Long-term Survival and Success of Oral Implants in the Treatment of Full and Partial Arches: A 7-year Prospective Study with the ITI Dental Implant System

Eugenio Romeo[1]/Diego Lops[2]/Emilio Margutti[3]/Marco Ghisolfi[4]/Matteo Chiapasco[5]/Giorgio Vogel[6]

Purpose: *This study evaluated the long-term survival and success of different implant-supported prostheses supported by ITI implants.* ***Materials and Methods:*** *Two hundred fifty consecutive patients were rehabilitated using implant-supported prostheses. Seven hundred fifty-nine implants were loaded. Single-tooth prostheses (n = 106), cantilever fixed partial prostheses (n = 42), fixed partial prostheses (n = 137), fixed complete prostheses (n = 5), implant/tooth–supported prostheses (n = 13), and overdentures (n = 37) were used. The mean follow-up period was 3.85 years. Life table analyses were performed. Implant survival rates were calculated by means of standard life table principles. Statistical analysis was performed to compare the implant survival and success by implant placement site for each type of prosthesis.* ***Results:*** *The cumulative implant survival rates were calculated for implants supporting single-tooth prostheses (95.6%), cantilever fixed partial prostheses (94.4%), fixed partial prostheses (96.1%), fixed complete prostheses (100%), implant/tooth–connected prostheses (90.6%), and overdentures (95.7%). Similar survival and success rates were documented for implants placed in maxillae and mandibles. Implant size did not influence survival.* ***Discussion:*** *Seven-year survival rates were similar for implants supporting single-tooth prostheses, cantilever fixed partial prostheses, fixed partial prostheses, and implant/tooth–supported prostheses. Medium-long term implant survival and success were not influenced by the site (maxilla or mandible). Implant and prosthetic survival rates for overdentures supported by 2 implants were comparable to those for overdentures supported by 3 or more implants.* ***Conclusion:*** *Prostheses supported by ITI implants represent a reliable medium-term treatment.* (More than 50 references.) INT J ORAL MAXILLOFAC IMPLANTS 2004;19:247–259

Key words: *dental implants, implant-supported restorations, peri-implant bone resorption*

Implant dentistry is a valid and predictable treatment option for the rehabilitation of partially and completely edentulous arches. An important contribution to this field has been provided by the continuous quality improvement of prosthetic components. At present, a number of implant-supported prosthetic solutions can satisfy patients' expectations regarding esthetics and function. The success of the ITI implant system (Straumann, Waldenburg, Switzerland) is well documented in international literature, particularly regarding the treatment of completely edentulous arches.[1–13] Prospective and longitudinal studies related to partial edentulism indicate cumulative implant success rates ranging from 89% to 95.3%, and cumulative survival rates ranging from 93.6% to 96.7%, 3 to 7 years after loading.[14–17]

The purpose of this study was to evaluate the medium to long-term survival and success of different implant-supported prostheses supported by ITI implants. Another purpose was to determine whether significant differences in survival and success could be observed for different implant placement sites.

[1]Chairman, Department of Prosthodontics, Dental Clinic, School of Dentistry, University of Milan, Italy.
[2]Assistant, Department of Prosthodontics, Dental Clinic, School of Dentistry, University of Milan, Italy.
[3]Assistant, Department of Prosthodontics, Dental Clinic, School of Dentistry, University of Milan, Italy.
[4] Assistant, Department of Prosthodontics, Dental Clinic, School of Dentistry, University of Milan, Italy.
[5]Chairman, Department of Oral Surgery, Dental Clinic, School of Dentistry, University of Milan, Italy.
[6]Head, Dental Clinic, School of Dentistry, University of Milan, Italy.

Correspondence to: Dr Eugenio Romeo, Department of Prosthodontics, Dental Clinic, School of Dentistry, University of Milan, Via Beldiletto 1/3, 20142 Milano, Italy. Fax: 0250319040. E-mail: eugenio.romeo@unimi.it

Table 1 Implant Placement Location

Location	n	%
Maxillary		
Anterior	112	14.8
Posterior	223	29.4
Mandibular		
Anterior	99	13.0
Posterior	325	42.8
Total	759	100.0

*Two mandibular posterior implants were removed before prosthetic loading. Seven hundred fifty-seven implants were loaded and followed up.

Table 2 Implant Features

Parameter	n
Height	
8 mm	72
10 mm	402
12 mm	236
14 mm	48
16 mm	1
Diameter	
3.3 mm	149
4.1/4.0 mm	579
4.8 mm	31
Type	
Hollow screw	195
Solid screw	564
Surface	
Titanium plasma-sprayed	703
Sandblasted acid-etched	56

MATERIALS AND METHODS

Patient Selection

Two hundred fifty patients (106 men and 144 women between 20 and 67 years of age) were consecutively treated between May 1995 and June 2002. Patients were treated at the Dental Clinic, Department of Medicine Surgery and Medicine, University of Milan, Italy. All patients signed an informed consent form. After prosthesis placement, the patients were seen for follow-up for periods ranging from 16 months to 7 years (mean 3.85 years).

Inclusion criteria were:

- Partial or complete edentulism
- Adequate bone volume at implant site for an implant at least 3.3 mm in diameter and 8 mm in length. Bone volume was evaluated by juxtagingival radiographs and clinical judgment.
- A favorable maxillomandibular relationship

Exclusion criteria were:

- Periodontal disease
- Heart disease
- Coagulation or leukocytic diseases
- Metabolic disorders
- Radiotherapy in the head or neck area
- Parafunctions such as clenching or bruxism
- A smoking habit (more than 10 cigarettes per day) or alcohol or drug abuse[13]

Implants and Prostheses

Patients were restored with ITI implant-supported prostheses. Seven hundred fifty-nine implants were placed. Two implants were removed before prosthetic loading. During the 7-year follow-up period, 49 patients with 82 implants and 45 restorations were lost to follow-up. Five patients died after they had received fixed prostheses; 4 patients developed severe illness that prevented further follow-up; 24 patients moved and dropped out of the study; and 14 patients could not be reached. Two patients were transferred to a private practice but never attended scheduled follow-up visits. The corresponding implants have been classified as "dropouts" and are unaccounted for.

The distribution of the implants is shown in Table 1. Three hundred thirty-five implants were placed in the maxilla and 424 were placed in the mandible. Loaded implants ranged from 8 to 16 mm in length and from 3.3 to 4.8 mm in width (Table 2).

