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ORIGINAL ARTICLE

Early outcome of an implant system with a resorbable adhesive calcium–phosphate coating—a prospective clinical study in partially dentate patients

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Abstract This study aims to investigate the early outcome of a dental implant with bioactive calcium–phosphate (CaP) coating in the first year of usage in different clinical indications in partially edentulous patients, after early and delayed prosthetic loading. Therefore, in a prospective follow-up study, the cumulative survival and success rate of a conical, self-drilling and self-tapping implant system after 6 months and 1 year post-insertion was evaluated. A total of 311 CaP-coated implants were placed in 124 patients. Seventy-two implants in clinical high-quality bone situation were loaded after 2 weeks post-insertion with the definite restoration; the rest after 6 months. The indication for implant placement was treatment of partial dentate mandible and maxilla. One hundred sixty-three implants were placed in the posterior mandible, 117 in the posterior maxilla. In the frontal maxilla, 25 implants and in the frontal mandible, eight implants were used. In 126 cases (36%), bone augmentation procedures (guided bone regeneration and sinus lift) were performed concomitant with implant placement. The difference between primary and secondary stability (implant stability quotient (ISQ), Periotest, insertion torque), peri-implant clinical parameter as well as survival and success criteria were evaluated. In total, ISQ mean values after 6 months were higher than after implant placement. Periotest values increased in the period of the first 6 months and remained constant afterwards. After 6 months of insertion, the mean bone loss was 0.051 mm. After 12 months, a bone gain with a mean of +0.016 mm was observed; implants in the posterior maxilla showed significant less bone resorption than implants in the posterior mandible ($p<0.0001$). In the most of the implants (74%), clinical normal gingival tissue could be observed. In 24%, a mild inflammation was analysed. In 35 implants, a provocation of peri-implant bleeding was possible. In the early loading group, no implant failure was seen. Altogether, one implant in D4 bone has been lost. The cumulative survival rate summed up to 99.7%. In general, implant success assessment analysis according to Albrektsson and Buser displayed success in 99.7% of the implants. With respect to the patient selection including 124 implants with minor and major augmentations as well as early loading prosthetic function, the 1-year clinical use of the studied implant system with CaP coating showed good results, comparable to that of conventional implants without a specific coating. After 1 year, neither special

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disadvantages nor benefits of CaP-coated implants could be evaluated. Long-term results are further needed.

Keywords Alfa Gate · Dental implant · Success assessment criteria · 1 Year · Bioactive® · Calcium–phosphate coating · Partial edentulous

Introduction

Placement of dental implants in partially and total edentulous people is an efficacious method for replacement of missing teeth [1]. The last decades have brought a vast variety of implant designs and technical modifications to improve healing and prevent bone loss. According to the literature, more than 1,300 types of dental implants are available, in different materials, shapes, sizes, lengths, with different surface characteristics or coatings [2]. The success rate for osseointegration of dental implants was shown to be very high for many different designs and brands of implants [3–5]. Primary stability, which is one of the most important criteria of implant integration and success rate in the early healing phase, depends mainly on the enosseous design of the implant (length, diameter, shape, and thread) besides the surgical technique, volume, and mechanical quality of local bone [3, 4]. During the osseointegration period, bone gradually remodels to the implant threads and thus the secondary stability is attained by direct bone to implant contact [5]. It is proportioned with implant success rate, depending on bone remodelling induced by a mechanical stress situation during the initial phase of bone healing and surface modification of the implants [6]. According to current literature, there are discussions concerning the ability of implants to withstand early or immediate loading in order to reduce waiting time for the patient. In addition to the mentioned parameters of the primary and secondary stability, the implant surface osteoconductive characteristics are factors which affect the implant bone response and quality of the bone implant interface [7, 8]. Surface treatment helps to enhance secondary stability after insertion by promoting osseointegration [6, 9, 10]. Various methods have been developed and tested in order to coat metal implants, e.g., plasma spraying, sputter deposition, sol–gel coating, electrophoretic deposition or biomimetic precipitation [11, 12]. Electrochemical methods to modify native titanium surfaces are relatively simple, cheap and effective techniques [11, 13, 14]. Calcium–phosphate (CaP) coatings are well-known in dental implantology [12, 15] and may enhance osseointegration of a dental implant due to biologically active surface chemistry [16, 17]. Recently, a surface implant system with a completely resorbable and adhesive CaP coating (Bioactive®) is available (Fig. 1). Bioactive® coating is a newly developed electrochemical process for implant coating in an aqueous solution containing calcium and phosphate ions. According to the manufacturers dates, the calcium phosphate coating properties are: low coating thickness of 20–30 μm with a large active surface, high capillarity effect on blood, stimulation of the body's own osteosynthesis [18] and substitution of Bioactive® coating by young bone directly on the implant surface within 6–10 weeks postoperative. The implant is a five-grade titanium alloy with a sandblasted and etched microstructure, internal hexagon, spiral, conical, self-drilling, self-tapping, double-thread system, with deep and especially sharp threads decreasing towards the implant shoulder, enabling implant self-retention, aiming for high primary stability. To our knowledge, additionally to the animal experiments of Reigstad et al. [18], no clinical follow-up studies regarding implants with this surface were published. Therefore, the aim of the present study was to investigate the early outcome of a recently developed dental implant with CaP coating (Alfa Gate, Kfa Qara, Israel) after 6 months and 1 year of usage in different clinical situations in partially edentulous patients. The difference between primary and secondary stability (implant stability quotient (ISQ), Periotest), peri-implant clinical parameter as well as survival and success criteria were evaluated.

