CLINICAL ORAL IMPLANTS RESEARCH

*Jung-Chul Park**
*Won-Sun Baek**
Seong-Ho Choi
Kyoo-Sung Cho
Ui-Won Jung

Long-term outcomes of dental implants placed in elderly patients: a retrospective clinical and radiographic analysis

Authors' affiliations:
Jung-Chul Park, Department of Periodontology, College of Dentistry, Dankook University, Cheonansi, Korea
Won-Sun Baek, Seong-Ho Choi, Kyoo-Sung Cho, Ui-Won Jung, Department of Periodontology, Research Institute for Periodontal Regeneration, College of Dentistry, Yonsei University, Seoul, Korea

Corresponding author:
Ui-Won Jung
Department of Periodontology
Research Institute for Periodontal Regeneration
College of Dentistry
Yonsei University
50-1 Yonseiro, Seodaemun-gu
Seoul 120-752
Korea
Tel.: +82 2 2228 3185
Fax: +82 2 392 0398
e-mail: drjew@yuhs.ac

Key words: aging, dental implant, risk factors, survival analysis

Abstract

Objectives: The aim of this retrospective study was to determine the clinical and the radiographic outcomes of dental implants placed in elderly people older than 65 years.

Materials and methods: In total, 902 implants in 346 patients (age: 65–89 years) were followed up for 2–17 years following the implant surgery. The survival rate of these implants was recorded and analyzed. Changes in marginal bone levels were also analyzed in serial radiographs, and Cox regression analysis for implant loss was performed.

Results: The survival rates were 95.39% and 99.98% in the implant- and patient-based analyses, respectively (involving a total of 29 implant failures), and the marginal bone loss at the implants was 0.17 ± 0.71 mm (mean ± SD). The number of failures was greatest in patients aged 65–69 years. The Cox regression with shared frailty analysis showed that implant loss was significantly greater in those aged 65–69 years than in those aged 70–74 years ($P < 0.05$), and it varied between specific implant systems.

Conclusions: Within the limitations of this retrospective study, it was concluded that implant therapy can be successfully provided to elderly patients and that age alone does not seem to affect the implant survival rate.

Elderly people often present with physiologic or pathologic changes such as severe alveolar ridge resorption, osteoporosis, xerostomia, diabetic mellitus, or cardiovascular diseases during the aging process (Zarb & Schmitt 1994; Al Jabbari et al. 2003). As osseointegration is largely governed by the wound-healing response of a patient, successful outcomes for dental implants could be expected to be less likely in older patients due to the relationships of age with osteoporosis (Cummings et al. 1985) or gingival healing capacity (Holm-Pedersen & Loe 1971). The alveolar bone quantity and quality are often compromised in elderly people relative to younger subjects (Bryant 1998), which can present more challenging clinical situations for implant placement. Also, elderly people tend to consume more medications associated with systemic diseases, and some such medications have been demonstrated to affect the prognosis of dental implants (Fu et al. 1997).

It was demonstrated that advanced age is a potential contraindication to the success of osseointegration (Salonen et al. 1993), which was subsequently supported in another study (Brocard et al. 2000). This situation has resulted in practicing dentists and dental researchers paying considerable attention to the impact of aging itself on the prognosis of implants (Zarb & Schmitt 1994; Garg et al. 1997; Bryant & Zarb 1998, 2003; Al Jabbari et al. 2003). Although there are previous reports of the age-related characteristics of dental implant prognosis, the true impact of age on dental implants remains controversial. For instance, Smith et al. (1992) investigated the medical risks associated with dental implants in 104 patients with a mean age of 52.8 years with 313 implants and concluded that age, sex, and concurrent use of drugs were not correlated with increased implant failure rates. Another study found that most of their 48 patients older than 80 years with 254 implants experienced minimal problems postsurgery (as for younger patients), and it was concluded that age is not a risk factor for dental implant outcome (Jemt 1993).

As implant failures seem to be a multifactorial problem, it is difficult to evaluate the

*These authors contributed equally to this work.