One hundred thirty-seven prostheses were placed in the maxilla and 203 were placed in the mandible. The following types were used (Table 3): 110 fixed single-tooth (ST) prostheses (Fig 1a), 42 cantilever fixed partial (CFP) prostheses (24 with mesial cantilever and 18 with distal) (Figs 1b and 1c), 137 fixed partial (FP) prostheses (Fig 1d), 5 fixed complete (FC) prostheses (Figs 1e and 1f), 13 implant/tooth–supported (ITS) prostheses (Fig 1g), and 37 overdentures (ODs) (Figs 1h and 1i).

Clinical and Radiographic Assessment

Peri-implant tissue was evaluated for suppuration,[19] probing pocket depth and probing attachment level,[20] bleeding on probing (Bleeding Index score of 0 to 3),[21] and peri-implant inflammation (using the guidelines suggested by Mombelli and Lang).[22] Plaque Index scores (on a scale of 0 to 3),[21] implant mobility (either given a score of 0 to 2 [see Mombelli and coworkers[21]] or evaluated using the Periotest [Siemens, Bansheim, Germany]), and percussion[18] were also noted.

Intraoral radiographs were taken using the paralleling technique to control projection geometry,

Table 3a Implants

	Maxilla	Mandible	Total
Prosthesis supported			
Single tooth	44	62	106
Cantilever fixed partial	40	44	84
Fixed partial	121	174	295
Fixed complete	21	14	35
Implant/tooth-supported	22	9	31
Overdenture	40	74	114
Total	288*	377*	665*

*Implants of patients considered to be dropouts are excluded.

Table 3b Prostheses

	Maxilla	Mandible	Total
Prosthesis			
Single tooth	44	62	106
Cantilever fixed partial	20	22	42
Fixed partial	53	84	137
Fixed complete	3	2	5
Implant/tooth-supported	8	5	13
Overdenture	9	28	37
Total	137*	203*	340*

*Implants of patients considered to be dropouts are excluded.

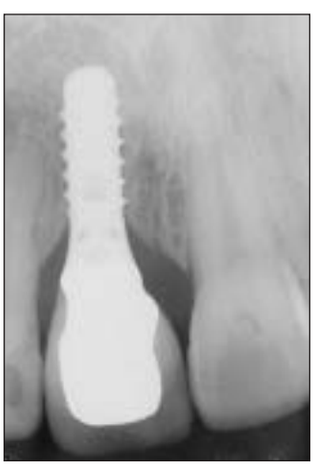

Fig 1a Juxtagingival radiograph of an ST prosthesis.

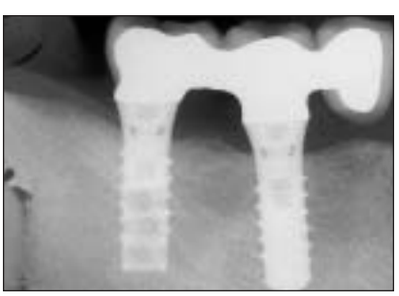

Fig 1b Juxtagingival radiograph of a fixed prosthesis cantilevered mesially.

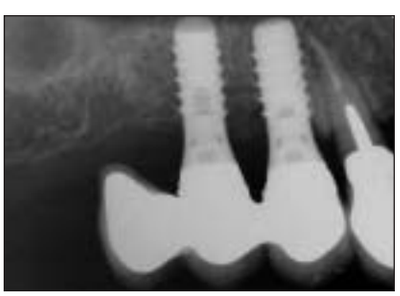

Fig 1c Juxtagingival radiograph of a fixed prosthesis cantilevered distally.

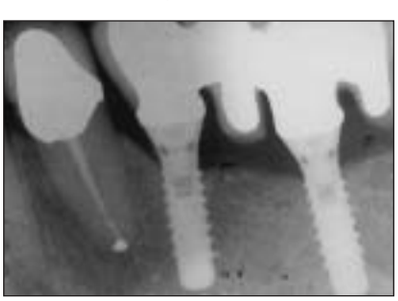

Fig 1d Juxtagingival radiograph of an FP prosthesis.

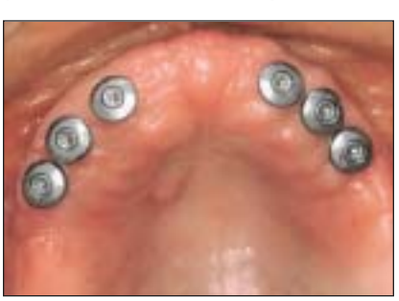

Fig 1e Cover screws used during healing for implants supporting an FC prosthesis.

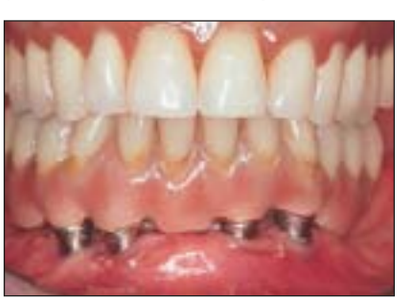

Fig 1f Loading of an FC prosthesis.

Fig 1g Juxtagingival radiograph of an ITS prosthesis.

Fig 1h Bar anchorage of 4 implants used for OD support.

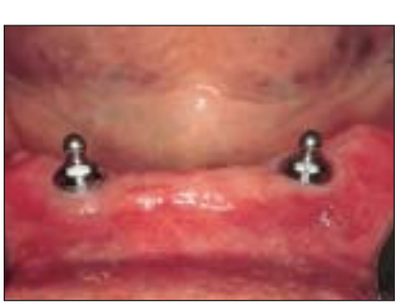

Fig 1i Ball attachment anchorage of 2 implants used for OD support.

with exposure parameters of 65 to 90 kV, 7.5 to 10 mA, and 0.22 to 0.25 seconds.[23–29] Radiographs were taken at loading, at 6 and 12 months after loading, and annually thereafter. They were subsequently stored on a personal computer and analyzed using the program ImageJ (US National Institute of Mental Health, Bethesda, MD) to determine bone level changes. Peri-implant bone resorption was assessed at bone levels mesial and distal to the implants.

Prosthetic Treatment

Patients with type 1 or type 2 bone quality were recalled for a preprosthetic evaluation 3 months after implant placement; patients with type 3 or type 4 bone quality were recalled after 6 months.[30] After the removal of the cover screws used during healing 3 to 6 months after implant placement, the abutments were screwed into position using 35 Ncm of torque. Solid abutments or Octa abutments (Straumann) with cast-to parallelized gold copings were used for cemented prostheses. Octa abutments with cast-to gold copings were used for screw-retained prostheses.