Fig. 1 Picture of the CaP-coated implant

Materials and methods

Patients and implants

The results from 311 implants consecutively placed by our team in the period between January 2008 and December

2008 have been analysed. All implants used in the study are the Alfa Gate Bioactive implant system (Alfa Gate Dental Implants, Kfar Qara, Israel). The implants were inserted in 124 patients, 71 were male and 53 were female. The mean age at implant placement was 41.44 years (18–62; standard deviation (SD) 11.2). The inclusion criteria were: partial dentate mandible or maxilla, older than 18 years of age, patient's informed consent, fixed prosthetic rehabilitation. Exclusion criteria were: edentulous patients, treatment with removable prosthesis on implants, acute and chronic sinus infections, maxillary cysts, tumours, root tips; physical and psychiatric severe consideration that may affect the implant procedure; history of chemotherapy and radiotherapy of the maxillofacial and cervical areas, and severe smoking. There were, however, no restrictions on bone quality and quantity or additional bone grafting and regeneration procedures intended for implant placement. Inclusion criteria for early loading of the implants (2 weeks after implant placement) was a clinically stable situation with a subjective bone density <D4 [19]. No other inclusion or exclusion criteria were applied. Demographic and anamnesis data were recorded by an independent investigator.

One hundred sixty-three implants were placed in the posterior mandible, 117 in the posterior maxilla. In the frontal maxilla, 25 implants and in the frontal mandible, eight implants were used. The aetiology of teeth loss and implant insertion had been chronic periodontitis in 284 cases, prior dental trauma in 14 cases, orthodontic reasons (n=6) and extractions of former blade implants (n=6). In 126 cases (36%), bone augmentation procedures (guided bone regeneration, sinus lift) were performed concomitant with implant placement. In 41 of these cases, an internal sinus lift without bone substitutes materials (mean bone distraction 2.2 mm (1–4 mm)); in 15 of these cases, an external sinus lift with bone substitutes: autogenous bone, CaP material and collagen membrane (mean 8.1 mm bone reconstruction (1–12 mm)) was done during implant placement. The implants differed in diameter (3.3/3.75/4.2/4.7 mm) and in length (6/8/10/11.5/13/16 mm). Implant placement was done after a mean of 48.12 months after extraction (0–122; SD 33 months). In clinical high quality bone situations, 72 implants were loaded 2 weeks after implant placement with the fixed and definite prosthetic restoration. In 239 implants, the time between implant placement and loading was 6 months. Standard abutments were used. All restorations were cemented.

Outcome criteria

The primary outcome criteria were implant survival and success rate according to the criteria of Albrektsson et al. [20] which was recorded in accordance with implant's survival time or time to loss, mobility of the implant, peri-implant radiographic translucency, bone loss, signs of infection/inflammation and lesions of the anatomical structures. Also, the success rate according to the criteria of Buser et al. [21] was estimated. These criteria are in accordance with position of the implant, mobility of the implants, peri-implant radiographic translucency, infection and/or inflammation and absence of chronic pain, dysesthesia and/or foreign body feeling.

