Eugenio Romeo
Diego Lops
Leonardo Amorfini
Matteo Chiapasco
Marco Ghisolfi
Giorgio Vogel

Clinical and radiographic evaluation of small-diameter (3.3-mm) implants followed for 1–7 years: a longitudinal study

Authors' affiliations:
Eugenio Romeo, Diego Lops, Leonardo Amorfini, Marco Ghisolfi, Department of Prosthodontics, Dental Clinic, School of Dentistry, University of Milan, Milan, Italy
Matteo Chiapasco, Department of Oral Surgery, Dental Clinic, School of Dentistry, University of Milan, Milan, Italy
Giorgio Vogel, Dental Clinic, School of Dentistry, University of Milan, Milan, Italy

Correspondence to:
Eugenio Romeo
Department of Prosthodontics
Dental Clinic, School of Dentistry
University of Milan
Via Beldiletto 1/3, 20142 Milano
Italy
Tel.: +025 031 9039
Fax: +025 031 9040
e-mail: eugenio.romeo@unimi.it

Date:
Accepted 10 March 2005

To cite this article:
Romeo E, Lops D, Amorfini L, Chiapasco M, Ghisolfi M, Vogel G. Clinical and radiographic evaluation of small-diameter (3.3-mm) implants followed for 1–7 years: a longitudinal study.
Clin. Oral Impl. Res. **17**, 2006; 139–148
doi: 10.1111/j.1600-0501.2005.01191.x

Key words: narrow implants, partial edentulism, partial fixed prostheses, peri-implant bone resorption, single-tooth prostheses, standard-diameter implants

Abstract: Implants with a small diameter may be used where bone width is reduced or in single-tooth gaps with limited mesiodistal space, such as for the replacement of lateral maxillary or mandibular incisors. The purpose of the present longitudinal study was to compare the prognosis of narrow implants (3.3-mm-diameter) to standard (4.1-mm-diameter) implants. Over a 7-year period, 122 narrow implants were inserted in 68 patients to support 45 partial fixed prostheses (PFD) and 23 single-tooth prostheses (ST). Furthermore, 120 patients received 208 standard implants and were restored with 70 PFD and 50 ST, respectively. Clinical and radiographic assessment data were provided. Six (1.8%) out of 330 implants failed. Cumulative survival and success rates were calculated with life-table analyses processed by collecting clinical and radiographic data. For narrow implants, the cumulative survival rate was 98.1% in the maxilla and 96.9% in the mandible. The cumulative success rate was 96.1% in the maxilla and 92% in the mandible. Conversely, standard-diameter implants showed a cumulative survival rate of 96.8% in the maxilla and 97.9% in the mandible. The cumulative success rate was 97.6% in the maxilla and 93.8% in the mandible. Cumulative survival and success rates of small-diameter implants and standard-diameter implants were not statistically different ($P > 0.05$). Type 4 bone was a determining failure factor, while marginal bone loss was not influenced by the different implant diameters. The results suggest that small-diameter implants can be successfully used in the treatment of partially edentulous patients.

Bone quantity and quality often determine whether or not a standard implant can be placed. A reduced buccolingual dimension (less than 4 mm in width) does not allow the placement of a standard-diameter implant without increasing the risk of implant threads' exposure. Techniques for local bone augmentation have been described, and their successful use has been documented (Buser et al. 1990; Hämmerle et al. 1998; Chiapasco et al. 2001). However, reconstructive procedures add additional risk and cost because of the necessity of bone harvesting and grafting. Moreover, guided bone regeneration (GBR) may present some limitations such as unpredictable bone gain, risk of membrane exposure, unpredictable bone resorption after barriers are removed and elongation of treatment time. Hence, narrow-diameter implants present an alternative treatment option (Polizzi et al. 1999; Andersen et al. 2001; Zinsli et al. 2004) in areas with limited ridge width. They can also be placed between adjacent teeth that have only a narrow space such as for the replacement of incisors.

Nevertheless, an increased implant surface area can engage more cortical bone. An

experimental study in rabbits showed that wider implant diameters resulted in increased removal torque values (Ivanoff et al. 1999). Clinical reports indicated higher success rates for 4-mm-diameter implants as compared with 3.75-mm-diameter implants in soft quality bone (van Steenberghe et al. 1990; Lekholm 1992). In addition, decreasing the diameter also means increasing the risk of implant fracture because of reduced mechanical stability, and increasing the risk of overload (Schwarz 2000). Some studies focused exclusively on the use of small-diameter implants (Block et al. 1990; Barber & Seckinger 1994; Davarpanah et al. 2000); positive treatment outcomes were documented, but their long-term results remain to be determined (Vigolo & Givani 2000).

The aim of the present longitudinal study was to compare the clinical outcome of small-diameter ITI® implants with standard-diameter ITI® implants, consecutively placed over a 7-year interval. In addition, this study aimed to identify prognostic variables associated with implant failures, as bone quality and implant positioning site.

Material and methods

Patients

Patients included in the present study were treated at the Dental Clinic, Department of Medicine, Surgery and Dentistry, University of Milan, Italy.

Over a time period of 7 years (September 1996–July 2003), a total of 188 partially edentulous patients (83 men and 105 women) in Applegate–Kennedy Classes I and II were consecutively treated with 330 two-part, grade IV, pure titanium, solid screw, ITI® (Institute Straumann, Waldenburg/BL, Switzerland) implants. The age of the patients ranged between 21 and 74 years (mean age: 55.8 years).

All patients presented good general health at the time of surgical procedure, with absence of local inflammation and absence of mucosal disease. The exclusion criteria were as follows: tobacco abuse, i.e., more than 10 cigarettes/day; history of radiotherapy in the head and neck region; leukocyte diseases at the time of surgical procedure; uncontrolled diabetes; severe clenching or bruxism; noncompliant patients; and bone grafts or local GBR before implant placement.

Patients with prostheses supported by small-diameter and standard-diameter implants used in combination were excluded from the study. No patients received more than one implant-supported prosthesis. No implants of 8 mm in length were included in the study.

Routine documentation was as follows: panoramic radiographs taken before treatment and perioapical radiographs taken before treatment, at the time of implant placement, at the time of prosthetic rehabilitation and every year thereafter. Twenty-three patients showing severe atrophic ridges were also evaluated before treatment with computed tomography (CT) scans whenever radiographs were not sufficient to plan the implant treatment.

Two groups of patients were considered: 68 patients were treated with 122 small-diameter (3.3-mm) implants supporting 45 partial fixed prostheses (PFD) and 23 single-tooth prostheses (ST). Another 120 patients received 208 standard-diameter (4.1-mm) implants supporting 70 PFD and 50 ST, respectively (Table 1). Both for small-(3.3-mm) and standard-diameter (4.1-mm) implants, two different lengths (10 and 12 mm) were considered. All implants were titanium plasma-sprayed (TPS) surfaced. Small-diameter implants were used for the following clinical indications: narrow buccolingual width of the maxillary or mandibular ridge in partial edentulous patients; and reduced single-tooth mesiodistal gaps in the maxilla or mandible. Overall, 159 and 171 implants were placed in the maxilla and mandible (Table 2), respectively.