For ODs, the framework and esthetic veneer were fabricated from gold alloy and resin; all other prosthetics were fabricated from gold alloy and porcelain. No soldering was performed. Cemented prostheses were fixed with zinc oxyphosphate cement or zinc-eugenol oxide cement, while screw-retained prostheses were secured by applying a 15-Ncm torque to the abutment-framework screw using a manual torque driver.

Statistical Analysis

The statistical analysis was performed with the life table analysis described by Kalbleish and Prentice[31] and Colton.[32] The data were analyzed at the end of December 2002. Thus, all restored implants completed at least the 1-year examination. The following analyses were performed for the entire group of 759 implants:

- *Cumulative survival rate:* The internal survival rate for each time interval and the cumulative survival rate for the entire 8-year period were calculated. In the present study, survival rate was defined as the percentage of load-bearing implants that did not show symptoms of pain, mobility,[21] or infection (not including successfully treated peri-implant inflammation).[22]
- *Cumulative success rate:* In this analysis, which was more strict than the survival rate analysis, implants exhibiting a suppurative peri-implant infection at the last annual examination were classified as "failures." In addition to failed implants, this index also took into account the failure criteria established by Albrektsson and colleagues,[33] Buser and colleagues,[34] and van Steenberghe.[35]

Life tables included the following parameters: time period (observation time), number of implants at interval start (O^x), number of early failures (ie, implants that failed prior to loading), number of loaded implants, number of implants lost to follow-up as a result of patient dropout (w^x), number of implants at risk (ie, the "harmonic mean" of the implants at the beginning of an interval and those remaining at the end), number of failed implants (d^x) in each interval (q^x), interval survival rate, and cumulative survival rate.[32] The interval failure rate formula was

$$q^x = \frac{d^x}{O^x - \frac{w^x}{2}}$$

The interval survival rate (p^x) formula was $p^x = 1 - q^x$. However, the authors have accounted for the correlation structure associated with multiple implants in the same subject. Thus, unless the patient was restored with a single implant supporting a single crown, the reduced significance of any comparison was considered.

A 4-field table[36,37] was used to present the number of successes, survivals, unaccounted-for implants, and failures up to the 7-year examinations. The matrix gave a qualitative description of the materials and the methods of evaluation used and presented the results. The failure rate was always cumulative, and the sum of the 4 fields was 100% (ie, all placed implants).

Prognostic Criteria

The following criteria for implant evaluation were considered[37]:

- *Failure:* An implant was regarded as a failure if it had to be removed for any reason. If there was clinical mobility, implant removal was indicated without question. Absence of mobility was checked by applying a light tightening force to the implant with an abutment screwdriver without simultaneously counteracting the force with an abutment clamp. Any mobility or sensation (eg, pain) was regarded as a sign of lost osseointegration. Other conditions for which implant removal could be indicated included, for example, incurable soft tissue infection, persistent pain, paresthesia, or discomfort. Information

regarding any adverse event, including condition on onset, measures taken, and recovery, was recorded. Adverse events did not always result in removal.

- *Survival:* Implants that did not fail were included in the survival group.
- *Success:* Surviving implants were considered successful if radiographic evaluation revealed no more than 1.0 mm of marginal bone loss during the first year of loading and no more than 0.2 mm resorption per year in subsequent years, if there was no peri-implant pathosis or radiolucency, and if probing depth (measured with a calibrated plastic probe) was no greater than 3 mm on any side (mesial, buccal, distal, or lingual-palatal). Juxtagingival radiographs taken at the time of abutment connection and at the time of the last follow-up were used for measurements. All successful implants were in clinical function.

RESULTS

Results of the 7-year Life Table Analysis

Two mandibular implants were lost before loading because of persistent paresthesia and were classified as "early failures." During the 7-year follow-up period, 30 implants failed (Table 4). Implant mobility was recorded for 27 implants (14 maxillary, 13 mandibular) in 21 patients (Figs 2 and 3) owing to severe peri-implantitis (n = 21) and biomechanical overloading (n = 6). Three maxillary implant fractures occurred—two in implants supporting CFP prostheses and 1 in an implant supporting an FP prosthesis. All failed implants were removed. Six failed implants were short (8 mm in height) and 8 were narrow (3.3 mm in diameter); 1 failed implant was short and narrow.

Twenty-eight cases of peri-implantitis were successfully treated.[22] Thirty-five implants showed more than 1.0 mm of marginal bone loss during the first year of loading, followed by more than 0.2 mm bone resorption per year. Seven implants had a peri-implant probing depth greater than 3 mm.

Cumulative survival rates were calculated for implants supporting ST prostheses (95.6%), CFP prostheses (94.4%), FP prostheses (96.1%), FC prostheses (100%), ITS prostheses (90.6%), and ODs (95.7%) as shown in Table 5.

The 4-field analysis included calculation of the 7-year failure rate for implants supporting ST prostheses (4.0%), CFP prostheses (5.4%), FP prostheses (3.6%), FC prostheses (0%), ITS prostheses (8.8%), and ODs (4.0%), as shown in Table 6. Dropout rates were 13.8% for implants supporting ST prostheses, 9.7% for CFP prostheses, 12.2% for FP prostheses, 25.5% for FC prostheses, 8.8% for ITS prostheses, and 9.5% for ODs. The proportion of successes after 7 years was 75.6% for implants supporting ST prostheses, 76.3% for CFP prostheses, 73.8% for FP prostheses, 63.8% for FC prostheses, 70.6% for ITS prostheses, and 78.6% for OD prostheses.

Prosthetic complications such as decemention (4 ST and 5 FP prostheses), abutment-framework connection screw loosening (3 FP prostheses), retention anchor failure (n = 3), and retaining screw loosening (2 OD prostheses) also occurred. One abutment screw and 1 prosthetic pontic, both in FP prostheses, fractured; 6 aesthetic veneer fractures (2 in ST prostheses and 4 in FP prostheses) were observed. OD fracture was recorded twice in 2 different patients (Table 7).