The secondary outcome criteria were appreciation of modified Loe and Silness gingival index [22], plaque index according to Mombelli [23] as well as bleeding score according to Mühlemann [24].

For gingival index, the buccal, mesial, oral and distal surfaces of the gingival tissues were scored according to the following criteria: 0, clinical visible normal gingiva, no inflammation; 1 mild inflammation—slight changes in colour, slight oedema, no bleeding on probing; 2, moderate inflammation—redness, oedema and glazing, bleeding upon probing; 3, severe inflammation—marked redness and oedema, ulceration, tendency to bleed spontaneously. The gingival score was measured at four aspects of the implants, the highest score per implant being used for data analysis. The plaque score was scored as 0 (no plaque), 1 (greater than 0, but less than 1/3 surface covered with plaque), 2 (1/3 to 1/2 surface covered with plaque) and 3 (greater than 1/2 surface covered with plaque). It was used to quantify the amount of plaque retained on the surface of the supragingival part of the implant. The plaque score was measured at four aspects of the implants, the highest value per implant being used for data analysis. While measuring the bleeding score (0, none; 1, induced and 2, spontaneous), the highest value per implant was used for data analysis [25].

The following paraclinical analyses [22] were determined to access the necessary dates for success and survival rate of implants: the implant primary and secondary stability (the resonance frequency analysis (ISQ; Osstells Mentor®, Osstell AB, Gothenburg, Sweden)) and Periotest® (Siemens AG, Bensheim, Germany) as well as radiological outcomes of the bone changes around implants.

Surgical procedures

All surgeries were performed under local anaesthesia with open flap access to the bone. Osteotomy preparations of neo alveolas were performed with low speed high-torque drill units (800 rpm) using intense irrigation with a cold saline solution. During each site preparation of the neo alveolas for the implants, the bone quality (I–IV [26]) was recorded. All implants were placed manually nonsubmerged and final torque was measured with a manual torque control wrench. A standard nonsubmerged healing abutment was used. For the quantitative evaluation of implant stability, resonance frequency analysis was recorded with the Osstell Mentor device after implant

placement and 6 months post-insertion. Periotest measurements were done after implant placement, 6 months and 1 year post-insertion. The Periotest values were recorded three times and the replicates' median value was documented. Orthopantomographic X-ray images were used for calculation of radiological bone loss and the respective success criterion [27, 28].

Statistics

A one-way analysis of variance with Tukey simultaneous post hoc test was conducted to compare groups in regard of implant stability (ISQ, Periotest, insertion torque) as well as in regard of peri-implant bone loss. The nature of this experiment was descriptive, exploratory without a primary hypothesis. Therefore, we report descriptive p values of tests and no adjustment to multiple testing was done. P values<.05 were termed significant. The Kaplan–Meier survival function was used for the description of survival rates. The analyses were conducted using SPSS version 15.0 (SPSS, Chicago, Il., USA).

Results

Clinical follow-up

All 124 patients with 311 implants were seen at 6 months and at 1 year clinical follow-up examinations. The observed results were as follows. The primary and secondary stability was assessed with the Osstell Mentor and Periotest devices. Osstell ISQ dates were collected at the beginning to the all implants insertion and after 6 months only for 238 implants placed with 6-month healing period. The Periotest dates were obtained in all cases immediate after surgery, after 6 and 12 months postsurgery. Mean values for all implants are given below, subgroup data analysing the influence of augmentation as well as implant location on implant stability and bone resorption are given in Tables 1, 2 and 3.

The ISQ mean values for the 238 implants prosthetic rehabilitated after 6 months of loading period were 59.1 (41–72; SD 5.7) compared with a mean value of 63.1 (56–73; SD 3.5) after implant placement. After implant placement, the mean value for the Periotest analysis was −3.64 (−8 to 3; SD 2.14). After 6 months the value was −4.74 (−8 to −1; SD 1.57). The mean value of the Periotest examination after 12 months postoperative was −4.75 (−8 to 2; SD 1.57; Fig. 2). A comparison between Periotest values of early and delayed loaded implants is given in Fig. 3. The results of the study show an insertion torque average from 10 to 50 Ncm for the all of implants. The clinical dense bone quality (D1) exhibited the highest torque placement with 47.7 Ncm (40–50; SD 3.1). A significant difference (p<0.0001; Fig. 4) of insertion torque and bone quality was noted: bone D1—mean insertion torque of 47.7 Ncm, 5.5 of cases; D2 bone—mean insertion torque of 37.6 Ncm (30–45; SD 2.96), 39.2% of cases; bone D3—mean insertion torque of 30 Ncm (15–35; SD 3.7), 40.2% of cases and soft bone of D4 density—mean insertion torque of 21 Ncm (10–25; SD 3.3), 15.1% of cases.