Date:
Accepted 20 December 2015

To cite this article:
Park J-C, Baek W-S, Choi S-H, Cho K-S, Jung U-W. Long-term outcomes of dental implants placed in elderly patients: a retrospective clinical and radiographic analysis.
Clin. Oral Impl. Res. **00**, 2016, 1–6
doi: 10.1111/clr.12780

impact of age alone on the results of implant treatment. However, most of the discrepancies among previous studies seem to be associated with improper or prebiased study designs. Therefore, studies involving larger samples with long-term evaluation periods are required to determine the effects of age on implant therapy with adequate statistical power.

The aim of this retrospective study was to determine the clinical and radiographic outcomes of dental implants placed in elderly people older than 65 years.

Material and methods

A retrospective 17-year follow-up study was performed involving elderly patients aged over 65 treated consecutively with dental implants at a single clinic by two experienced surgeons (K.S.C. and U.W.J.) in the Department of Periodontology, College of Dentistry, Yonsei University, Seoul, Korea, between 1997 and 2012 (Orimo et al. 2006). The enrolled patients were recalled for checkups from May 2013 to June 2014.

Study population

The original study group consisted of 367 patients and 945 implants. However, 21 patients with 43 implants were lost to follow up for reasons of death (two patients with five implants), refusal to attend checkup (10 patients with 14 implants), and loss of contact (nine patients with 24 implants). Therefore, the final study group consisted of 346 patients and 902 implants. The patients were aged from 65 to 89 years (70.34 ± 4.67 years, mean±SD) at the time of the surgery, and the follow-up duration was 71.19 ± 43.45 months (median = 2171 days [IQR = 2249 days]). The study design was reviewed and authorized by the Institutional Review Board of Yonsei University Dental Hospital (approval no. 14-0094).

The information regarding systemic diseases was obtained from the patient records. There was at least 1 systemic disease present in 236 of the 346 patients. No adverse reactions related to systemic disease were observed following the surgical procedures. The dominant disease was hypertension (n = 149) and 110 of the subjects were healthy without any reported diseases.

Patient registration

All data were retrieved retrospectively from the patients' dental records, including information on age, sex, general health, time of implant surgery, implant manufacturer, and position and number of implants. Patients were recalled for checkup on a routine basis, but also individually recalled for closer checkups if this was considered necessary. Moreover, all of the patients were encouraged to contact the clinic if they experienced any problems with their prostheses.

Outcome measurements

The following outcome measurements for implants placed in elderly populations were applied in this study:

Implant failure

Implant failure was assessed based on implant loss, presence of mobility, or removal due to severe peri-implant infection or implant fracture. Implant survival was considered to have occurred for the following outcomes (Buser et al. 1997; Cochran et al. 2002): (a) absence of clinically detectable implant mobility, (b) absence of pain and subjective discomfort, (c) absence of peri-implant infection, and (d) absence of continuous radiolucency around the implant.

Peri-implant marginal bone loss

Panoramic radiographs obtained at implant placement and at every follow-up visit were analyzed based on changes in marginal bone levels (Akesson 1991; Draenert et al. 2012). The distance between the implant reference point (the fixture–abutment junction) and the marginal bone level, on both the mesial and distal sides of the implants, was recorded by two blinded examiners (J.C.P. and W.S.B.). The value between the mesial and distal sides of the implant was used for calculating the marginal bone loss.

Statistical analysis

Data collection and analysis were performed by two independent examiners (J.C.P. and W.S.B.). Conventional descriptive statistics (mean and SD values) were used for the present study materials. The overall survival rate of implants was estimated by Kaplan–Meier survival estimates for implant-based analysis, and by Cox regression with shared frailty hazard regression for patient-based analysis. The analysis unit was each inserted implant in the implant-based analysis, whereas it was each patient – considered as many times as the number of implant surgical sessions undertaken – in the surgery-based analysis. Finally, the patient-based analysis considered each patient only once independently of the number of implants received. The cutoff for statistical significance was set at 5%. Cox proportional hazards regression (with forward stepwise selection in the 2 log likelihood ratio test) was used to identify the risk factors related to implant loss. The covariates studied included age, sex, implant position, bone type and quantity, the reason for extraction, and the implant system. Descriptive statistics, Student's t-test, and two-tailed Pearson's correlation test were performed using standard statistical software (Stata, version 13, Stata Corporation, College Station, TX, USA).