If a patient could not be followed at consecutive annual examination, the corresponding implants were classified as 'drop-out implants'. The reasons for drop-outs were death (one patient), moving out of the area (eight) and lack of interest in attending the examinations (five). Moreover, 13 patients could not be reached. Thus, a total of 27 patients, representing 48 implants (corresponding to 14.5% of the placed implants) and 27 restorations, were excluded from the follow-up protocol.

Surgical treatment

All patients were prepared and draped to ensure strict asepsis. The type of anesthesia was chosen according to the predetermined duration of the procedure and patience compliance. A horizontal incision was beveled toward the crest of the ridge, and then it was extended around the cervical margins of each of the adjacent teeth. Vertical release incisions were avoided whenever possible. Otherwise, it was made one tooth away from the recipient site to include the papilla; it was then extended into the unattached mucosa. After elevating a full-thickness flap, each of the recipient sites was adequately prepared and the implants were positioned. Healing abutments were screwed to each of the positioned implants. The surgical access was sutured with horizontal mattress sutures at the level of the crestal incision and with sutures separated by the releasing incisions. All patients received antibiotics and nonsteroidal analgesics post-operatively. 0.2% chlorhexidine mouthwash was prescribed. After a 7-day waiting period for closure of the surgical wound, sutures were removed.

Prosthetic treatment

Following a healing period of 3–6 months, patients were recalled for a clinical and radiographic evaluation (perioapical radiographs were used); the healing duration was

Table 1. **Implant distribution according to the type of prosthesis**

Implant (mm)	Implants supporting single-tooth prostheses ST (73)	Implants supporting partial-fixed prostheses PFD (115)
3.3 × 10	8	20
3.3 × 10	8	39
3.3 × 12	5	24
3.3 × 12	2	16
4.1 × 10	16	83
4.1 × 10	19	26
4.1 × 12	8	26
4.1 × 12	7	23
Total	73	257

ST, single-tooth prosthesis; PFD, partial fixed prosthesis.

based on bone quality (Lekholm & Zarb 1985). Standards of the ITI® system were followed for prosthodontic procedures (Romeo et al. 2001, 2003).

Frameworks and esthetic veneers were fabricated in gold alloy and porcelain. No welding was performed. Cemented prostheses were fixed with zinc oxyphosphate cement (58 ST and 83 PFD prostheses, respectively). Screw-retained prostheses (15 ST and 32 PFD prostheses, respectively) were secured to the abutments with abutment-framework screws; a manual torque driver was used. Fourty-one temporary prostheses were used to restore anterior teeth. Opposite dentition was natural teeth, fixed prostheses and partial or total mobile prostheses for 172, 127 and 31 implants, respectively.

Assessments

After completion of prosthetic treatment, patients were enrolled in a recall program of supportive therapy and visits every year by means of radiographic and clinical examinations. For the statistical analyses, radiographic and clinical assessments were considered at time of implant proshtetic loading and at last evaluation (Table 3).

The following parameters were considered: (I) peri-implant bone resorption (MBL) radiographic assessment mesial and distal to each implant. Perioapical radiographs (Kodak Ekta-speed EP-22, Eastman Kodak Co., Rochester, NY, USA) were taken with a parallel technique to control projection geometry: the following exposure parameters (65–90 kV, 7.5–10 mA and 0.22–0.25 s) were used (Hausmann et al. 1989, 1991). A computerized analysis (Image-J® image processing software) was performed to determine MBL values (Brägger 1994; Romeo et al. 2003) after converting radiographs to digitalized images (Canoscan® radiograph scanner, Japan). Images were 512 × 512 pixels, having 64 gray levels. In 50 randomly selected cases (66 implants), MBL was remeasured. The mean difference between the first and second assessment was small (0.021 mm), and it can be considered negligible. Measurements were made by one of the authors. (II) Peri-implant soft tissue parameters such as modified bleeding index (MBI) and probing depth (PD) (Mombelli & Lang 1994, 1998) were assessed with a calibrated plastic probe (TPS probe, Vivadent, Schaan, Liechtenstein). Four sites for each implant (mesial, distal, buccal and lingual) were considered for recording probing depth scores. (III) Implant stability, both manually (score 0–2) (Mombelli et al. 1987) and by means of Periotest Instrument® (Siemens AG, Bensheim, Germany) (Chiapasco et al. 2001). The Periotest® was used, with the rod of the device applied tangential to the implant, perpendicular to the longitudinal axis. The patient's head was positioned so that the device could be held horizontally. The test was repeated until the Periotest® values (PTvs) were identical on two subsequent measurements. (IV) Peri-implant bone quality: jawbone quality classification recognized four groups (Lekholm & Zarb 1985): (1) Almost the entire jaw comprised of homogeneous compact bone. (2) A thick layer of compact bone surrounded a core of dense trabecular bone. (3) A thin layer of cortical bone surrounded a core of dense trabecular bone of favorable strength. (4) A thin layer of cortical bone surrounded a core of low-density trabecular bone. Bone quality

Table 2. **Implant distribution by site**

Site	Narrow-diameter implants		Standard-diameter implants	
	No. placed	No. failed	No. placed	No. failed
Maxillary anterior*	29	0	21	0
Maxillary posterior†	27	1	82	1
Mandibular anterior*	18	2	8	0
Mandibular posterior†	48	0	97	2
Total	122	3	208	3

*Anterior region included the canine and incisive districts.
†Posterior region included premolar and molar districts.

Table 3. **Implant distribution: complications and failures**

Site	Bone quality*	Implant dimensions (mm)	Type of prosthesis	Cause of compliance	Cause of failure
24	IV	3.3 × 10 SS	ST	–	Mobility because of severe peri-implantitis
41	IV	3.3 × 10 SS	ST	–	Mobility because of severe peri-implantitis
31	III	3.3 × 10 SS	ST	–	Mobility because of severe peri-implantitis
11	IV	3.3 × 12 SS	ST	Successfully treated peri-implantitis	–
43	III	3.3 × 10 SS	PFD	Pathologic peri-implant bone resorption	–
35	III	3.3 × 10 SS	PFD	Pathologic peri-implant bone resorption	–
36	II	3.3 × 10 SS	ST	Pathologic peri-implant bone resorption	–
36	II	4.1 × 10 SS	ST	–	Mobility because of severe peri-implantitis
47	IV	4.1 × 10 SS	ST	–	Mobility because of severe peri-implantitis
15	IV	4.1 × 12 SS	PFD	–	Mobility because of biomechanical overloading
36	III	4.1 × 10 SS	PFD	Successfully treated peri-implantitis	–
16	III	4.1 × 10 SS	ST	Pathologic peri-implant bone resorption	–
36	II	4.1 × 10 SS	PFD	Successfully treated peri-implantitis	–
37	III	4.1 × 12 SS	PFD	Pathologic peri-implant bone resorption	–
46	I	4.1 × 10 SS	ST	Successfully treated peri-implantitis	–

*Lekholm–Zarb classification (1985).
Tooth numbers: 11 = maxillary right first incisor, 14 = maxillary right first premolar, 16 = maxillary right first molar, 24 = maxillary left first premolar, 31 = mandibular left first incisor, 35 = mandibular right second premolar, 36 = mandibular left first molar, 37 = mandibular left second molar, 41 = mandibular right first incisor, 43 = mandibular right first canine, 46 = mandibular right first molar, 47 = mandibular right second molar.
SS, solid screw; ST, single-tooth prosthesis; PFD, partial-fixed prosthesis.

within the jaw was determined during explorative drilling in the implant site preparation.