Table 4 Failed Implants

Reason failed	Diameter (mm)	Height (mm)	Prosthesis supported	Location
Implant fracture (biomechanical overloading)				
1	3.3	10	CFP	Maxilla
2	3.3	10	CFP	Maxilla
3	4.1	12	FP	Maxilla
Implant mobility (biomechanical overloading)				
1	4.1	12	OD	Mandible
2	4.1	10	OD	Mandible
3	4.1	8	ST	Mandible
Implant mobility (peri-implantitis)				
1	4.1	10	FP	Mandible
2	3.3	10	FP	Mandible
3	4.8	10	FP	Mandible
4	4.1	10	FP	Mandible
5	3.3	8	FP	Mandible
6	4.1	10	FP	Maxilla
7	4.1	8	FP	Maxilla
8	3.3	10	FP	Maxilla
9	4.1	10	FP	Maxilla
10	4.1	8	FP	Maxilla
11	4.1	10	FP	Maxilla
12	4.8	10	CFP	Mandible
13	4.1	12	CFP	Mandible
14	3.3	10	CFP	Maxilla
15	4.1	10	ST	Maxilla
16	4.1	8	ST	Maxilla
17	4.1	12	ST	Mandible
18	3.3	10	ST	Mandible
19	4.1	10	OD	Maxilla
20	4.1	10	OD	Maxilla
21	4.1	10	OD	Maxilla
22	4.1	12	ITS	Mandible
23	4.1	8	ITS	Maxilla
24	3.3	10	ITS	Maxilla
Persistent paresthesia				
1	4.1	10	Not loaded	Mandible
2	4.1	10	Not loaded	Mandible

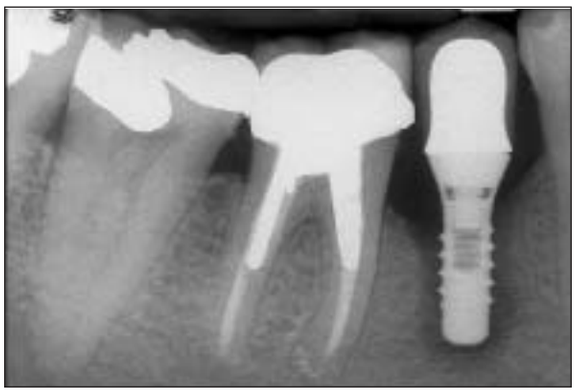

Fig 2 Juxtagingival radiograph of a failed implant. The failure was related to biomechanical overloading.

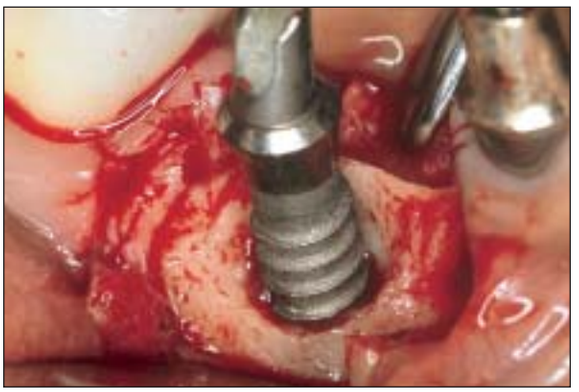

Fig 3 An implant whose failure was related to peri-implantitis. Note the peri-implant bone resorption and the exposure of the implants threads.

Maxillary and mandibular implants showed similar outcomes. Mandibular implants demonstrated 7-year cumulative survival rates of 95.6% for ST prostheses, 95.7% for CFP prostheses, 97.2% for FP prostheses, 100% for FC prostheses, 89.9% for ITS prostheses, and 97.5% for OD prostheses (Table 8). Maxillary implants (Table 9) showed cumulative survival rates of 95.7% for ST prostheses, 92.8% for CFP prostheses, 95.6% for FP prostheses, 100% for FC prostheses, 91.7% for ITS prostheses, and 92.5% for ODs.

Finally, the outcomes of implants supporting ODs supported by 2 implants were compared to those of implants supporting ODs supported by 3 or more implants. The former group had a cumulative survival rate of 93.6%; the latter had a cumulative survival rate of 96.7% (Table 10).

DISCUSSION

Overall, implant and prosthesis success and survival rates were satisfactory; however, these data had a relative value. Prosthetic restorations were in fact exposed to qualitatively and quantitatively different complications. Literature studies[30,31] have demonstrated higher survival probability for osseointegrated mandibular implants than for maxillary implants. The reasons for this are likely the lower mechanical stress that the maxilla can withstand because of its thinner cortical layer, as well as the lower density of the maxillary spongiosa.[37]

Further, Scurria and associates[38] reported outcomes of dental implant therapy for a range of patients requiring various degrees of tooth replacement. Life table analyses produced Kaplan-Meier survival curves for different locations and prosthesis types. Proportional hazards modeling combined with SUDAAN modeling (RTI International, Research Triangle Park, NC) identified removable prosthesis type and maxillary location as being significantly associated with implant failure. For this reason, the present study analyzed implant survival and success by prosthesis type and implant location (maxilla or mandible).

Study results were comparable to those found in the international literature related to ST prostheses,[13,15,17,38] FP prostheses,[17,39–42] CFP prostheses,[43] ITS prostheses,[44,45] FC prostheses,[42,46,47] and ODs.[4,8,48–50]

It was also noted that implant location did not represent a significant prognostic factor; the works of Adell and coworkers,[51] Bass and Triplett,[52] Jaffin and Berman,[53] and Jemt and coworkers[54] support