The highest torque was obtained in the anterior mandible with the medium value of 40 Ncm and the lowest in the posterior maxilla with medium torque of 29 Ncm (Fig. 5). Of the torques, 33 and 34 Ncm were documented for the posterior mandible and anterior maxilla (Table 1). For the 72 implants loaded after 2 weeks post-insertion, the values of insertion torque were: five implants in D3 bone with mean torque of 33 Ncm (30–35; SD 2.7); 63 implants in D2 bone of 38 Ncm (30–45; SD 3.3) and four implants in D1 bone with a mean 46 Ncm insertion torque (40–50; SD 4.8). A comparison between the insertion torque of early (mean 38 Ncm (30–50; SD 4.1)) and delayed loaded implants (mean 29.7 Ncm (10–50; SD 8.3)) is given in Fig. 6. A significant difference (P<0.0001) was estimated regarding implant diameter and insertion torque: the highest values were noted for the implants with 3.3 mm diameter (40–50 Ncm), 3.75 mm (30–35 Ncm), 4.2 mm (25–35 Ncm) and 4.7 mm (30–40 Ncm). The length of the implant did not influence the insertion procedure.

Altogether, after 6 months of implants insertion, the mean bone loss was 0.051 mm. After 12 months, a bone gain with a mean of +0.016 mm was observed (Fig. 7). For the 126 implant placed with simultaneous bone augmentation procedures (36%), we observed more bone formation after 6 months postsurgery (+0.045 mm). In the cases without augmentation procedures after 6 months, the bone loss was 0.004 mm; this difference was statistical significant (Table 2). For the implants inserted in the frontal maxilla (n=24) after 6 months, the mean bone loss was 0.013 mm (−0.2 to 0.1; SD 0.0612), after 12 months a bone loss was 0.05 mm (−0.4 to 0.1; SD 0.1022). Eight implants from the frontal inferior jaw presented after 6 months a mean bone gain of 0.063 mm (−0.2 to 0.3; SD 0.1506). After 12 months, the mean bone loss was 0.025 mm (−0.1 to 0; SD 0.0463; Tables 2 and 3). After 12 months, compared to the posterior mandible, implants in the posterior maxilla showed significant less peri-implant bone resorption (p<0.0001; Table 3).

In the most of the implants (n=229, 73.9%), a clinical normal, unsuspicious gingival tissue without signs of inflammation could be observed. In 23.9% (n=74), a mild inflammation was analysed [22]. No plaque accumulation was seen in most of the implants (n=283, 91.6%). Only in 26 cases, a moderate plaque score could be calculated (n=26, 8.4%) [23]. In 275 implants (88.7%), no bleedings

Table 1 ISQ, Periotest and insertion torque measurements after implant placement

After surgery			*p* value
	Augmented (*n*=126)	Not-augmented (*n*=185)	
ISQ	59.54 (SD 6.16)	61.14 (SD 5.36)	0.016
Periotest	−3.37 (SD 2.37)	−3.83 (SD 1.95)	0.058
Insertion torque (Ncm)	31.03 (SD 9.06)	32.38 (SD 7.65)	0.159
	Maxilla (anterior; *n*=25)	Maxilla (posterior; *n*=117)	
ISQ	61.96 (SD 7.72)	58.71 (SD 5.83)	0.02
Periotest	−4.21 (SD 2.45)	−3.05 (SD 2.23)	0.024
Insertion torque (Ncm)	33.96 (SD 8.6)	28.89 (SD 7.96)	0.006
	Mandible (anterior; *n*=8)	Mandible (posterior; *n*=163)	
ISQ	66.25 (SD 4.46)	61.28 (SD 4.98)	0.006
Periotest	−5.63 (SD 1.41)	−3.89 (SD 1.92)	0.013
Insertion torque (Ncm)	40 (SD 7.56)	33.24 (SD 7.77)	0.017
	Maxilla (anterior; *n*=25)	Mandible (anterior; *n*=8)	
ISQ	61.96 (SD 7.72)	66.25 (SD 4.46)	0.149
Periotest	−4.21 (SD 2.45)	−5.63 (SD 1.41)	0.133
Insertion torque (Ncm)	33.96 (SD 8.59)	40 (SD 7.56)	0.087
	Maxilla (posterior; *n*=117)	Mandible (posterior; *n*=163)	
ISQ	58.71 (SD 5.83)	61.28 (SD 4.98)	<0.0001
Periotest	−3.05 (SD 2.23)	−3.89 (SD 1.92)	0.001
Insertion torque (Ncm)	28.89 (SD 7.96)	33.24 (SD 7.77)	<0.0001