Results

Implant survival and Kaplan–Meier estimates

The 346 patients who received 902 dental implants comprised 217 males and 129 females (Table 1), with 506 and 243 implants placed in patients aged 65–69 and 70–74 years, respectively.

Twenty-nine implants were removed due to failure during the follow-up period in 18 patients. Most (n = 22) of the failures occurred in patients aged 65–69 years (Table 2), followed by three and four implants failing in patients aged 70–74 and 75–79 years, respectively. The overall survival rate of implants was estimated in implant- and patient-based analyses. At the end of the study period, the survival rates were 95.39% and 99.98% in the implant- and patient-based analyses, respectively. The Kaplan–Meier estimates and Cox regression with shared frailty hazard regression analysis of implant survival are illustrated in Fig. 1. The number of failures was highest for implants manufactured by Nobel Biocare

Table 1. **Patients and implant fixture distribution according to age group and sex**

Age group, years	Males n (%)	Females n (%)	Total	Number of implants
65–69	116 (62.4)	70 (37.6)	186	506
70–74	65 (63.7)	37 (36.3)	102	243
75–79	26 (56.5)	20 (43.5)	46	131
80–84	9 (90.0)	1 (10.0)	10	17
85–89	1 (50.0)	1 (50.0)	2	5
Total	217	129	346	902

(Gotenburg, Sweden) (Table 3). Each case was carefully analyzed in a dental chart. Fifteen implants in 11 patients were lost within the first year of loading. The reason for the loss of each implant is summarized in Table 4. The marginal bone level was measured in 882 implants of the 902 implants by two experienced examiner (J.C.P. and W.S.B.) and was 0.17 ± 0.71 mm. As only 71 implants showed marginal bone loss, the average of marginal bone loss for these implants was measured 2.08 ± 1.52 mm (median = 1.49 [IRQ = 1.79]). The bone loss was greatest (0.21 ± 0.79 mm) in those aged 65–69 years, while 22 implants placed in patients older than 80 years showed no marginal bone loss during the follow-up period.

Multivariable Cox regression with shared frailty for implant loss

Multivariable regression analysis using the Cox frailty model showed that the implant loss was not affected by sex, implant location (anterior/posterior or maxilla/mandible), bone type, or bone quantity. Instead, the age specificity of implant loss showed that this was significantly greater in those aged 65–69 years than in those aged 70–74 years ($P = 0.033$) (Table 5). Also, some of the implant systems showed significantly greater implant loss, and implant failure rate was significantly greater in males than in females.

Discussion

It is necessary to evaluate the nature of aging as a risk factor for dental implants given that this is considered to be a feasible treatment option for most of the older patients. However, there is lack of evidence on this issue (Kondell et al. 1988; Jemt 1993; Zarb & Schmitt 1993; Ochi et al. 1994). The present study investigated the impact of aging using a retrospective cohort study model with a 17-year follow-up period.

A previous study involving a relatively large group of patients found that advanced age appeared to increase the risk of implant failure, with the rate of adverse outcomes being twofold higher in patients older than 60 years (Moy et al. 2005). The present study found that the failure rate of implants placed in people older than 65 years was 4.61% at the implant level and 0.02% at the patient level; these proportions are similar to those found in previous studies (Kinsel & Liss 2007). However, there are little, if any, studies which compared the outcomes in older and younger patients in a case–control study form (Kondell et al. 1988; Zarb & Schmitt 1993; Ochi et al. 1994), and the results are conflicting which may be resulted from the different age criteria or the homogeneity of implant systems, diameter/length, additional surgeries, or prosthetic treatments. To fully investigate the age-specific impact on the prognosis of implants, a carefully designed prospective matched case–control study is required for further study.