Prognostic criteria

Implant stability, peri-implant conditions, marginal bone loss and other treatment-related complications, as well as success and survival criteria were evaluated according to Albrektsson et al. (1986) and Roos et al. (1997).

Implant success was calculated on the following parameters:

- Absence of mobility.
- Absence of painful symptoms or paresthesia.
- Absence of radiolucency during radiographic evaluation.
- Absence of progressive marginal bone loss (bone resorption in measurement areas not greater than 1 mm, during the first year of implant positioning, and 0.2 mm/year in subsequent years).
- Peri-implant probing depth ≤ 3 mm on each peri-implant site (mesial, distal, buccal, oral).

Implant survivals included:

- Therapeutic implant successes.
- Functional and asymptomatic *in situ* implants considered as showing a peri-implant probing MBL rate that exceeds the maximum limits established by the present study.
- Functional and asymptomatic *in situ* implants after peri-implantitis treatment (Mombelli & Lang 1998).

Clinical mobility (because of implant overloading, implant fracture or peri-implantitis not treated successfully) was mandatory for implant removal. Implants showing mobility were regarded as 'failures'.

Statistical analysis

The statistical analysis was performed with the life-table analysis described by Kalbleish & Prentice (1980) and Colton (1988). The data analysis was performed at end of February 2004. Thus, all restored implants had completed at least 1-year clinical examination. Cumulative survival and success rates were calculated for the group of 122 small-diameter implants and the one of 208 standard-diameter implants, divided by jaw. The internal survival rate for each time interval and the entire 6-year period was considered. Life tables included the following parameters: time period (observation time); number of implants at the start of the interval; number of early failed implants (not loaded implants); number of loaded implants; number of implants lost to follow-up as a result of patient dropout; number of implants 'under risk' (it represented the 'harmonic mean' of the implants at the beginning of an interval and the ones remaining at the end of the same interval); number of failed implants during the interval; annual survival and success rates; and cumulative survival and success rates. The χ^2 test was performed to compare the survival and success rates of small-diameter implants and standard-diameter implants, respectively. In addition, the influence of implant diameter on parameters such as MBL and PTvs was tested by means of multiple linear regression analyses.

Results

No early failures were observed; thus, all the positioned implants (330) were loaded. During the follow-up period, two standard-diameter and three small-diameter implants were found to be mobile because of untreatable peri-implant infection and were therefore removed. One standard-diameter implant failed owing to biomechanical overload after 3 years of function. No implant fractures occurred. Failed implants sizes were 3.3×10 mm (three), 4.1×10 mm (two), and 4.1×12 mm (one), respectively. Two failed implants were positioned in the maxilla and four in the mandible. The distribution of failed implants is reported in Table 3. Furthermore, four peri-implantitis were observed and successfully treated by providing interceptive supportive therapy. For one of these implants, professional cleaning was prescribed, followed by a phase (14 days) of administering 0.2% chlorhexidine rinse. For three implants, the threads were smoothed by polishing the implant surface, and the implants were maintained without further complications.

Two standard and three narrow implants showed more than 1 mm of marginal bone loss during the first year of loading, followed by more than 0.2 mm bone resorption per year, respectively. Five standard- and four small-diameter implants were recorded as 'complications' in life-table analysis (Table 3). Six standard-diameter and five small-diameter implants had peri-implant PD > 3 mm on each peri-implant site.

Table 4. **Implant distribution according to bone quality**

Arch	Bone quality*			
	1	2	3	4
Maxilla	10	28	81	40
Mandible	32	94	34	11
Total	42	122	115	51

*According to the Lekholm–Zarb classification (1985).

Implant distribution according to jaw-bone quality is reported in Table 4. Four failed implants were placed in a type 4 quality bone, while one failed implant was placed in a type 2 bone and one was positioned in a type 3 bone. A significantly higher ($P < 0.05$) rate of failures was recorded for implants placed in type 4 bone (7.8%) than implants placed in type 3 bone (0.9%) or type 2 bone (0.8%), respectively.

The mean MBL, PD and MBI values were recorded for narrow- and standard-diameter implants at the beginning of prosthetic load and at the time of the last control (Table 5). A progressive peri-implant bone resorption was observed and regarded to be comparable with the limits suggested by Albrektsson et al. (1986) and Roos et al. (1997). Moreover, PD and MBI scores recorded at first clinical evaluation exhibited small changes as compared with those recorded at last evaluation: this trend was noted both for narrow- and standard-diameter implants. No statistically significant differences in MBL, PD and MBI values were observed between small- and standard-diameter implants ($P > 0.05$): hence, no relationship between implant diameter and these parameters was seen, as tested by multiple linear regression analysis.

After the prostheses placement, the mean PTvs for maxillary 3.3- and 4.1-mm implants were -2.1 and -3.5 U, respectively, whereas the mean PTvs for mandibular 3.3- and 4.1-mm implants were -3.9 and -5.0 U, respectively (Table 6). PTvs obtained for maxillary and mandibular 4.1-mm implants were 1.4 and 1.1 U lower, respectively, than those obtained for 3.3-mm-diameter implants. Instead, at the last check-up visit, the PTv observed for maxillary and mandibular 4.1-mm-diameter

Table 5. **Radiographic and clinical assessments at the time of prosthetic loading and at last evaluation**

