

	Time					
	0–1 y	1–5 years	1–10 years	1–15 years	5–10 years	10–15 years
Follow-up (n)						
Implants	70	61	41	25	41	24
Bone loss (mm)						
Mean	0.40	0.01	0.12	-0.16	0.06	0.04
SD	0.56	0.49	0.66	0.48	0.62	0.33
Bone loss (no. of implants)						
0.0 mm	26 (37.1%)	35 (57.4%)	23 (56.1%)	17 (68.0%)	24 (58.5%)	17 (70.8%)
0.1–0.6 mm	25 (35.7%)	19 (31.1%)	11 (26.8%)	7 (28.0%)	11 (26.8%)	6 (25.0%)
0.7–1.2 mm	12 (17.1%)	7 (11.5%)	5 (12.2%)	1 (4.0%)	5 (12.2%)	1 (4.2%)
1.3–1.8 mm	6 (8.6%)	0	1 (2.4%)	0	1 (2.4%)	0
1.9–2.4 mm	1 (1.4%)	0	1 (2.4%)	0	0	0
> 2.4 mm	0	0	0	0	0	0

(SD: 0.73) up to 15 years of follow-up. The corresponding mean bone loss for implants with no fistulas at the termination of the study (n = 23) was 0.68 mm (SD: 0.59) and 0.69 mm (SD: 0.61), respectively.

Control Group

Three implants were lost during the follow-up period, resulting in a 15-year CSR of 95.4% in the anterior edentulous maxilla (Table 2). This was not significantly different from results from the single implants ($P > .05$).

Buccal fistulas/pus were reported in association with 2 implants (2.6%). There were significantly fewer mucosal problems compared to reported mucosal problems for the single-implant sites ($P < .05$). Other problems related to the central implants in the edentulous maxilla were limited, with only a few composite resin fillings in the screw access holes requiring replacement.

Mean marginal bone levels and mean marginal bone loss at the anterior implants are presented in Tables 6a and 6b. Changes of bone levels and bone loss at the implants showed similar patterns as observed for the single-implant situation during the 15 years of follow-up. The overall mean marginal bone loss was 0.57 mm (SD: 0.68) during the 15 years of follow-up.

Discussion

Within the limitations of the relatively small sample size in the study group, the present data indicate similar survival of implants in young patients provided with single implants compared to central implants in older edentulous patients ($P > .05$). Thus, the higher age and more compromised general and dental health situation for the edentulous patients failed to produce a significant difference in implant survival. Still, a few implants were lost in the control group (CSR: 95.4%), and it is reasonable to assume that with larger numbers of patients in the 2 groups it would have been possible to show significantly better implant survival for young healthy patients compared to older edentulous patients during comparable periods of follow-up.

Fig 2 *(left)* Wide cement margin between the abutment and lateral incisor crown restoration.

Fig 3 Palatal placement of an implant in the central incisor region.

Fig 4 Buccal extension of a single crown restoration to compensate for palatal placement of the implant.

The importance of the design and material of the abutment screw as well as the preload in the screw to establish a long-term stable screw joint has been discussed in earlier publications.[25] After original abutment screws were replaced by gold alloy screws (31.9 %) and occlusion had been adjusted to avoid overload, the screw loosening problem was clearly reduced during the last 10 years in function (Table 4). Thus, these early single-implant patients had to contribute to an increased understanding of screw joints in single-implant situations, but once this knowledge was established, these patients could benefit from better function and comfort in later stages of the follow-up period. Today, screw loosening is a rare problem in single-implant patients.[10,11]

It was after the CeraOne technique (Nobel Biocare) had been introduced with a controlled tightening of the abutment screw that intraoral cementation of the crowns without access holes became more widely used in dentistry.[11] Still, several of the present crowns cemented extraorally showed wide cement margins up to 1 mm (Fig 2). However, it was not possible to relate increased marginal bone loss or higher incidences of fistulas to these situations, as suggested by Wannfors and Smedberg.[26] Nevertheless, cemented single restorations with early problems with screw loosening presented significantly more mucosal problems with fistulas ($P < .05$) compared to the central implants in the edentulous maxilla. However, it is interesting to note that irrespective of the significantly higher incidence of mucosal problems and fistulas at the single implants, the pattern of marginal bone loss was similar in both groups (see Tables 5b and 6b).