One particularly interesting finding is that 15 of the osseointegration failures in the present study took place within 1 year after the implant placement. It has been well demonstrated that aging impedes skeletal healing in both humans (Skak & Jensen 1988) and animals (Shirota et al. 1993; Meyer et al. 2004). Recent developments in implants with various macroscopic and microscopic designs, better implant surface treatment techniques, and the introduction of better surgical procedures have significantly elevated the success rate of dental implant therapies. However, it remains important to fully advise patients about the possibility of early failure due to poor skeletal healing, and the implant system should be carefully selected so as to maximize bone healing (Chae et al. 2015). As the quality and quantity of bone is greatly affected by aging, objective analysis prior to surgery is also crucial. However, recent systematic reviews have concluded that it is not clear whether the systemic osteoporosis is associated with the jawbone density. Therefore, aged patients with osteoporosis may present different jawbone state and the clinicians should evaluate the skeletal bone densities as a separate entity (Calciolari et al. 2015a,b).

Another interesting finding was that most of the implant failures occurred in those aged 65–69 years, and the survival rate was fairly good in patients older than 70 years. Furthermore, there were no cases of failure in

Table 2. **Surviving and failed implants according to age group**

Age group, years	Surviving *n* (%)	Failed *n* (%)	Total	Number of patients with failed implants
65–69	484 (95.7)	22 (4.4)	506	14
70–74	240 (98.8)	3 (1.2)	243	2
75–79	127 (97.0)	4 (3.1)	131	2
80–84	17 (100.0)	0 (0)	17	0
85–89	5 (100.0)	0 (0)	5	0
Total	873	29	902	18

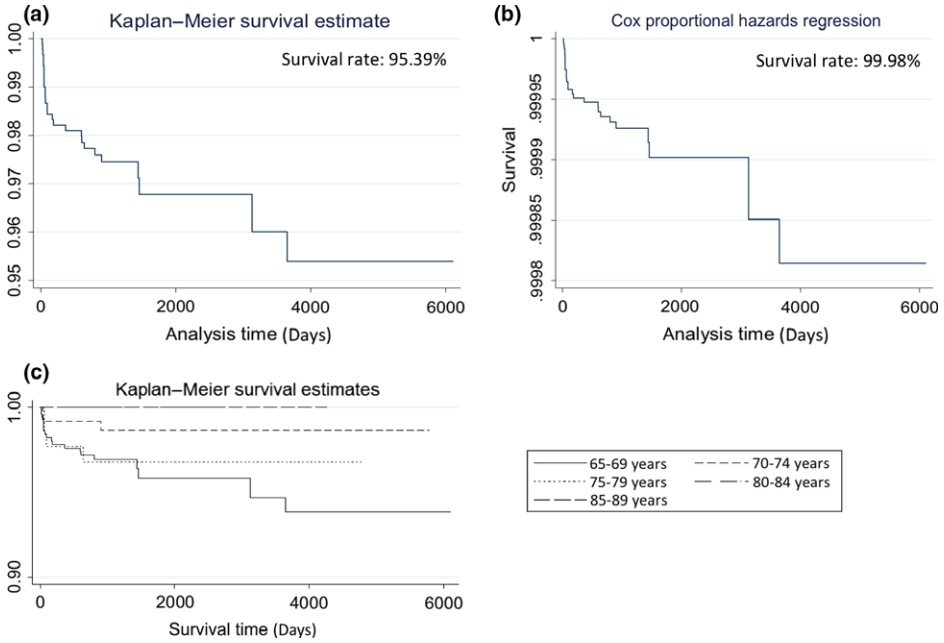

Fig. 1. The implant survival analysis. (a) Kaplan–Meier survival estimates for implant-based analysis show survival rate of 95.39% over time. (b) Cox regression with shared frailty for the survival of implants at patient level reveals the survival rate of 99.98%. (c) The overall Kaplan–Meier survival estimates grouped by ages show that the survival rate was the lowest in 65–69 age group.

Table 3. **Number of failed implants according to implant system**

Implant system	Failed implants/total implants
Branemark (Nobel Biocare)	20/345
Straumann	5/352
Osstem	2/139
Replace (Nobel Biocare)	2/35
Other systems*	0/31
Total	29/902

*Other systems include Implantium (Dentium, Seoul, South Korea), Luna (Shinhung, Seoul, South Korea), Neo (Neo Biotech, Seoul, South Korea), SPI (Thommen Medical, Waldenburg, Switzerland), and 3i (Biomet, Warsaw, IN, USA).

subjects older than 80 years. It seems that retrospective cohort studies may have been influenced by selection bias, with the success rates being higher due to elderly patients not being willingly to undergo implant placement involving an advanced bone graft or when an extended healing period is expected. Also, the advanced and complex surgical modalities would have been circumvented using shorter and narrower implants in older patients. These factors could have interfered with evaluations of impact of age on implant outcomes.