Comparisons were conducted between the augmented and not-augmented, between anterior and posterior maxilla, anterior and posterior mandible as well as between the anterior and posterior group. Mean values as well as standard deviations (SD) are given. Differences were calculated descriptively and significances are given

Table 2 ISQ, Periotest and bone loss measurements after implant placement

After 6 months			*p* value
	Augmented (ISQ *n*=112; rest *n*=126)	Not-augmented (ISQ *n*=126; rest *n*=185)	
ISQ	63.33 (SD 3.86)	62.99 (SD 3.23)	0.454
Periotest	−4.66 (SD 1.65)	−4.8 (SD 1.52)	0.43
Bone loss (mm)	+0.045 (SD 0.095)	0.004 (SD 0.04)	<0.0001
	Maxilla (anterior; ISO *n*=16; rest *n*=25)	Maxilla (posterior; ISO *n*=90; rest *n*=117)	
ISQ	63.06 (SD 4.77)	62.32 (3.18)	0.43
Periotest	−5.17 (SD 2.2)	−4.52 (SD 1.43)	0.07
Bone loss (mm)	0.013 (SD 0.61)	+0.031 (SD 0.06)	0.01
	Mandible (anterior; ISO *n*=7; rest *n*=8)	Mandible (posterior; ISO *n*=122; rest *n*=163)	
ISQ	66.86 (SD 3.98)	63.56 (SD 3.43)	0.016
Periotest	−6.25 (SD 1.04)	−4.77 (SD 1.54)	0.008
Bone loss (mm)	0.063 (SD 0.15)	0.007 (SD 0.08)	0.027
	Maxilla (anterior; ISO *n*=16; rest *n*=25)	Mandible (anterior; ISO *n*=7; rest *n*=8)	
ISO	63.06 (SD 4.67)	66.86 (SD 3.98)	0.076
Periotest	−5.17 (SD H22.2)	−6.25 (SD 1.04)	0.192
Bone loss (mm)	0.013 (SD 0.0612)	+0.063 (SD 0.15)	0.051
	Maxilla (posterior; ISO *n*=92; rest *n*=117)	Mandible (posterior; ISO *n*=128; rest *n*=163)	
ISQ	62.32 (SD 3.12)	63.56 (SD 3.44)	0.007
Periotest	−4.52 (SD 1.43)	−4.77 (SD 1.54)	0.174
Bone loss (mm)	0.031 (SD 0.076)	0.007 (SD 0.06)	0.004

Comparisons were conducted between the augmented and not-augmented, between anterior and posterior maxilla, anterior and posterior mandible as well as between the anterior and posterior group. Mean values as well as standard deviations (SD) are given. Differences were calculated descriptively and significances are given

Table 3 Periotest and bone loss measurements after implant placement

After 12 months			*p* value
	Augmented (n=126)	Not-augmented (n=185)	
Periotest	−4.79 (SD 1.68)	−4.71 (SD 1.49)	0.666
Bone loss (mm)	0.048 (SD 0.095)	0.054 (SD 0.08)	0.592
	Maxilla (anterior; n=25)	Maxilla (posterior; n=117)	
Periotest	−5.04 (SD 2.331)	−4.75 (SD 1.29)	0.392
Bone loss (mm)	0.05 (SD 0.1)	0.03 (SD 0.0725)	0.26
	Mandible (anterior; n=8)	Mandible (posterior; n=163)	
Periotest	−5.88 (SD 1.25)	−4.64 (SD 1.61)	0.035
Bone loss (mm)	0.025 (SD 0.05)	0.068 (SD 0.1)	0.21
	Maxilla (anterior; n=25)	Mandible (anterior; n=8)	
Periotest	−5.04 (SD 2.33)	−5.88 (SD 1.25)	0.345
Bone loss (mm)	0.05 (SD 0.1)	0.025 (SD 0.05)	0.512
	Maxilla (posterior; n=117)	Mandible (posterior; n=163)	
Periotest	−4.75 (SD 1.29)	−4.64 (SD 1.61)	0.551
Bone loss (mm)	0.03 (SD 0.073)	0.068 (SD 0.1)	<0.0001