Implants	Marginal bone loss*			PD*			MBI		
		Loading: $X \pm \sigma$	Last eval: $X \pm \sigma$		Loading: $X \pm \sigma$	Last eval: $X \pm \sigma$		Loading: $X \pm \sigma$	Last eval: $X \pm \sigma$
Narrow diameter ($n = 122$)	Mesial	0.4 ± 0.5	1.3 ± 1.3	Mesial	2.1 ± 1.6	2.3 ± 0.9	Mesial	0.2 ± 0.4	0.3 ± 0.5
	Distal	0.5 ± 0.4	1.7 ± 1.6	Distal	2 ± 1.3	2.4 ± 1.6	Distal	0.3 ± 0.5	0.3 ± 0.5
	Mean	0.5 ± 0.5	1.5 ± 1.5	Buccal	2.1 ± 1	1.9 ± 1.4	Buccal	0.3 ± 0.5	0.4 ± 0.5
				Lingual	1.9 ± 1.2	2.2 ± 1.9	Lingual	0.4 ± 0.5	0.3 ± 0.7
				Mean	2 ± 1.4	2.2 ± 1.6	Mean	0.3 ± 0.5	0.3 ± 0.5
Standard diameter ($n = 208$)	Mesial	0.3 ± 0.4	1.4 ± 1.1	Mesial	1.7 ± 1.3	2 ± 1.6	Mesial	0.3 ± 0.5	0.3 ± 0.5
	Distal	0.5 ± 0.6	1.3 ± 1.1	Distal	2.2 ± 1.5	2.4 ± 2	Distal	0.3 ± 0.6	0.4 ± 0.4
	Mean	0.4 ± 0.5	1.4 ± 1.1	Buccal	1.8 ± 1.2	1.9 ± 1.5	Buccal	0.3 ± 0.4	0.3 ± 0.4
				Lingual	1.8 ± 0.8	2.1 ± 1.8	Lingual	0.4 ± 0.6	0.5 ± 0.5
				Mean	1.9 ± 1.3	2.1 ± 1.7	Mean	0.3 ± 0.5	0.4 ± 0.5

*Marginal bone loss and probing depth were measured in millimeters.
n, implants; *X*, mean; σ, standard deviation; MBI, modified bleeding index; PD, probing depth.

Table 6. **Variations of the mean periotest values (PTv) related to the implant diameter**

Time	Implant width (mm)			
	Maxillary		Mandibular	
	3.3	4.1	3.3	4.1
Implant loading	− 2.1 (SD ± 0.7)	− 3.5 (SD ± 0.9)	− 3.9 (SD ± 0.8)	− 5 (SD ± 0.9)
Last evaluation	− 4.6 (SD ± 1.1)	− 4.8 (SD ± 0.8)	− 5.6 (SD ± 0.8)	− 5.9 (SD ± 1)

SD, standard deviation.

implants was slightly lower (0.2 and 0.3 U only, respectively) than those of 3.3-mm-diameter implants: these data were similar so that no relationship between implant diameters and implant stability was seen ($P > 0.05$).

Implant distribution according to opposing teeth or prostheses was considered: 95 (45.6%) and 84 (40.4%) standard-diameter (4.1-mm) implants were opposed to natural teeth and fixed prostheses, respectively. Seventy-seven (63.1%) and 43 (35.2%) small-diameter (3.3-mm) implants were opposed to natural teeth and fixed prostheses, respectively; 29 (13.9%) standard and 12 (9.8%) narrow implants were opposed to partial mobile prostheses, respectively. Distribution of failed implants according to opposing dentition did not indicate significant differences between natural teeth or prostheses ($P > 0.5$), as both implants opposed to natural teeth and implants opposed to fixed prostheses showed three failures each.

Over the 7-year follow-up period, survival and success rates were calculated for implants inserted into the maxilla and into the mandible, respectively (Tables 7–10). The maxillary narrow implants exhibited cumulative survival and success rates of 98.1% and 96.1%, respectively; those placed in the mandible revealed cumulative survival and success rates of 96.9% and 92%, respectively. Conversely, cumulative survival and success rates of 98.8% and 97.6%, respectively, have been a result of standard-diameter implants placed in the maxilla. The corresponding implants placed in the mandible showed cumulative survival and success rates of 97.9% and 93.8%, respectively. When cumulative survival and success rates of narrow implants were compared with those of standard-diameter implants, no statistical differences ($P > 0.05$) were found. Similar results were exhibited by the comparison between maxillary and mandibular implants ($P > 0.05$).

The prosthetic restoration of failed implants is reported in Table 3: five single-tooth crowns and one fixed partial prosthesis were used. During the follow-up period, one pontic (3-U PFD prosthesis supported by three 4.1 × 10-mm implants) and one porcelain (single-crown prosthesis supported by a 3.3 × 10-mm implant) fractures were observed. Moreover, 12 abutment-framework fixing screw loosening also occurred. These prosthetic complications concerned partial fixed prostheses supported by small-diameter implants (five) and standard-diameter implants (seven), respectively.

Discussion

From the outcomes of the present study, using small-diameter implants seems to be a treatment option as predictable as using standard-diameter implants. The cumulative survival and success rates of the two groups of implants were comparable, both for the maxillary and mandibular implants. Cumulative survival rates of small-diameter ITI® implants were 98.1% and 96.9% for those placed in the maxilla and in the mandible, respectively. One of the three failed small-diameter implants was positioned in the posterior region of maxilla; also, two narrow implants positioned in the anterior areas of the mandibula failed (Table 3). Conversely, all failed standard-diameter implants (three) were placed in the posterior regions of maxilla (one) and mandibula (two). In the current report, the low number of implant failures was not statistically significant. In addition, data on implant prognosis suggest that high rates of implant survival can be achieved in maxillary sites, even those with a low trabecular density. Hence, a clear positive relatioship between implant location and failure was not found by the authors.

Lekholm et al. (1999) published a 10-year prospective multicenter study on the rehabilitation of 125 partial edentulous patients. Four-hundred and sixty-one implants were placed in 71 mandibles and 56 maxillae. At the end of the 10-year period, implant survival rates of 90.2% and 93.7% were found for the maxilla and the mandible, respectively. Nevertheless, observations made in other reports are in direct opposition to this trend: a total of 1920 IMZ implants were evaluated retrospectively by

Table 7. **Survival rates of narrow-diameter implants**

Interval (years)	Maxilla							Mandible						
	Implants at the start of the interval	Loaded implants	Drop outs*	Implants under risk†	Failures during the interval	Survival rate (%)	Cumulative survival rate (%)	Implants at the start of the interval	Loaded implants	Drop outs*	Implants under risk†	Failures during the interval	Survival rate (%)	Cumulative survival rate (%)
0–1	57	57	1	57	0	100	100	65	65	0	65	0	100	100
1–2	56	56	2	55	0	100	100	65	65	2	64	1	98.5	98.5
2–3	54	54	0	54	0	100	100	62	62	2	61	1	98.4	96.9
3–4	54	54	0	54	0	100	100	59	59	1	58.5	0	100	96.9
4–5	54	54	2	53	0	100	100	58	58	2	57	0	100	96.9
5–6	52	52	0	52	0	100	100	56	56	0	56	0	100	96.9
6–7	52	52	3	50.5	1	98.1	**98.1**	56	56	0	56	0	100	**96.9**

Life-table analysis (1–7 years).
*Implants lost to follow-up.
†Harmonic mean of the implants at the beginning of an interval and the ones remaining at the end of the same interval.