Regarding the true effect of age on crestal bone loss around dental implants, a more definitive conclusion should be corroborated by more scientific and tenable long-term studies involving broader age ranges. It is reasonable to assume that aging is associated with impairment of the healing potentials of soft tissue and skeletal healing (Holm-Pedersen & Loe 1971). However, no study has compared the survival of implants between elderly subjects and properly matched younger groups. A few studies (Kondell et al. 1988; Bryant & Zarb 1998) have tried to match the test and control groups with respect to the diversity of various parameters, including sex, implant system, implant diameter and length, site, prosthetic result, and systemic health. As the elderly are usually provided with implant-supported dentures on edentulous jaws, the relatively high success rate of implants in this population could have been masked by favoring a site-specific basis rather than the age-specific difference (Bryant & Zarb 1998). As it is virtually impossible to perform a randomized, controlled clinical trial in a case study with matching ages, a long-term evaluation study with substantial numbers of subjects of various ages should be performed in order to fully

Table 4. **Case list of failed implants**

Patient characteristics				Implant characteristics			Surgery		Implant loss	
Patient number	Age, years	Sex	Systemic disease	Length, mm	Diameter, mm	System	Tooth number	Advanced surgery	Reason for failure	Duration before implant failure (months)
1	67	Male	HTN	13	3.75	Branemark	37	No	Screw fracture	116
			HTN	11.5	4	Osstem	46	No	Osseointegration fail	1.5
			HTN	10	4.5	Osstem	47	No	Osseointegration fail	1.5
			HTN	15	3.75	Branemark	36	No	Fixture fracture	116
2	65	Male	N-S	10	5	Branemark	47	No	Infection	0.5
3	69	Male	N-S	10	4.1	Straumann	14	No	Osseointegration failure	3
			N-S	8	4.1	Straumann	26	No	Peri-implantitis	20
4	71	Female	HTN	8.5	4	Branemark	37	No	Infection	1
			HTN	8.5	4	Branemark	36	No	Infection	1
5	68	Male	HTN	13	3.5	Replace	22	No	Osseointegration failure	1
6	65	Female	N-S	11.5	4	Branemark	46	No	Peri-implantitis	47
			N-S	8.5	5	Branemark	47	No	Peri-implantitis	47
7	66	Male	N-S	10	3.3	Straumann	32	No	Osseointegration failure	2
8	69	Male	N-S	8	4.8 WN	Straumann	37	Yes	Unknown	25
9	73	Male	DM	7	4	Branemark	35	No	Peri-implantitis	29
10	69	Male	HTN, DM	13	4	Branemark	15	No	Infection	0.5
11	75	Male	N-S	10	5	Branemark	37	No	Peri-implantitis	21
12	68	Male	N-S	10	5	Branemark	37	No	Osseointegration failure	12
13	69	Male	N-S	10	5	Branemark	17	No	Osseointegration failure	17
14	68	Male	N-S	11.5	4	Branemark	45	No	Fracture	120
15	68	Male	HTN	8.5	5	Branemark	27	No	Osseointegration failure	5.5
16	68	Female	HTN	8.5	5	Branemark	26	No	Peri-implantitis	115
			HTN	8.5	5	Branemark	27	No	Peri-implantitis	115
17	66	Male	HTN	11.5	4	Branemark	23	No	Peri-implantitis	48
			HTN	11.5	4	Branemark	25	No	Peri-implantitis	48
			HTN	8	4.1	Straumann	37	No	Osseointegration failure	6
18	76	Male	HTN	10	3.5	Replace	23	No	Osseointegration failure	3
			HTN	11.5	4	Branemark	24	No	Osseointegration failure	2
			HTN	11.5	4	Branemark	23	No	Osseointegration failure	2

HTN, hypertension; DM, diabetes mellitus; N-S,nonspecific; WN, wide neck.