Comparisons were conducted between the augmented and not-augmented, between anterior and posterior maxilla, anterior and posterior mandible as well as between the anterior and posterior group. Mean values as well as standard deviations (SD) are given. Differences were calculated descriptively and significances are given

could be provoked. In 35 implants (11.3%), it was possible to induce bleeding events [24].

Survival and success rates

One implant has been lost because of lacking primary stability in D4 bone in the pre-prosthetic phase after 2 weeks. It was inserted 36 months after extraction in the posterior maxilla. It had an implant length of 11.5 mm and a diameter of 4.2 mm. Guided bone regeneration techniques were used during the insertion of this implant. The insertion torque was 15 Ncm, the primary Periotest value was +2 and the Osstell value summed up to 47.

Altogether, the 1-year survival rate summed up to 99.7%. In regard to the assessment of success, the criteria based on Albrektsson's [20] and Buser's [21] groups were surveyed. Both criteria displayed a successful assessment in 99.7% of the implants.

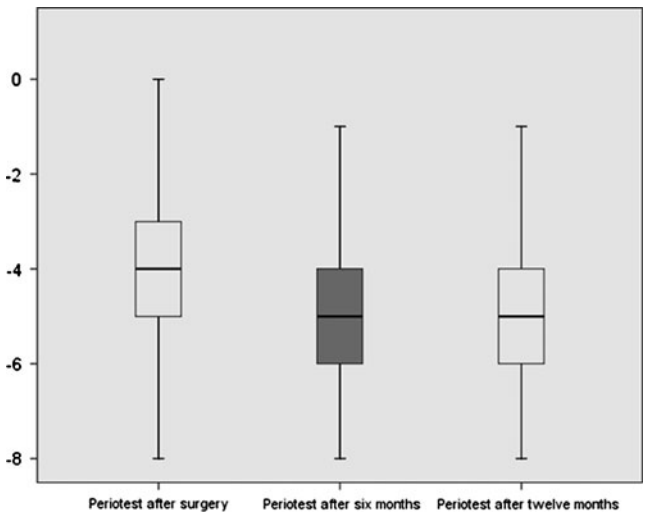

Fig. 2 Box plots of Periotest values after implant placement, after 6 and 12 months (n=311)

Discussion

The important influence of implant surface properties on the interface between implant and surrounding tissue is well known [10, 29, 30]. Though, no evidence of a superior long-time success of a particular type of dental implant could be found [2]. This makes the experimental and

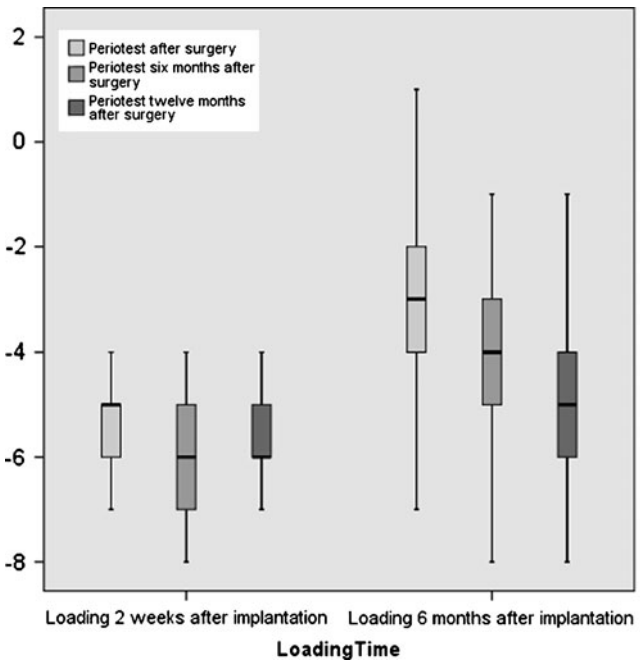

Fig. 3 Box plots showing the comparison between Periotest values of early (n=72) and delayed loaded implants (n=239)