These single implants were placed during an early period when osseointegration was the major focus, and esthetic considerations regarding crestal volume and placement of the implants was of a lower priority. Thus, no patient was at this time treated with local bone grafts to restore lost hard and soft tissues in the edentulous area. Accordingly, the implants were often placed deep into the alveolar crest to allow bone to surround the entire implant head. This procedure resulted in implants placed palatally (Fig 3) with the implant head deep in the alveolar crest (Table 3). The result was that subgingival abutment cylinders were longer (5 mm), and many of the single crowns were designed with buccal ridge laps (Fig 4). Thus, many of these early single-implant restorations were not designed in accordance to present state-of-the-art standards, but they still seemed to function well, and no higher incidence of problems was found for this design compared to the more favorably designed restorations.

If probing had been performed, the present protocol with deep placement of implants would have inevitably resulted in situations in which deep probing depths were found. Probing would probably induce traumatic bleeding but would not necessarily cause inflammation in the area, at least when implants are placed high up in the crest. However, probing with the aim to reach the bottom of the pocket at the implants was not performed on a routine basis in the present study. Still, at individual implants, pocket depths of 10 to 15 mm were common observations. These clinical findings have occasionally been misinterpreted during the years by clinicians who are not aware of this early surgical technique, which does not seem to be related to any pathology or increased bone loss (Figs 5a and 5b).

Fig 5a *(left)* Left central incisor supported by a single implant after 15 years in function. Probing depth of 16 mm is evident due to deep placement of the implant into the crest.

Fig 5b *(right)* Radiograph of the left central incisor after 15 years in function. Total bone loss was 1.7 mm during the follow-up period.

It is interesting to note that the 9 restorations that presented persistent fistulas during the entire follow-up period showed similar amounts of total bone loss (mean: 58 mm, SD: 0.73) as did restorations with no fistulas (mean: 0.69 mm, SD: 81) at the termination of the study. Some of these patients were surgically treated for fistulas up to 4 times during the follow-up period without success. Fistulas at teeth are usually associated with pathology and severe complications, and it is reasonable to consider fistulas at implants in a similar way. However, the present observation that bone level at the implants was unaffected by the fistulas over a 15-year period challenges the pathologic perception of fistulas, at least in some implant situations. An alternative interpretation of some fistulas at implants could possibly be discussed. Such an alternative approach could be to reduce the pathologic part of the definition of a fistula and instead emphasize the surgical part of the definition. Accordingly, perception of pathology could be reduced by using the definition of a surgically created "abnormal passage or communication…leading from an internal organ to the surface"[27] as the main definition in association with implants. In light of this definition, fistulas will be an integral part of the implant treatment procedure to allow an artificial communication between the oral cavity and bone-supported implant. This also allows for alternative clinical judgment of buccal (secondary) implant fistulas, which could occasionally be tolerated and simply supervised when no or only minor inflammation is present.

The present study indicates that there is a clear difference between the success of the single implants (CSR: 100%) compared to the original single crown restorations (CSR: 77.0%). Thus, the longevity of the implant becomes of a higher importance than the original single crown restoration. Besides the obvious problems establishing stable screw joints in this early group of single-implant patients, several single crowns were replaced during the follow-up period for various reasons. Many of these crowns were replaced due to esthetic considerations regarding shade and form, but replacement due to implant crown infraposition was recorded for 2 patients. Since both these patients were female, earlier observations suggesting that female patient are at greater risk for anterior tooth migration is further strengthened.[9] The 15-year survival rate for original crown restorations is in good agreement with the long-term experience of alternative tooth-supported 3-unit fixed prostheses.[28]

Conclusions

Within the limitations of the present study, several conclusions can be drawn. There is an obvious difference in longevity of the single implants (15-year cumulative success rate: 100%) compared to the original single-implant crown restorations (77%). The early single-implant crown restorations showed significantly ($P < .05$) more mechanical/fistula problems compared to central implants in the edentulous maxilla. However, bone resorption at the implants was similar for both groups during 15 years of follow-up. Bone loss was also similar for single implants placed deep below the cemento-enamel junction of the adjacent teeth compared to implants placed closer to the cementoenamel junction, as well as for single implants with or without mechanical or mucosal problems or persistent fistulas during the follow-up period. The 15-year cumulative success rate is comparable for single implants and central implants supporting fixed prostheses in the edentulous maxilla.