Table 8. **Success rates of narrow-diameter implants**

Interval (years)	Maxilla							Mandible						
	Implants at the start of the interval	Loaded implants	Drop outs*	Implants under risk†	Failures during the interval	Survival rate (%)	Cumulative survival rate (%)	Implants at the start of the interval	Loaded implants	Drop outs*	Implants under risk†	Failures during the interval	Survival rate (%)	Cumulative survival rate (%)
0–1	57	57	1	57	0	100	100	65	65	0	65	0	100	100
1–2	56	56	2	55	0	100	100	65	65	2	64	2	96.9	96.9
2–3	54	54	0	54	0	100	100	61	61	2	60	1	98.4	95.3
3–4	54	54	0	54	0	100	100	58	58	1	57.5	1	98.3	93.7
4–5	54	54	2	53	0	100	100	56	56	2	55	0	100	93.7
5–6	52	52	0	52	1	98.1	98.1	54	54	0	54	0	100	93.7
6–7	51	51	3	49.5	1	98	**96.1**	54	54	0	54	1	98.2	**92**

Life-table analysis (1–7 years).
*Implants lost to follow-up.
†Harmonic mean of the implants at the beginning of an interval and the ones remaining at the end of the same interval.

Table 9. **Survival rates of standard-diameter implants**

Interval (years)	Maxilla							Mandible						
	Implants at the start of the interval	Loaded implants	Drop outs*	Implants under risk†	Failures during the interval	Survival rate (%)	Cumulative survival rate (%)	Implants at the start of the interval	Loaded implants	Drop outs*	Implants under risk†	Failures during the interval	Survival rate (%)	Cumulative survival rate (%)
0–1	105	105	0	105	0	100	100	103	103	2	102	0	100	100
1–2	105	105	6	102	0	100	100	101	101	2	100	0	100	100
2–3	99	99	2	98	0	100	100	99	99	0	99	1	99	99
3–4	97	97	11	91.5	0	100	100	98	98	4	96	0	100	99
4–5	86	86	3	84.5	0	100	100	94	94	0	94	0	100	99
5–6	83	83	0	83	0	100	100	94	94	3	92.5	1	98.9	97.9
6–7	83	83	0	83	1	98.8	**98.8**	90	90	0	90	0	100	**97.9**

Life-table analysis (1–7 years).
*Implants lost to follow-up.
†Harmonic mean of the implants at the beginning of an interval and the ones remaining at the end of the same interval.

Table 10. Success rates of standard-diameter implants

Interval (years)	Maxilla							Mandible						
	Implants at the start of the interval	Loaded implants	Drop outs*	Implants under risk†	Failures during the interval	Survival rate (%)	Cumulative survival rate (%)	Implants at the start of the interval	Loaded implants	Drop outs*	Implants under risk†	Failures during the interval	Survival rate (%)	Cumulative survival rate (%)
0–1	105	105	0	105	0	100	100	103	103	2	102	0	100	100
1–2	105	105	6	102	0	100	100	101	101	2	100	0	100	100
2–3	99	99	2	98	0	100	100	99	99	0	99	2	98	98
3–4	97	97	11	91.5	0	100	100	97	97	4	95	2	97.9	95.9
4–5	86	86	3	84.5	0	100	100	91	91	0	91	0	100	95.9
5-6	83	83	0	83	0	100	100	91	91	3	89.5	2	97.8	93.8
6–7	83	83	0	83	2	97.6	**97.6**	86	86	0	86	0	100	**93.8**

Life-table analysis (1–7 years).
*Implants lost to follow-up.
†Harmonic mean of the implants at the beginning of an interval and the ones remaining at the end of the same interval.

Haas et al. (1996); life-table analysis revealed a significantly lower cumulative survival rate for maxillary implant (71.6% after 60 months) than for mandibular implants (90.4% after 100 months). Conversely, implants diameter had no statistically significant influence on the cumulative survival rate. Implants placed in the anterior region of the maxilla failed significantly more often than those placed in the posterior region: this was not observed in the mandible. Similar findings were reported by Jemt et al. (1989) and van Steenberghe et al. (1989).

In a multicenter retrospective study, Lazzara et al. (1996) published the results of 1871 implants (3i implant system) after 5 years. The authors reported on 202 plasma-sprayed cylinder implants of 3.3-mm diameter. Twenty implants were excluded from the study because of lack of follow-up information. Success rates in the mandible and maxilla were 96% and 95.5%, respectively. From a total of eight failures, five of them were 7-mm-long implants. Failures were because of the absence of osseointegration for six implants and pathologic bone loss for two implants. These prognostic data are consistent with the findings reported by further clinical reports regarding narrow implants (Block et al. 1990; Sethi et al. 1996; Ivanoff et al. 1999; Zinsli et al. 2004) and standard-diameter implants (Wedgood et al. 1992; Bernard et al. 1995; Ten Bruggenkate 1996; Romeo et al. 2001). Several studies focused attention on the role of implant length in conditioning narrow implants prognosis. In 1996, Saadoun & Le Gall published an 8-year clinical report concerning 1499 Steri-Oss® (Nobel Biocare, Göteborg, Sweden) implants placed in 605 patients. Three-hundred and six narrow implants were placed, and 296 of them were loaded. Different lengths were used: 8, 10, 12, 14 and 16 mm. The authors reported 34 failures (89% success rate); 16 failures were 8-mm-long implants (failure rate of 43.2%). The use of mini implants (8 × 3.3 mm) was not recommended by the authors. Consequently, reduced implant height (less than 10 mm) was regarded by the authors of the present study as influencing the prognosis of narrow implants; therefore, only implants of 10 and 12 mm length have been included in the current report.

Moreover, the present study revealed mobility of three narrow-diameter implants and two standard-diameter implants because of peri-implant bone infection. Instead, one narrow-diameter and three standard-diameter implants remained clinically stable (osseointegrated) after successful treatment of peri-implant inflammation by interceptive therapy. In addition, one standard-diameter implant showed mobility on account of biomechanical overloading 3 years after prosthetic load.

Hoshaw & Brunsky (1993) came to the conclusion that implant mechanical loading may affect interfacial bone modelling and remodelling and cause bone microfracture. Consequently, peri-implant bone resorption and fibrous tissue interposition may occur. Lateral forces are involved in implant overload and peri-implant bone resorption more than axial forces (Rangert et al. 1995). Furthermore, Kaptein et al. (1999) reported that occlusal pattern may be modified during the implant-supported prosthesis function (occlusion and chewing). Therefore, correct occlusal contacts may become incongruent after years of function and may produce heavy loads on the implant-supported prosthesis. This biomechanical overload may lead to peri-implant bone resorption. Occlusal contact verification is recommended at the time of periodic control visits. According to this, the authors of the present paper attribute the failure of the biomechanically overloaded implant to an occlusal pattern modification. Moreover, by means of two retrospective studies, Esposito et al. (1998a, 1998b) came to the conclusion that technical and biomechanical problems led to implant failure more frequently than peri-implantitis. Experimental studies (Ivanoff et al. 1997; Kido et al. 1997) demonstrated that removal torque and pull-out force increase because of wider implant diameters; however, the difference was not statistically significant. Furthermore, despite the reduced dimensions and resistance to loading forces, no differences were recorded between survivals of small-diameter (3- and 3.25-mm) and standard-diameter (3.75- and 4.25-mm) implants. According to these results, a recent study (Friberg et al. 2002) on implants of various diameters suggested that the biomechanical aspects of the bone–implant interface may have a greater impact on implant stability than the diameter itself. In an ITI multicenter study with 2359 implants,

Buser et al. (1997) ascribed the failure of 23 loaded implants (about 1%) to peri-implant infection. Similar findings were obtained by Zinsli et al. (2004): four loaded implants (1.4%) were reported with manifestations of peri-implantitis that could be treated and maintained successfully. Nevertheless, in the present study, only one (4.1 × 12 mm) of the six failed implants showed complete peri-implant bone resorption and mobility on account of biomechanical overloading. No narrow implant failed owing to biomechanical overloading, and the other failures were because of untreatable peri-implant infections. Poor oral hygiene was noted at periodic control visits for all patients who experienced implant failures because of peri-implant infections: the authors considered that oral hygiene appeared to be a factor associated with marginal bone resorption more than load-related factors. A prospective 15-year follow-up study of Lindquist et al. (1996) agreed with these findings, concluding that smoking habit and oral hygiene influenced the implant prognosis more than biomechanical factors. Poor oral hygiene was positively correlated to bone loss around anterior implants.