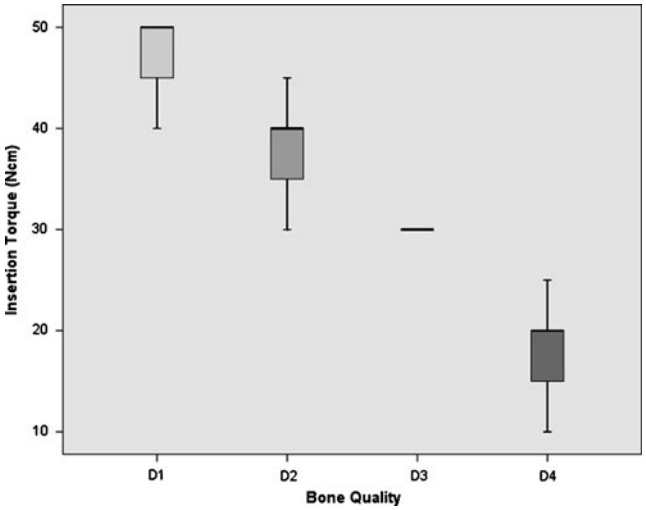

Fig. 4 Box plots showing the association between insertion torque and bone quality (n=311)

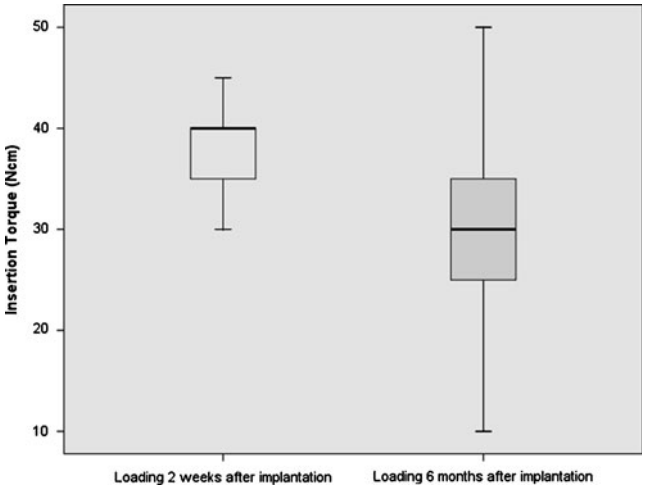

Fig. 6 Box plots showing the comparison between insertion torque of early (n=72) and delayed loaded implants (n=239)

clinical optimization of implant surfaces to be a dynamic field [2, 31]. The bioactive CaP coating results in forming enlarged structures covering even complicated implant shapes together with an increased solubility and a controlled absorption rate of calcium and phosphate ions during the first healing period of osseointegration [32]. The biological fixation of titanium implants to bone is faster with CaP coating than without [33, 34]. Animal studies concerning this easy applicable surface modification showed controversial but mostly positive results in early osseointegration [14, 18, 35, 36]. Human studies comparing the success rate of thin CaP-coated implants with surface-roughened implants are lacking [8]. Therefore, in this prospective case series study of the 1-year function of more than 300 oral implants in 124 patients, we have evaluated the clinical and paraclinical parameters of CaP coated implants to predict implant outcomes.

Invasive (i.e., reverse torque) and non-invasive (i.e., ISQ and Periotest analysis) methods are frequently used in clinics to evaluate the bone/implant interface. The ISQ testing and the use of the Periotest device for signs of initial and secondary implant stability could show notable result. A higher ISQ value after 6 months of healing, compared to values after surgery, was noted. The values for the Periotest increased in the period of first 6 months and remained constant after 12 months of examination. These values indicate an early healing with bony ingrowth of the implant system.