Table 5 Life Table Analysis for Implant Survival

Interval (y)	Implants at start of interval	Early failures	Loaded implants	Dropouts	Implants at risk	Failures during interval	Survival rate (%)	Cumulative survival rate (%)
ST prostheses								
0 to 1	123	2	121	3	119.5	0	100	100
1 to 2	118	0	118	0	118	0	100	100
2 to 3	118	0	118	5	115.5	3	97.4	97.4
3 to 4	110	0	110	3	108.5	2	98.2	95.6
4 to 5	**105**	**0**	**105**	**2**	**104**	**0**	**100**	**95.6**
5 to 6	103	0	103	0	103	0	100	95.6
6 to 7	103	0	103	2	102	0	100	95.6
CFP prostheses								
0 to 1	93	0	93	0	93	0	100	100
1 to 2	93	0	93	0	93	0	100	100
2 to 3	93	0	93	3	91.5	1	99	99
3 to 4	89	0	89	2	88	0	100	99
4 to 5	**87**	**0**	**87**	**4**	**85**	**2**	**97.7**	**96.7**
5 to 6	81	0	81	0	81	2	97.6	94.4
6 to 7	79	0	79	0	79	0	100	94.4
FP prostheses								
0 to 1	336	0	336	4	334	0	100	100
1 to 2	332	0	332	10	327	0	100	100
2 to 3	322	0	322	6	319	2	99.4	99.4
3 to 4	314	0	314	7	310.5	4	98.7	98.1
4 to 5	**303**	**0**	**303**	**4**	**301**	**4**	**98.7**	**96.8**
5 to 6	295	0	295	8	291	2	99.3	96.1
6 to 7	285	0	285	2	284	0	100	96.1
FC prostheses								
0 to 1	47	0	47	0	47	0	100	100
1 to 2	47	0	47	0	47	0	100	100
2 to 3	47	0	47	6	44	0	100	100
3 to 4	41	0	41	6	38	0	100	100
4 to 5	**35**	**0**	**35**	**0**	**35**	**0**	**100**	**100**
5 to 6	35	0	35	0	35	0	100	100
6 to 7	35	0	35	0	35	0	100	100
ITS prostheses								
0 to 1	34	0	34	0	34	0	100	100
1 to 2	34	0	34	0	34	0	100	100
2 to 3	34	0	34	1	33.5	0	100	100
3 to 4	33	0	33	0	33	1	97	97
4 to 5	**32**	**0**	**32**	**1**	**31.5**	**1**	**96.8**	**93.8**
5 to 6	30	0	30	1	29.5	0	100	93.8
6 to 7	29	0	29	0	29	1	96.6	90.6
OD prostheses								
0 to 1	126	0	126	0	126	0	100	100
1 to 2	126	0	126	2	125	0	100	100
2 to 3	124	0	124	2	123	0	100	100
3 to 4	122	0	122	2	121	2	98.4	98.4
4 to 5	**118**	**0**	**118**	**4**	**116**	**0**	**100**	**98.4**
5 to 6	114	0	114	2	113	0	100	98.4
6 to 7	112	0	112	0	112	3	97.3	95.7

Table 6 Implant Distribution After the 7-Year Follow-up

Prosthesis	Success n (%)	Dropout n (%)	Survival n (%)	Failure n (%)
ST	93 (75.6)	17 (13.8)	8 (6.6)	5 (4.0)
CFP	71 (76.3)	9 (9.7)	8 (8.6)	5 (5.4)
FP	248 (73.8)	41 (12.2)	35 (10.4)	12 (3.6)
FC	30 (63.8)	12 (25.5)	5 (10.7)	0 (0.0)
ITS	24 (70.6)	3 (8.8)	4 (11.8)	3 (8.8)
ODs	99 (78.6)	12 (9.5)	10 (7.8)	5 (4.0)

Table 7 Complications and Failures in Overdentures

	Anchors*		Bars†		Lock-pins‡	
	n (%)	Cause	n (%)	Cause	n (%)	Cause
Implant						
Complication	1 (3.1)	TP	5 (9.2)	PBR	4 (11.1)	TP
Failure	2 (6.2)	FIO	3 (5,5)	FIP	0	
Prosthetic						
Complication	3 (20.0)	RAR	2 (14.2)	RSL	0	
Failure	1 (6.6)	ODF	1 (7.1)	ODF	0	

*32 implants, 15 prostheses.
†54 implants, 14 prostheses.
‡36 implants, 8 prostheses.
PBR = peri-implant bone resorbtion exceeding success parameters; FIO = implant failure due to biomechanical overload; FIP = implant failure due to perimplantitis; TP = successfully treated peri-implantitis; RAR = retention anchors replacement; RSL = retaining screw loosening; ODF = overdenture fracture.

these findings. Nevertheless, in experimental and clinical literature, there are reports of implant survival and success being significantly influenced by placement site.[38,55,56] Scurria and colleagues,[38] Romeo and colleagues,[55] and Balshi and colleagues[56] emphasized the greater biomechanical loads supported by posterior segments.

Comparing FP prostheses and CFP prostheses, statistically different implant and survival rates were not documented. This supports the reliability of a suitably fabricated cantilever prosthesis if the occlusal and biomechanical forces are appropriately addressed.

No notable difference was observed between survival rates of implant-supported FC prostheses and ODs, although the materials used to fabricate the suprastructure of an OD are usually more fragile than those used for an FC prosthesis, and ODs usually have a higher crown-to-implant ratio. The percentage of prosthetic complications was greater for ODs than for any other type of prosthesis (13.5% for ODs; 0% to 7.6% for other prostheses). This is probably related to the relative weakness of the anchorage components used for connecting the implants to the prosthetic framework. The results of a number of studies on the functionality of ODs supported by 2 or more implants[12,57] were partly confirmed. Implants supporting ODs supported by 2 implants survived nearly as well as implants supporting ODs supported by 3 or more implants.

Finally, implant failure did not appear to be significantly influenced by length and diameter; only 20% of failed implants were 8 mm long, and only 26.6% were 3.3 mm wide. Friberg and colleagues[58] published a long-term follow-up study of 49 patients in whom 260 short implants were placed. Their outcome showed the high predictability of that treatment procedure. Texeira and coworkers[59] investigated the applicability of short hydroxylapatite-coated dental implants in the posterior mandible of partially edentulous patients. In a 5-year survival study, the overall cumulative implant survival rate was 94%, and the overall cumulative prosthetic survival rate was 91%. Predictable success