According to Lekholm & Zarb (1985) and Jaffin & Berman's (1991) evaluations on peri-implant bone quality and quantity, this prospective study confirmed the role of bone quality in conditioning the implant prognosis: in fact, 66.6% of the failed standard and narrow implants were positioned in type 4 bone. Although the maxillary arch exhibited soft bone quality as compared with the mandible, only two maxillary implants failed. However, the low number of failures has answered the authors to perform further researches on a larger number of implants so that these statements can be confirmed.

Friberg et al. (1991) suggested that jaw shape and bone quality seemed to be the two most important factors in implant survival. In 32% of the implant losses, they considered bone quality at fixture placement to be extremely soft. Similar conclusions were made by Engquist et al. (1988) in a retrospective multicenter report about osseointegrated implants supporting overdenture prostheses. Furthermore, a multicenter study on factors related to the success and failure of 510 Brånemark implants was performed by Hutton and coworkers (1995): by means of a multivariate analysis (multiple logistic regression), it was revealed that dental arch ($P = 0.0193$) and bone quality 4 ($P = 0.0434$) were the only variables that remained significantly ($P < 0.05$) related to implant failure. Such a relationship did not clearly exist from the results of a retrospective clinical report presented by Ivanoff et al. (1999): however, they explained the lack of a relationship between implant failure, jaw type and bone quality by the fact that the number of failed implants was low, which results in a low power. According to the results of the present study, they also denied a relationship between different implant diameters and marginal bone loss.

In this longitudinal report, the mean marginal bone loss scores of narrow- and standard-diameter implants were comparable (Table 5); this result was not in accordance with previous experimental findings using finite-element method analysis, in which increasing implant diameters were associated with lower stress in the marginal compact bone around implants (Matsushita et al. 1990). Besides, in a prospective clinical study by Andersen et al. (2001), MBL values were reported for standard and small-diameter implants. Both groups showed a measurable tendency toward increased mean bone loss at each examination. This is comparable with the results in the present study, where the restorations were followed for 7 years (Table 5).

Finally, the authors assessed the correlation of different implant diameters to the implant stability: Periotest® measurements were performed because the radiofrequency resonance analysis was not available since the start of the examinations. Objections have been rasied on the clinical use of the Periotest® method. Although a good inter-examiner reliability has been reported, PTVs can be increased or decreased by changes in the vertical measuring point on the implant abutment, the handpiece angulation and the horizontal distance of the handpiece from the implant. Therefore, the use of the resonance frequency analysis device seems to be safer in assessing reliable implant stability data, because variables during standardized measurements are kept to a minimum (Meredith et al. 1998). Isidor (1998) showed that the use of Periotest Instrument® was of little additional value in assessing the stability of implants, as compared with manual mobility assessments. However, a number of researchers (Salonen et al. 1993; van Steenberghe & Quirynen 1993; van Steenberghe et al. 1995; Chiapasco et al. 2001; Romeo et al. 2003) have reported the use of the Periotest® to detect sub-clinical mobility of osseointegrated implants; in a retrospective study after monitoring the damping capacity of 1182 consecutively inserted implants, Aparicio & Orozco (1998) proposed the use of the Periotest® as an initial criteria of success.

PT values exhibited in the current study (Table 6) agreed with the range (between −7 and +1 U for maxillary implants and between −7 and 0 U for mandibular implants) established by van Steenberghe & Quirymen (1993). The initial PTVs of standard-diameter implants were 1.4 and 1.1 U lower than those of small-diameter implants; one reason why the mean Periotest® values obtained at the implant loading for 4.1-mm-diameter implants were lower than the values for 3.3-mm-diameter implants might be related to the fact that standard-diameter implants have a lower flexural modulus than narrow implants. Nevertheless, the difference was buffered afterward till the PT values were 0.2 and 0.3 U lower for maxillary and mandibular implants, respectively (Table 6). Furthermore, by means of multi-linear regression analysis, no relationship was found between implant stability assessed by Periotest® and 3.3- or 4.1-mm implant diameters.

The results presented can be summarized as follows:

(i) Narrow implants medium-term prognosis is comparable to the one of standard-diameter implants followed up in the present study. Therefore, the high reliability of small-diameter implants is confirmed.
(ii) Standard and narrow implant prognoses were influenced by peri-implant bone infection more than biomechanical factors, such as implant overloading.
(iii) Peri-implant bone resorption was not significantly influenced by different implant diameters (3.3 and 4.1 mm).
(iv) Bone quality seems to be an important prognosis factor both for standard- and small-diameter implants; spongy bone (type 4) may increase

implant failures. This trend needs to be confirmed by the clinical evaluation of a larger number of implants.

(v) Survival of standard and narrow implants does not seem to be affected by implant location. However, because of the low number of implant failures observed in the current study, further research is required to elucidate the most appropriate implant distribution.

Acknowledgements: The authors gratefully acknowledge the assistance of Mr Stefano Storelli, Department of Prosthodontics, Dental Clinic, School of Dentistry, University of Milan, Italy in collecting and analyzing data.

要旨
直径が細いインプラントは、骨幅の狭い部位や上顎側切歯や下顎切歯のように近遠心的な幅が限られている単独歯の欠損部位に用いることができる。本縦断的研究は、細いインプラント（３．３ｍｍ径）と標準（４．１ｍｍ径）インプラントの予後を比較した。７年間に患者６８名に細いインプラント１２２本を埋入して、上部構造として固定式部分義歯（ＰＦＴ）４５個と単独歯補綴物（ＳＴ）２３個を装着した。さらに患者１２０名に標準インプラント２０８本を埋入して、ＰＦＤ７０個とＳＴ５０個の補綴物を装着した。臨床的及びレントゲン像による評価データを収集した。インプラント３３０本のうち６本（１．８％）が失敗した。
臨床的データとＸ線データを処理して、生命表分析によって累積存続率と成功率を計算した。細いインプラントの累積存続率は、上顎が９８．１％、下顎が９６．９％であった。累積成功率は、上顎が９６．１％、下顎が９２％であった。逆に標準径のインプラントの累積存続率は、上顎が９６．８％、下顎が９７．９％であった。累積成功率は上顎が９７．６％、下顎が９３．８％であった。細いインプラントと標準インプラントの累積存続率と成功率には統計学的有意差はなかった（ｐ＞０．０５）。タイプ４の骨質であることが失敗の決定要素であったが、辺縁骨の喪失はインプラントの異なる直径によって影響されなかった。これらの結果は、細い径のインプラントは、部分無歯顎患者の治療に成功裏に用いることができる事を示唆している。

References

Albrektsson, T., Zarb, G. & Worthington, P. (1986) The long term efficacy of currently used dental implant: a review and proposed criteria of success. *International Journal of Oral & Maxillofacial Implants* **1**: 33–40.