Table 5. **Multivariable Cox regression with shared frailty for implant loss**

Predictor	Hazard ratio	Standard error	*P*	95% confidence interval	
Age, years (reference: 65–69 years)					
70–74	0.14	0.13	**0.033**	0.02	0.85
75–79	0.51	0.43	0.419	0.1	2.63
80–84	0	0	1	–	–
85–89	0	0	1	–	–
Females (reference: males)	0.23	0.16	**0.04**	0.05	0.93
Mandible (reference: maxilla)	2.18	1.22	0.161	0.73	6.51
Posterior (reference: anterior)	2.08	1.37	0.265	0.57	7.57
Bone type (reference: 4)					
1	3.74	6.63	0.458	0.12	121.32
2	1.02	1.09	0.983	0.13	8.27
3	1.88	1.77	0.499	0.3	11.83
Bone quantity (reference: D)					
A	0	0	1	–	–
B	0.69	0.95	0.788	0.05	10.08
C	1.7	2.26	0.691	0.12	23.18
External reason (reference: periodontitis)					
Nonrestorable caries damage	4.78	4.65	0.108	0.71	32.18
Root fracture	0	0	1	–	–
Unknown	13.82	11.11	**0.001**	2.86	66.79
Fixture company (reference: Straumann)					
Branemark (Nobel Biocare)	11.05	8.19	**0.001**	2.59	47.21
Osstem	6.75	6.45	**0.046**	1.04	43.98
Replace (Nobel Biocare)	25.25	31.02	**0.009**	2.27	280.5
Shinhung	0	0	1	–	–
Neobiotech	0	0	1	–	–
Dentium	0	0	1	–	–

Bold values represent statistically significant factors $P < 0.05$. –, no failures were observed.

understand the impact of aging on implant outcomes.

Another interesting result in the present study was that marginal bone loss was relatively greater in males (data not shown), which may be interpreted interchangeably with the greater incidence of peri-implantitis in males, especially in the presence of a history of periodontitis or smoking habit (Strietzel et al. 2007; Koldsland et al. 2011; Mombelli et al. 2012; Busenlechner et al. 2014). Although a large amount of literature points to the accumulation of biofilm being the main reason for bone resorption around an implant (i.e., "peri-implantitis"), several authors have indicated that many factors other than infection may be involved, including patient-, clinician-, and foreign-body-related factors (Albrektsson et al. 2012). Therefore, meticulous consideration of elderly patients throughout these treatments as well as the appropriate maintenance of correct oral hygiene and high patient compliance should be emphasized (Mombelli et al. 2012).

The results obtained in the present study suggest that the patient's age does not represent a factor of major prognostic significance in implant treatment, whereas bone quantity, bone quality, or implant systems may be more critical to a favorable result (de Baat 2000). Recent studies indicate that the life-course epidemiology could be a useful instrument to investigate a causal connection between early exposures and later outcomes of chronic oral conditions, and age as a risk factor for dental implants could be considered as the results from the accumulated events throughout the life course (Nicolau et al. 2007a,b; Nascimento et al. 2014). Also, the concurrent occurrence of medical conditions including oral dryness and osteoporosis may cause delayed healing (Garg et al. 1997), and so extra care should be applied both during and after surgery.

Within the limitations of the present study, it has been shown that age alone does not appear to affect the success of implants nor the marginal bone loss, with fairly high implant survival rates being observed during a long-term follow-up period.

Acknowledgements: This present research was conducted by the research fund of Dankook University in 2014 (R-0001-27206). We thank Dr. Hoi-In Jung (Oral Science Research Center, College of Dentistry, Yonsei University, Seoul, Korea) for performing the statistical analysis.

Competing interests

None.

References

Akesson, L. (1991) Panoramic radiography in the assessment of the marginal bone level. *Swedish Dental Journal. Supplement* **78**: 1–129.

Al Jabbari, Y., Nagy, W.W. & Iacopino, A.M. (2003) Implant dentistry for geriatric patients: a review of the literature. *Quintessence International* **34**: 281–285.