Table 8 Life Table Analysis for Survival of Loaded Mandibular Implants

Interval (y)	Implants at start of interval	Early failures	Loaded implants	Dropouts	Implants at risk	Failures during interval	Survival rate (%)	Cumulative survival rate (%)
ST prostheses								
0 to 1	72	2	70	2	69	0	100	100
1 to 2	68	0	68	0	68	0	100	100
2 to 3	68	0	68	2	68	1	98.5	98.5
3 to 4	64	0	64	1	63.5	2	97.1	95.6
4 to 5	**62**	**0**	**62**	**2**	**61**	**0**	**100**	**95.6**
5 to 6	60	0	60	0	60	0	100	95.6
6 to 7	60	0	60	1	59.5	0	100	95.6
CFP prostheses								
0 to 1	49	0	49	0	49	0	100	100
1 to 2	49	0	49	0	49	0	100	100
2 to 3	49	0	49	3	49	1	98	98
3 to 4	45	0	45	0	45	0	100	98
4 to 5	**45**	**0**	**45**	**2**	**44**	**0**	**100**	**98**
5 to 6	43	0	43	0	43	1	97.7	95.7
6 to 7	42	0	42	0	42	0	100	95.7
FP prostheses								
0 to 1	195	0	195	2	194	0	100	100
1 to 2	193	0	193	7	189.5	0	100	100
2 to 3	186	0	186	4	184	0	100	100
3 to 4	182	0	182	4	180	1	99.4	99.4
4 to 5	**177**	**0**	**177**	**0**	**177**	**2**	**98.9**	**98.3**
5 to 6	175	0	175	4	173	2	98.9	97.2
6 to 7	169	0	169	0	169	0	100	97.2
FC prostheses								
0 to 1	14	0	14	0	14	0	100	100
1 to 2	14	0	14	0	14	0	100	100
2 to 3	14	0	14	0	14	0	100	100
3 to 4	14	0	14	0	14	0	100	100
4 to 5	**14**	**0**	**14**	**0**	**14**	**0**	**100**	**100**
5 to 6	14	0	14	0	14	0	100	100
6 to 7	14	0	14	0	14	0	100	100
ITS prostheses								
0 to 1	10	0	10	0	10	0	100	100
1 to 2	10	0	10	0	10	0	100	100
2 to 3	10	0	10	1	9.5	0	100	100
3 to 4	9	0	9	0	9	0	100	100
4 to 5	**9**	**0**	**9**	**0**	**9**	**0**	**100**	**100**
5 to 6	9	0	9	0	9	0	100	100
6 to 7	9	0	9	0	9	1	89.9	89.9
OD prostheses								
0 to 1	84	0	84	0	84	0	100	100
1 to 2	84	0	84	2	83	0	100	100
2 to 3	82	0	82	0	82	0	100	100
3 to 4	82	0	82	2	81	2	97.5	97.5
4 to 5	**78**	**0**	**78**	**4**	**76**	**0**	**100**	**97.5**
5 to 6	74	0	74	2	73	0	100	97.5
6 to 7	72	0	72	0	72	0	100	97.5

Table 9 Life Table Analysis for Survival of Loaded Maxillary Implants

Interval (y)	Implants at start of interval	Early failures	Loaded implants	Dropouts	Implants at risk	Failures during interval	Survival rate (%)	Cumulative survival rate (%)
ST prostheses								
0 to 1	51	0	51	1	50.5	0	100	100
1 to 2	50	0	50	0	50	0	100	100
2 to 3	50	0	50	3	48.0	1	97.9	97.9
3 to 4	46	0	46	2	45	1	97.8	95.7
4 to 5	**43**	**0**	**43**	**0**	**43**	**0**	**100**	**95.7**
5 to 6	43	0	43	0	43	0	100	95.7
6 to 7	43	0	43	1	42.5	0	100	95.7
CFP prostheses								
0 to 1	44	0	44	0	44	0	100	100
1 to 2	44	0	44	0	44	0	100	100
2 to 3	44	0	44	0	44	0	100	100
3 to 4	44	0	44	2	43	0	100	100
4 to 5	**42**	**0**	**42**	**2**	**41**	**2**	**95.3**	**95.3**
5 to 6	38	0	38	0	38	1	97.4	92.8
6 to 7	37	0	37	0	37	0	100	92.8
FP prostheses								
0 to 1	141	0	141	2	140	0	100	100
1 to 2	139	0	139	3	137.5	0	100	100
2 to 3	136	0	136	2	135	2	98.5	98.5
3 to 4	132	0	132	3	130.5	3	98.7	97.2
4 to 5	**126**	**0**	**126**	**4**	**124**	**2**	**98.4**	**95.6**
5 to 6	120	0	120	4	118	0	100	95.6
6 to 7	116	0	116	2	115	0	100	95.6
FC prostheses								
0 to 1	33	0	33	0	33	0	100	100
1 to 2	33	0	33	0	33	0	100	100
2 to 3	33	0	33	6	30	0	100	100
3 to 4	27	0	27	6	24	0	100	100
4 to 5	**21**	**0**	**21**	**0**	**21**	**0**	**100**	**100**
5 to 6	21	0	21	0	21	0	100	100
6 to 7	21	0	21	0	21	0	100	100
ITS prostheses								
0 to 1	24	0	24	0	24	0	100	100
1 to 2	24	0	24	0	24	0	100	100
2 to 3	24	0	24	0	24	0	100	100
3 to 4	24	0	24	0	24	1	95.9	95.9
4 to 5	**23**	**0**	**23**	**1**	**22.5**	**1**	**95.6**	**91.7**
5 to 6	21	0	21	1	20.5	0	100	91.7
6 to 7	20	0	20	0	20	0	100	91.7
OD prostheses								
0 to 1	42	0	42	0	42	0	100	100
1 to 2	42	0	42	0	42	0	100	100
2 to 3	42	0	42	2	41	0	100	100
3 to 4	40	0	40	0	40	0	100	100
4 to 5	**40**	**0**	**40**	**0**	**40**	**0**	**100**	**100**
5 to 6	40	0	40	0	40	0	100	100
6 to 7	40	0	40	0	40	3	92.5	92.5

Table 10 Life Table Analysis for Survival of Implants Supporting ODs

Interval (y)	Implants at start of interval	Early failures	Loaded implants	Dropouts	Implants at risk	Failures during interval	Survival rate (%)	Cumulative survival rate (%)
3 or more implants supporting ODs								
0 to 1	92	0	92	0	92	0	100	100
1 to 2	92	0	92	0	92	0	100	100
2 to 3	92	0	92	2	91	0	100	100
3 to 4	90	0	90	0	90	0	100	100
4 to 5	**90**	**0**	**90**	**0**	**90**	**0**	**100**	**100**
5 to 6	90	0	90	0	90	0	100	100
6 to 7	90	0	90	0	90	3	96.7	96.7
2 implants supporting ODs								
0 to 1	34	0	34	0	34	0	100	100
1 to 2	34	0	34	2	33	0	100	100
2 to 3	32	0	32	0	32	0	100	100
3 to 4	32	0	32	2	31	2	93.6	93.6
4 to 5	**28**	**0**	**28**	**4**	**26**	**0**	**93.6**	**93.6**
5 to 6	24	0	24	2	23	0	93.6	93.6
6 to 7	22	0	22	0	22	0	93.6	93.6

for the application of short implants to the posterior mandible was suggested. In contrast to the aforementioned studies, Fartash and colleagues[60] documented a lower success rate for short implants than for long implants. In addition, Bert[61] suggested the use of wide-diameter implants with tapping placement. Although the clinical results of short implants were favorable, further research is required to elucidate the most appropriate implant size and distribution, as well as the most favorable prosthetic restorations.