Andersen, E., Saxegaard, E., Knutsen, B.M. & Haanes, H.R. (2001) A prospective clinical study evaluating the safety and effectiveness of narrow-diameter threated implants in the anterior region of the maxilla. *International Journal of Oral & Maxillofacial Implants* **16**: 217–224.

Aparicio, C. & Orozco, P. (1998) Use of 5-mm-diameter implants: periotest® values related to a clinical and radiographic evaluation. *Clinical Oral Implants Research* **9**: 398–406.

Barber, H.D. & Seckinger, R.J. (1994) The role of the small diameter implant: a preliminary report on the minimplant system. *Compendium* **15**: 1390–1392.

Bernard, J.P., Belser, U.L., Szmukler-Moncler, S. & Martinet, J.P. (1995) The utilization of the ITI implant system with variable longness in the posterior sectors. Results from 3 to 5 years. *Medicina Buccale e Chirurgia Buccale* **6**: 482–488.

Block, M.S., Delgado, A. & Fontenot, M.G. (1990) The effect of diameter and length of hydroxylapatite-coated dental implants on ultimate pullout force in dog alveolar bone. *International Journal of Oral and Maxillofacial Surgery* **48**: 174–178.

Brägger, U. (1994) Radiographic parameters for the evaluation of peri-implant tissues. *Periodontology 2000* **4**: 87–97.

Buser, D., Brägger, U., Lang, N.P. & Nyman, S. (1990) Regeneration and enlargement of jaw bone using guided tissue regeneration. *Clinical Oral Implants Research* **1**: 22–32.

Buser, D., Mericske-Stern, R., Dula, K. & Lang, N. (1997) Long-term evaluation of non submerged ITI implants. Part 1: eight year life table analysis of a prospective multicenter study with 2359 implants. *Clinical Oral Implants Research* **8**: 161–172.

Chiapasco, M., Romeo, E. & Vogel, G. (2001) Vertical distraction osteogenesis of edentulous ridges for improvement of oral implant positioning: a clinical report of preliminary results. *International Journal of Oral & Maxillofacial Implants* **16**: 43–51.

Colton, T. (1988) *Calcolo delle tabelle di sopravvivenza. Statistica in medicina*. 1st edition, 246–251. Padova: Piccin.

Davarpanah, M., Martinez, H., Tecucianu, J.F., Celletti, R. & Lazzara, R. (2000) Small-diameter implants: indications and contraindications. *International Journal of Esthetic dentistry* **12**: 186–194.

Engquist, B., Bergendal, T., Kallus, T. & Linden, U. (1988) A retrospective multicenter evaluation of osseointegrated implants supporting overdentures. *International Journal of Oral & Maxillofacial Implants* **3**: 129–134.

Esposito, M., Hirsch, J.M., Lekholm, U. & Thomsen, P. (1998a) Biological factors contributing to failures of osseontegrated oral implants (I). Success criteria and epidemiology. *European Journal of Oral Science* **106**: 527–551.

Friberg, B., Ekestubbe, A. & Sennerby, L. (2002) Clinical outcome of Brånemark system implants of various diameters: a retrospective study. *International Journal of Oral and Maxillofacial Surgery* **17**: 671–677.

Friberg, B., Jemt, T. & Lekholm, U. (1991) Early failures in 4,641 consecutively placed Brånemark dental implants: a study from stage 1 surgery to the connection of completed prostheses. *International Journal of Oral & Maxillofacial Implants* **6**: 142–146.

Haas, R., Mensdorff-Pouilly, N., Mailath, G. & Watzek, G. (1996) Survival of 1,920 IMZ implants followed for up to 100 months. *International Journal of Oral & Maxillofacial Implants* **11**: 581–588.

Hämmerle, C., Brägger, U., Schmid, B. & Lang, N.P. (1998) Successfull bone formation at immesdiate transmucosal implants. *International Journal of Oral & Maxillofacial Implants* **13**: 522–530.

Haussmann, E., Allen, K., Christianson, L. & Genco, R. (1989) Effect of x-ray beam vertical angulation on radiographic alveolar crest level measurement. *Journal of Periodontal Research* **24**: 8–19.

Haussmann, E., Allen, K.M. & Piedimonte, M.R. (1991) Influence of variations in projection geometry and lesion size on detection of computer-simulated crestal alveolar bone lesions by subtraction. *Journal of Periodontal Research* **26**: 48–51.

Hoshaw, S.J. & Brunsky, J. (1993) Mechanical loading of Brånemark implants affects interfacial bone modelling and remodelling. *International Journal of Oral & Maxillofacial Implants* **9**: 345–360.

Hutton, J.E., Heath, M.R., Chai, J.Y., Harnett, J., Jemt, T., Johns, R.B., McKenna, S., McNamara, D.C., van Steenberghe, D. & Taylor, R. (1995) Factors related to success and failure rates at 3-year follow-up in a multicenter study of overdentures supported by Branemark implants. *International Journal of Oral & Maxillofacial Implants* **10**: 33–42.

Isidor, F. (1998) Mobility assessment with periotest system in relation to histologic findings of oral implants. *International Journal of Oral & Maxillofacial Implants* **3**: 377–383.

Ivanoff, C.J., Gröndahl, K., Sennerby, L., Bergström, C. & Lekholm, U. (1999) Influence of variations in implant diameters: a 3- to 5-year retrospective clinical report. *International Journal of Oral & Maxillofacial Implants* **14**: 173–180.

Ivanoff, C.J., Sennerby, L., Johansson, C., Rangert, B. & Lekholm, U. (1997) Influence of implant diameters on the integration of screw implants. An experimental study in rabbits. *International Journal of Oral & Maxillofacial Surgery* **26**: 141–148.

Jaffin, R.A. & Berman, C.L. (1991) The excessive loss of Brånemark fixtures in type IV bone. *Journal of Periodontology* **62**: 2–4.

Jemt, T., Lekholm, U. & Adell, R. (1989) Osseointegrated implants in the treatment of partially edentulous patients: a preliminary study on 876 consecutively placed fixtures. *International*

Journal of Oral & Maxillofacial Implants **4**: 211–217.