Albrektsson, T., Buser, D., Chen, S.T., Cochran, D., DeBruyn, H., Jemt, T., Koka, S., Nevins, M., Sennerby, L., Simion, M., Taylor, T.D. & Wennerberg, A. (2012) Statements from the Estepona consensus meeting on peri-implantitis, February 2–4, 2012. *Clinical Implant Dentistry & Related Research* **14**: 781–782.

de Baat, C. (2000) Success of dental implants in elderly people – a literature review. *Gerodontology* **17**: 45–48.

Brocard, D., Barthet, P., Baysse, E., Duffort, J.F., Eller, P., Justumus, P., Marin, P., Oscaby, F., Simonet, T., Benque, E. & Brunel, G. (2000) A multicenter report on 1,022 consecutively placed ITI implants: a 7-year longitudinal study. *The International Journal of Oral & Maxillofacial Implants* **15**: 691–700.

Bryant, S.R. (1998) The effects of age, jaw site, and bone condition on oral implant outcomes. *The International Journal of Prosthodontics* **11**: 470–490.

Bryant, S.R. & Zarb, G.A. (1998) Osseointegration of oral implants in older and younger adults. *The International Journal of Oral & Maxillofacial Implants* **13**: 492–499.

Bryant, S.R. & Zarb, G.A. (2003) Crestal bone loss proximal to oral implants in older and younger adults. *The Journal of Prosthetic Dentistry* **89**: 589–597.

Busenlechner, D., Furhauser, R., Haas, R., Watzek, G., Mailath, G. & Pommer, B. (2014) Long-term implant success at the Academy for Oral Implantology: 8-year follow-up and risk factor analysis. *Journal of Periodontal & Implant Science* **44**: 102–108.

Buser, D., Mericske-Stern, R., Bernard, J.P., Behneke, A., Behneke, N., Hirt, H.P., Belser, U.C. & Lang, N.P. (1997) Long-term evaluation of non-submerged ITI implants. Part 1: 8-year life table analysis of a prospective multi-center study with 2359 implants. *Clinical Oral Implants Research* **8**: 161–172.

Calciolari, E., Donos, N., Park, J.C., Petrie, A. & Mardas, N. (2015a) Panoramic measures for oral

bone mass in detecting osteoporosis: a systematic review and meta-analysis. *Journal of Dental Research* **94**: 17S–27S.

Calciolari, E., Donos, N., Park, J.C., Petrie, A. & Mardas, N. (2015b) A systematic review on the correlation between skeletal and jawbone mineral density in osteoporotic subjects. *Clinical Oral Implants Research*. doi: 10.1111/clr.12597.

Chae, S.W., Kim, Y.S., Lee, Y.M., Kim, W.K., Lee, Y.K. & Kim, S.H. (2015) Complication incidence of two implant systems up to six years: a comparison between internal and external connection implants. *Journal of Periodontal & Implant Science* **45**: 23–29.

Cochran, D.L., Buser, D., ten Bruggenkate, C.M., Weingart, D., Taylor, T.M., Bernard, J.P., Peters, F. & Simpson, J.P. (2002) The use of reduced healing times on ITI implants with a sandblasted and acid-etched (SLA) surface: early results from clinical trials on ITI SLA implants. *Clinical Oral Implants Research* **13**: 144–153.

Cummings, S.R., Kelsey, J.L., Nevitt, M.C. & O'Dowd, K.J. (1985) Epidemiology of osteoporosis and osteoporotic fractures. *Epidemiologic Reviews* **7**: 178–208.

Draenert, F.G., Sagheb, K., Baumgardt, K. & Kammerer, P.W. (2012) Retrospective analysis of survival rates and marginal bone loss on short implants in the mandible. *Clinical Oral Implants Research* **23**: 1063–1069.

Fu, E., Nieh, S. & Wikesjo, U.M. (1997) The effect of plaque retention on cyclosporine-induced gingival overgrowth in rats. *Journal of Periodontology* **68**: 92–98.

Garg, A.K., Winkler, S., Bakaeen, L.G. & Mekayarajjananonth, T. (1997) Dental implants and the geriatric patient. *Implant Dentistry* **6**: 168–173.