CONCLUSIONS

Clinical and radiographic preliminary results have demonstrated that restoration of complete and partially edentulous arches with ITI implants can be a reliable medium- to long-term treatment in this study population.

Medium- to long-term implant survival and success were not influenced by position site (maxilla or mandible). More research is required to explain the influence of implant placement sector (anterior or posterior) on implant survival and success.

Implants supporting fixed ST prostheses, CFP prostheses, FP prostheses, and ITS prostheses demonstrated similar 7-year survival rates. OD survival rates approximated those for FC prostheses, although ODs were more susceptible to prosthetic complications than other types of prostheses. Nevertheless, more research is needed to confirm this trend, owing to the reduced number of implants supporting this type of prosthesis. Implant and prosthetic survival rates for ODs supported by 2 implants were comparable to those for ODs supported by 3 or more implants.

REFERENCES

1. Mericske-Stern R, Geering AH. Implantate in der Totaiprothetik. Die Verankerung der Totalprothese im zahnlosen Unterkiefer durch zwei Implantate mit Einzelattachment. Schweiz Monatsschr Zahnmed 1988;8:871–876.
2. Mericske-Stern R. Clinical evaluation of overdenture restorations supported by osseointegrated titanium implants: A retrospective study. Int J Oral Maxillofac Implants 1990;5: 375–383.
3. ten Bruggenkate C, Muller K, Oosterbeek H. Clinical evaluation of the ITI (F-Type) hollow cylinder implant. Oral Surg Oral Med Oral Pathol 1990;70:693–697.
4. Gerring AH, Mericske-Stern R. Mandibular overdentures on ITI implants. In: Schepers E, Naert I, Theumiers G (eds). Overdentures on Oral Implants. Leuven, Belgium: Leuven University Press, 1991:83–91.
5. Mericske-Stern R, Zarb GA. Overdentures: An alternative implants methodology for edentulous patients. Int J Prosthodont 1993;6:203–208.
6. Cune MS, de Putter C. Comparative evaluation of some outcome measures of implant systems and suprastructure types in mandibular implant-overdenture treatment. Int J Oral Maxillofac Implants 1994;9:548–555.

7. Mericske-Stern R, Steinlin-Scheffner T, Marti P, Gerring AH. Peri-implant mucosal aspects of ITI implants supporting overdentures. A 5-year longitudinal study. Clin Oral Implants Res 1994;5:9–18.
8. Leimola-Virtanen R, Peltola J, Oksala E, Helenius H, Happonen RP. ITI titanium plasma-sprayed screw implants in the treatment of edentulous mandibles: A follow-up study of 39 patients. Int J Oral Maxillofac Implants 1995;10:373–378.
9. Versteegh PAM, van Beek GJ, Slagter AP, Ottervanger JP. Clinical evaluation of mandibular overdentures supported by multiple-bar fabrication: A follow-up study of two implant systems. Int J Oral Maxillofac Implants 1995;10:595–603.
10. Wismeijer D, van Waas AJ, Vermeeren J. Overdentures supported by ITI implants: A 6.5-year evaluation of patient satisfaction and prosthetic after-care. Int J Oral Maxillofac Implants 1995;10:744–749.
11. Donatsky O, Hillerup S. Non-submerged osseointegrated dental implants with ball attachments supporting overdentures in patients with mandibular alveolar ridge atrophy. A short-term follow-up. Clin Oral Implants Res 1996;7:170–174.
12. Batenburg RHK, Meijer HJA, Raghoebar GM, Vissink A. Treatment concept for mandibular overdentures supported by endosseous implants: A literature review. Int J Oral Maxillofac Implants 1998;13:539–545.
13. Weber C, Crohin CC, Fiorellini JP. A 5-year prospective clinical and radiographic study of non-submerged dental implants. Clin Oral Implants Res 2000;11:144–153.
14. Wedgwood D, Jennings KJ, Critchlow HA, et al. Experience with ITI osseointegrated implants at five centres in the UK. Br J Oral Maxillofac Surg 1992;30:377–381.
15. Buser D, Mericske-Stern R, Bernard JP, et al. Long-term evaluation of non-submerged ITI implants. Clin Oral Implants Res 1997;8:161–172.
16. ten Bruggenkate CM, Asikainen P, Fatzik C, Krekeler G, Sutter F. Short (6-mm) nonsubmerged dental implants: Results of a multicenter clinical trial of 1 to 7 years. Int J Oral Maxillofac Implants 1998;13:791–798.
17. Behneke A, Behneke N, d'Hoedt B, Wagner W. Hard and soft tissue reactions to ITI screw implants: 3-year longitudinal results of a prospective study. Int J Oral Maxillofac Implants 1997;12:749–757.
18. Esposito M, Hirsch JM, Lekholm U. Biological factors contributing to failures of osseointegrated oral implants. (I) Success criteria and epidemiology. Eur J Oral Sci 1998;106: 527–551.
19. Mombelli A, Lang NP. Clinical parameters for the evaluation of dental implants. Periodontol 2000 1994;4:81–86.
20. Lang NP, Wetzel AC, Stich H, Caffesse RG. Histologic probe penetration in healthy and inflamed peri-implant tissues. Clin Oral Implants Res 1994;5:191–201.
21. Mombelli A, Van Osten MAC, Schurch E, Lang NP. The microbiota associated with successful or failing osseointegrated titanium implants. Oral Microbiol Immunol 1987; 2:145–151.
22. Mombelli A, Lang NP. The diagnosis and treatment of periimplantitis. Periodontol 2000 1998;17:63–76.
23. Hausmann E, Allen K, Christianson L, Genco R. Effect of x-ray beam vertical angulation on radiographic alveolar crest level measurement. J Periodontal Res 1989;24:8–19.
24. Benn DK. A review of the reliability of radiographic measurements in estimating alveolar bone changes. J Clin Periodontol 1990;17:14–21.
25. Hausmann E, Allen KM, Piedimonte MR. Influence of variations in projection geometry and lesion size on detection of computer-simulated crestal alveolar bone lesions by subtraction. J Periodontal Res 1991;26:48–51.
26. Reddy MS, Mayfield-Donahoo TL, Jeffcoat MK. A semiautomated computer-assisted method for measuring bone support of dental implants. Clin Oral Implants Res 1992;3: 28–31.
27. Weber HP, Buser D, Fiorellini JP, Williams RC. Radiographic evaluation of crestal bone levels adjacent to nonsubmerged titanium implants. Clin Oral Implants Res 1992;4: 181–188.
28. Esposito M, Ekestubbe A, Gröndahl K. Radiological evaluation of marginal bone loss at tooth surfaces facing single Brånemark implants. Clin Oral Implants Res 1993;4:151–157.
29. Brägger U. Radiographic parameters for the evaluation of peri-implant tissues. Periodontol 2000 1994;4:87–97.
30. Lekholm U, Zarb GA. Patient selection. In: Lekholm U, Zarb GA, Albrektsson T (eds). Tissue-Integrated Prostheses: Osseointegration in Clinical Dentistry. Chicago: Quintessence, 1985:199–209.
31. Kalbleish JD, Prentice RL. Failure time data. The statistical analysis of failure time data (ed 1). New York: John Wiley and Sons, 1980:1–38.
32. Colton T. Calcolo delle tabelle di sopravvivenza. Statistica in Medicina (ed 1). Padova, Italy: Piccin, 1988:246–251.
33. Albrektsson T, Zarb GA, 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;1:11–25.
34. Buser D, Brägger U, Lang NP, Nyman S. Regeneration and enlargement of jaw bone using guided tissue regeneration. Clin Oral Implants Res 1990;1:449–454.
35. van Steenberghe D. Outcomes and their measurement in clinical trials of endosseous oral implants. Ann Periodontol 1997;2:291–298.
36. Albrektsson T, Zarb GA. Current interpretations of the osseointegrated response: Clinical significance. Int J Prosthodont 1993;6:95–105.
37. Roos J, Sennerby L, Lekholm U, Jemt T, Gröndal K, Albrektsson T. A qualitative and quantitative method for evaluating implant success: A 5-year retrospective analysis of the Brånemark implant. Int J Oral Maxillofac Implants 1997; 12:504–514.
38. Scurria MS, Morgan VZ 4th, Guckes AD, Li S, Koch G. Prognostic variables associated with implant failure: A retrospective effectiveness study. Int J Oral Maxillofac Implants 1998;13:400–406.
39. Jemt T, Lekholm V. Oral implant treatment in posterior partially edentulous jaws: A 5-year-follow-up report. Int J Oral Maxillofac Implants 1993;8:635–640.
40. Lindh T, Gunne J, Tillberg A, Molin M. A meta-analysis of implants in partial edentulism. Clin Oral Implants Res 1998; 9:80–90.
41. van Steenberghe D. A retrospective multicenter evaluation of the survival rate of osseointegrated fixtures supporting fixed partial prostheses in the treatment of partial edentulism. J Prosthet Dent 1989;61:217–223.
42. Collaert B, De Bruyn H. Comparison of Brånemark fixture integration and short term survival using one-stage or two-stage surgery in completely and partially edentulous mandibles. Clin Oral Implants Res 1998;9:131–135.
43. Rodriguez A, Aquilino S, Lund P. Cantilever and implant biomechanics: A review of the literature. Int J Prosthodont 1994;3:41–46.