References

1. Jemt T. Modified single and short span restorations supported by osseointegrated fixtures in the partially edentulous jaw. J Prosthet Dent 1986;55:243–247.
2. Jemt T, Ahlberg G, Henriksson K, Bondevik O. Changes of anterior clinical crown height in patients provided with single-implant restorations after more than 15 years of follow-up. Int J Prosthodont 2006;19:455–461.
3. Thilander B, Odman J, Jemt T. Single implants in the upper incisor region and their relationsip to the adjacent teeth. An 8-year follow-up study. Clin Oral Implants Res 1999;10:346–355.
4. Thilander B, Odman J, Lekholm U. Orthodontic aspects of the use of oral implants in adolescents: A 10-year follow-up study. Eur J Orthod 2001;23:715–731.
5. Op Heij D, Opdebeeck H, van Steenberghe D, Quirynen M. Age as a compromising factor for implant insertion. Periodontol 2000 2003;33:172–184.
6. Oesterle L, Cronin R Jr. Adult growth, aging, and the single-tooth implant. Int J Oral Maxillofac Implants 2000;15:252–260.
7. Bernard JP, Schatz JP, Christou P, Belser U, Kiliaridis S. Long-term vertical changes of the anterior maxillary teeth adjacent to single implants in young and mature adults. A retrospective study. J Clin Periodontol 2004;31:1024–1028.
8. Jemt T. Measurements of tooth movements in relation to single implant restorations during 16 years: A case report. Clin Implant Dent Relat Res 2005;7:200–208.
9. Jemt T, Ahlberg G, Henriksson K, Bondevik O. Tooth-movements adjacent to single-implant restorations after more than 15 years of follow-up. Int J Prosthodont 2007;20:626–632.
10. Henry P, Laney W, Jemt T, et al. Osseointegrated implants for single-tooth replacement: A prospective 5-year multicenter study. Int J Oral Maxillofac Implants 1996;11:450–455.
11. Andersson B, Odman P, Lindvall AM, Brånemark P-I. Cemented single crowns on osseointegrated implants after 5 years: Results from a prospective study on CeraOne. Int J Prosthodont 1998;11: 212–218.
12. Scheller H, Urgell JP, Kultje C, et al. A 5-year multicenter study on implant-supported single crown restorations. Int J Oral Maxillofac Implants 1998;13:212–218.
13. Scholander S. A retrospective evaluation of 259 single-tooth replacements by the use of Brånemark implants. Int J Prosthodont 1999;12;483–491.
14. Palmer RM, Palmer PJ, Smith BJ. A 5-year prospective study of Astra single tooth implants. Clin Oral Implants Res 2000;11: 179–182.
15. Gibbard LL, Zarb G. A 5-year prospective study of implant-supported single-tooth replacements. J Can Dent Assoc 2002;68: 110–116.
16. Wennström J,L, Ekestubbe A, Gröndahl K, Karlsson S, Lindhe J. Implant-supported single-tooth restorations: A 5-year prospective study. J Cin Periodontol 2005;32:567–574.
17. 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;10:387–416.
18. Adell R, Eriksson B, Lekholm U, Brånemark P-I, Jemt T. A long-term follow-up study of osseointegrated implants in the treatment of the totally edentulous jaw. Int J Oral Maxillofac Implants 1990;5: 347–358.
19. Jemt T, Johansson J. Implant treatment in the edentulous maxillae: A 15-year follow-up study on 76 consecutive patients provided with fixed prostheses. Clin Implant Dent Relat Res 2006;8:61–69.
20. Adell R, Lekholm U, Brånemark P-I. Surgical procedure. In: Brånemark P-I, Zarb G, Albreksson T (eds.). Tissue-Integrated Prostheses: Osseointegration in Clinical Dentistry. Chicago: Quintessence, 1985:211–232.
21. Lekholm U, Jemt T. Principles for single tooth replacements. In: Albrektsson T, Zarb G (eds). The Brånemark Osseointegrated Implant. Chicago: Quintessence, 1989:117–126.
22. Hollender L, Rockler B. Radiographic evaluation of osseointegrated implants of the jaws. Experimental study of the influence of radiographic techniques on the measurement of the relation between the implant and bone. Dentomaxillofac Radiol 1980;9:91–95.
23. 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;10:303–311.
24. Albrektsson T, Isidor F. Consensus report of session IV. In: Lang NP, Karring T (eds). Proceedings of the 1st European Workshop on Periodontology. London: Quintessence, 1993:365–369.
25. Jörnéus L, Jemt T, Carlsson L. Loads and designs of screw joints for single crowns supported by osseointegrated implants. Int J Oral Maxillofac Implants 1992;7:353–359.
26. Wannfors K, Smedberg JI. A prospective clinical evaluation of different single-tooth restoration designs on osseointegrated implants. A 3-year follow-up of Brånemark implants. Clin Oral Implants Res 1999;10:453–458.
27. Dorland's Illustrated Medical Dictionary, ed 27. Philadelphia: WB Saunders, 1988:635.
28. De Backer H, Van Maele G, De Moor N, Van den Berghe L. Single-tooth replacement: Is a 3-unit fixed partial denture still an option? A 20-year retrospective study. Int J Prosthodont 2006;19:567–573.