Kalbleish, J.D. & Prentice, R.L. (1980) *Failure Time Data. The Statistical Analysis of Failure Time Data*. 1st edition, 1–38. New York: Wiley and Sons Inc.

Kaptein, M.L., De Putter, C., De Lange, G.L. & Blijdorp, P.A.J. (1999) A clinical evaluation of 76 implant-supported superstructures in the composite grafted maxilla. *Journal of Oral Rehabilitation* **26**: 619–23.

Kido, H., Schulz, E.E., Kumar, A., Lozada, J. & Saha, J. (1997) Implant diameter and bone density: effect on initial stability and pull-out resistance. *Journal of Oral Implantology* **13**: 163–169.

Lazzara, R., Siddiqui, A.A., Binon, P., Feldman, S.A., Weiner, R., Phillips, R. & Gonshor, A. (1996) Retrospective multicenter analysis of 3i endosseous dental implants placed over a five-year period. *Clinical Oral Implants Research* **7**: 73–83.

Lekholm, U. (1992) The Brånemark implant technique. A standardized procedure under continuous developement. In: Laney, W.R. & Tolman, D.E., eds. *Tissue Integration in Oral, Orthopedic and Maxillofacial Reconstruction*, 194–199. Chicago: Quintessence.

Lekholm, U., Gunne, J., Henry, P., Higuchi, K., Linden, U., Bergström, C. & van Steenberghe, D. (1999) survival of the Bränemark implant in partially edentulous jaws: a 10-year prospective multicenter study. *International Journal of Oral & Maxillofacial Implants* **14**: 639–645.

Lekholm, U. & Zarb, G. (1985) Patient selection and preparation. In: Brånemark, P.I., Zarb, G. & Albrektsson, T., eds. *Tissue-Integrated Prostheses: Osseointegration in Clinical Dentistry*, 199–209. Chicago: Quintessence.

Lindquist, L.W., Carlsson, G.E. & Jemt, T. (1996) A prospective 15-year follow-up study of mandibular fixed prostheses supported by osseointegrated implants. Clinical results and marginal bone loss. *Clinical Oral Implants Research* **7**: 329–336.

Matsushita, Y., Kitoh, M., Mizuta, K., Ikeda, H. & Suetsugu, T. (1990) Two-dimensional FEM analysis of hydroxyapatite implants: diameter effects on stress distribution. *Journal of Oral Implantology* **16**: 6–11.

Meredith, N., Friberg, B., Sennerby, L. & Aparicio, C. (1998) Relationship between contact time measurements sand PTv values when using the periotest to measure implant stability. *International Journal of Prosthodontics* **11**: 269–275.

Mombelli, A. & Lang, N.P. (1994) Clinical parameters for evalutation of dental implants. *Periodontology 2000* **4**: 81–86.

Mombelli, A. & Lang, N.P. (1998) The diagnosis and treatment of peri-implantitis. *Periodontology 2000* **16**: 575–579.

Mombelli, A., Van Osten, M.A.C., Schurch, E. & Lang, N.P. (1987) The microbiota associated with successful or failing osseointegrated titanium implants. *Oral Microbiology and Immunology* **2**: 145–151.

Polizzi, G., Fabbro, S., Furri, M., Herrmann, I. & Squarzoni, S. (1999) Clinical application of narrow Brånemark system implants for single tooth restorations. *International Journal of Oral & Maxillofacial Implants* **14**: 496–503.

Rangert, B., Krough, P.H., Langer, B. & Van Roekel, N. (1995) Bending overload and implant fracture: a retrospective clinical analysis. *International Journal of Oral and Maxillofacial Implants* **10**: 326–334.

Romeo, E., Chiapasco, M., Ghisolfi, M. & Vogel, G. (2001) Long-term clinical effectiveness of oral implants in the treatment of partial edentulism. 7-year life table analysis of a prospective study with ITI dental implants system used for single-tooth restoration. *Clinical Oral Implants Research* **13**: 133–143.

Romeo, E., Lops, D., Margutti, E., Ghisolfi, M., Chiapasco, M. & Vogel, G. (2003) Implant-supported fixed cantilever prostheses in partially edentulous arches. A seven-year prospective study. *Clinical Oral Implants Research* **14**: 303–311.

Roos, J., Sennerby, L., Lekholm, U., Jemt, T., Gröndal, K. & Albrektsson, T. (1997) A qualitative and quantitative method for evaluating implant success: a 5-year retrospective analysis of the Brånemark implant. *International Journal of Oral & Maxillofacial Implants* **12**: 504–514.

Saadoun, A.P. & Le Gall, M.G. (1996) An 8-year compilation of clinical results obtained with steri-oss endosseous implants. *Compendium Continue Education Dentistry* **17**: 669–674, 676 passim; quiz 688.

Salonen, M., Oikarinen, K., Virtanen, K. & Pernu, H. (1993) Failures in the osseointegration of endosseous implants. *International Journal of Oral & Maxillofacial Implants* **8**: 92–97.

Schwarz, M.S. (2000) Mechanical complications of dental implants. *Clinical Oral Implants Research* **11** (Suppl 1): 156–158.

Sethi, A., Harding, S. & Sochor, P. (1996) Initial results of the osteo ti implant system in general dental practice. *European Journal of Prosthodontic Restorative Dentistry* **4**: 21–28.

Ten Bruggenkate, C.M. (1996) Succeses and failures at the iti system (1–7 year follow-up). Presented at the CMFI Meeting, Dordrecht, the Netherlands.

van Steenberghe, D., Lekholm, U., Bolender, C., Folmer, T., Henry, P. & Herrman, I. (1990) The applicability of osseointegrated oral implants in the rehabilitation of partial edentulism. *International Journal of Oral & Maxillofacial Implants* **5**: 271–281.

van Steenberghe, D. & Quirynen, M. (1993) Reproducibility and detection threshold of peri-implant diagnostics. *Advanced Dental Research* **7**: 191–195.

van Steenberghe, D., Sullivan, D., Lström, R., Balshi, T., Henry, P.J. & Worthington, P. (1989) A retrospective multicenter evaluation of the survival rate of osseointegrated fixtures supporting fixed partial prostheses in the treatment of partial edentulism. *Journal of Prosthetic Dentistry* **61**: 217–223.

van Steenberghe, D., Tricio, J., Naert, I. & Nys, A. (1995) Damping characteristiques of bone-to-implant interfaces. *Clinical Oral Implants Research* **6**: 31–39.

Vigolo, P. & Givani, A. (2000) Clinical evaluation of single tooth minimplant restorations. *Journal of Prosthetic Dentistry* **84**: 50–54.

Wedgood, D., Jennings, K.J., Critchlow, H.A. & Watkinson, A. (1992) Experience with ITI osseointegrated implants at five centers at U.K. *British Journal of Oral and Maxillofacial Surgery* **30**: 377–381.

Zinsli, B., Sägesser, T., Mericske, E. & Mericske-Stern, R. (2004) Clinical evaluation of small-diameter ITI implants: a prospective study. *International Journal of Oral & Maxillofacial Implants* **19**: 92–99.