44. 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;6:114–121.
45. Brägger U, Aeschliman S, Burgin W, Hammerle CH, Lang NP. Biological and technical complications and failures with fixed partial dentures (FPD) on implants and teeth after four or five years of function. Clin Oral Implants Res 2001;12: 26–34.
46. Neart I, Quirynen M, van Steenberghe D, Darius PA. Study of 589 consecutive implants supporting complete fixed prostheses. Part II: Prosthetic aspects. J Prosthet Dent 1992;68: 949–956.
47. Jemt T. Fixed implant-supported prostheses in the edentulous maxilla. A five-year follow-up report. Clin Oral Implants Res 1994;5:142–147.
48. Meijer HJA, Raghoebar GM, Van't Hof MA, Visser A, Geertman ME, Van Oort RP. A controlled clinical trial of implant-retained mandibular overdentures; Five-years' results of clinical aspects and aftercare of IMZ implants and Brånemark implants. Clin Oral Implants Res 2000;11: 441–447.
49. Bergendal T, Engquist B. Implant-supported overdentures: A longitudinal prospective study. Int J Oral Maxillofac Implants 1998;13:253–262.
50. Chiapasco M, Abati S, Romeo E, Vogel G. Implant-retained mandibular overdentures with Brånemark System MKII implants: A prospective comparative study between delayed and immediate loading. Int J Oral Maxillofac Implants 2001; 16:537–546.
51. Adell R, Eriksson B, Lekholm U, Brånemark PI, Jemt T. A long-term follow-up study of osseointegrated implants in the treatment of totally edentulous jaws. Int J Oral Maxillofac Implants 1990;5:347–359.
52. Bass SL, Triplett RG. The effects of preoperative resorption and jaw anatomy on implant success. A report of 303 cases. Clin Oral Implants Res 1991;2:193–198.
53. Jaffin RA, Berman CL. The excessive loss of Brånemark fixtures in type IV bone: A 5-year analysis. J Periodontol 1991; 62:2–4.
54. Jemt T, Heath MR, Johns RB, McNamara DC, van Steenberghe D, Watson RM. A 5-year prospective multicenter follow-up report on overdentures supported by osseointegrated implants. Int J Oral Maxillofac Implants 1996;11: 291–299.
55. Romeo E, Chiapasco M, Ghisolfi M, Vogel G. Long-term clinical effectiveness of oral implants in the treatment of partial edentulism. Seven-year life table analysis of a prospective study with ITI dental implants system used for single-tooth restorations. Clin Oral Implants Res 2002;13:133–143.
56. Balshi TJ, Ekfeldt A, Stenberg T, Vrielinck L. Three-year evaluation of Brånemark implants connected to angulated abutments. Int J Oral Maxillofac Implants 1997;12:52–58.
57. Wismeijer D, van Waas MAJ, Mulder J, Vermeeren JI, Kalk W. Clinical and radiological results of patients treated with three treatment modalities for overdentures on implants of the ITI Dental Implant System. A randomized controlled clinical trial. Clin Oral Implants Res 1999;10:297–306.
58. Friberg B, Grondahl 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.
59. Teixeira ER, Wadamoto M, Akagawa Y, Kimoto T. Clinical application of short hydroxylapatite-coated dental implants to the posterior mandible: A five-year survival study. J Prosthet Dent 1997;78:166–171.
60. Fartash B, Eliasson S, Arvidson K. Mandibular single crystal sapphire implants: Changes in crestal bone levels over three years. Clin Oral Implants Res 1995;6:181–188.
61. Bert M. Therapy of the severely atrophied mandible [in French]. Int J Dent Symp 1994;2(1):52–55.