Holm-Pedersen, P. & Loe, H. (1971) Wound healing in the gingiva of young and old individuals. *Scandinavian Journal of Dental Research* **79**: 40–53.

Jemt, T. (1993) Implant treatment in elderly patients. *The International Journal of Prosthodontics* **6**: 456–461.

Kinsel, R.P. & Liss, M. (2007) Retrospective analysis of 56 edentulous dental arches restored with 344 single-stage implants using an immediate loading fixed provisional protocol: statistical predictors of implant failure. *The International Journal of Oral & Maxillofacial Implants* **22**: 823–830.

Koldsland, O.C., Scheie, A.A. & Aass, A.M. (2011) The association between selected risk indicators and severity of peri-implantitis using mixed model analyses. *Journal of Clinical Periodontology* **38**: 285–292.

Kondell, P.A., Nordenram, A. & Landt, H. (1988) Titanium implants in the treatment of edentulousness: influence of patient's age on prognosis. *Gerodontics* **4**: 280–284.

Meyer, M.H., Etienne, W. & Meyer, R.A., Jr. (2004) Altered mRNA expression of genes related to nerve cell activity in the fracture callus of older rats: a randomized, controlled, microarray study. *BMC Musculoskeletal Disorders* **5**: 24.

Mombelli, A., Muller, N. & Cionca, N. (2012) The epidemiology of peri-implantitis. *Clinical Oral Implants Research* **23**(Suppl 6): 67–76.

Moy, P.K., Medina, D., Shetty, V. & Aghaloo, T.L. (2005) Dental implant failure rates and associated risk factors. *The International Journal of Oral & Maxillofacial Implants* **20**: 569–577.

Nascimento, G.G., Leite, F.R., Correa, M.B., Horta, B.L., Peres, M.A. & Demarco, F.F. (2014) Relationship between periodontal disease and obesity: the role of life-course events. *Brazilian Dental Journal* **25**: 87–89.

Nicolau, B., Netuveli, G., Kim, J.W., Sheiham, A. & Marcenes, W. (2007a) A life-course approach to assess psychosocial factors and periodontal disease. *Journal of Clinical Periodontology* **34**: 844–850.

Nicolau, B., Thomson, W.M., Steele, J.G. & Allison, P.J. (2007b) Life-course epidemiology: concepts and theoretical models and its relevance to chronic oral conditions. *Community Dentistry and Oral Epidemiology* **35**: 241–249.

Ochi, S., Morris, H.F. & Winkler, S. (1994) Patient demographics and implant survival at uncovering: Dental Implant Clinical Research Group Interim Report No. 6. *Implant Dentistry* **3**: 247–251.

Orimo, H., Ito, H., Suzuki, T., Araki, A., Hosoi, T. & Sawabe, M. (2006) Reviewing the definition of "elderly". *Geriatrics & Gerontology International* **6**: 149–158.

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

Shirota, T., Ohno, K., Suzuki, K. & Michi, K. (1993) The effect of aging on the healing of hydroxylapatite implants. *Journal of Oral and Maxillofacial Surgery* **51**: 51–56.

Skak, S.V. & Jensen, T.T. (1988) Femoral shaft fracture in 265 children. Log-normal correlation with age of speed of healing. *Acta Orthopaedica Scandinavica* **59**: 704–707.

Smith, R.A., Berger, R. & Dodso, T.B. (1992) Risk factors associated with dental implants in healthy and medically compromised patients. *International Journal of Oral Maxillofacial Implants* **7**: 367–372.

Strietzel, F.P., Reichart, P.A., Kale, A., Kulkarni, M., Wegner, B. & Kuchler, I. (2007) Smoking interferes with the prognosis of dental implant treatment: a systematic review and meta-analysis. *Journal of Clinical Periodontology* **34**: 523–544.

Zarb, G.A. & Schmitt, A. (1993) Implant therapy alternatives for geriatric edentulous patients. *Gerodontology* **10**: 28–32.

Zarb, G.A. & Schmitt, A. (1994) Osseointegration for elderly patients: the Toronto study. *The Journal of Prosthetic Dentistry* **72**: 559–568.