Various implant surfaces and designs were modified in the past to reduce the surgical trauma during placement, and

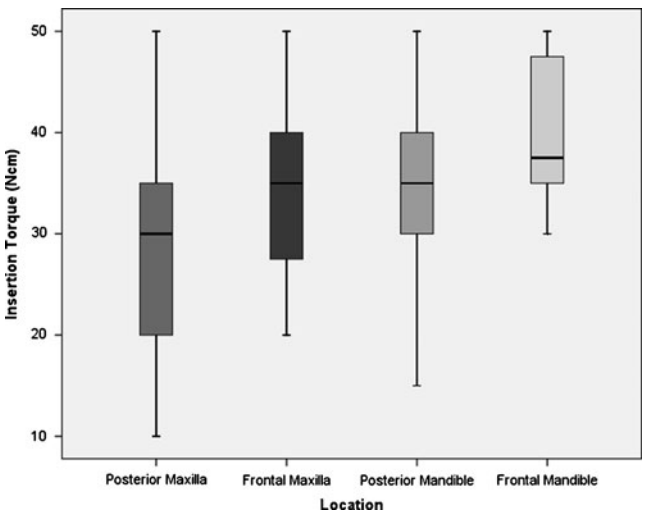

Fig. 5 Box plots of insertion torque related to the location of implant placement (n=311)

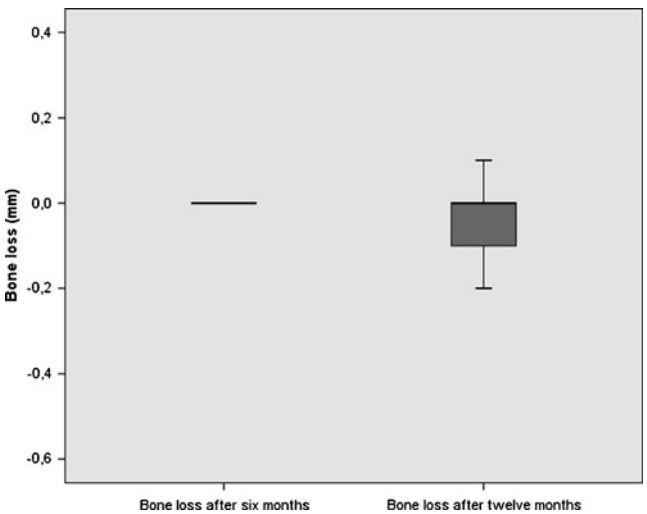

Fig. 7 Box plots of periimplantary bone loss (mm; y-axis) after 6 and 12 months (n=311)

enhance primary and secondary stability [37, 38]. Several clinical studies have investigated this correlation of various implant systems. Our results show an insertion torque for this self-tapping implant system with an average from 10 to 50 Ncm. The literature data report that the average insertion torque for the nonself-tapping implant system are 28.8 Ncm and for the self-tapping implant system are 25.9 Ncm [39]. Results of the NobelActive self tapping system demonstrated a final insertion torque from 15 to 70 Ncm [40]. However, the results also depend of the bone quality, site of implant placement and surgical technique. Alsaadi et al. noted that for 761 Ti-Unite Branemark MK-III implants the average torque of insertion was about 30 Ncm for types I and II bone, while it dropped to 22 Ncm in type III bone and to 17 Ncm in type IV bone when following the recommended protocol from the manufacturing implant company [41]. Akca's group reports for the ITI Straumann and Astra Tech implants insertion torque values of the 57.58 and 68.53 Ncm, respectively, for the anterior mandible with typically dense cortical bone. The values for the posterior maxilla had an average of 10.72 and 6.35 Ncm, respectively [42]. In our study, the dense bone quality exhibited the highest torque placement with 50 Ncm. The soft bone of D4 density had a mean insertion torque of 21 Ncm. The highest torque was obtained in the anterior mandible, the lowest in the posterior maxilla.

Clinical studies focusing on immediate loading of implants document the high success of this treatment procedure [30, 31]. Besides the treatment option of immediate implant loading, other authors have described the early loading mode, which was defined at the consensus meeting of the Implants World Congress in Barcelona in 2002 [43]. The early loading describes insertion of dentures within a few days after surgery, whereas immediate loading means inserting the denture on the day of surgery [44]. For our cases, the implants were loaded during first 2 weeks post-insertion in clinical high quality bone only. The broad standard deviation in insertion torque between early and delayed loading group may be due to the higher number of implants placed in the delayed loading group as well as in the clinical and subjective estimation of "high quality bone". Therefore, no statistical comparison between early and delayed loaded implants was conducted.

In most of the implants (73.9%), an unsuspicious normal gingival tissue could be observed. In 23.9%, a mild inflammation was analysed [22]. Only in 26 cases, a moderate plaque score could be calculated (8.4%). Our results show that only in 35 implants (11.3%) a light peri-implant bleeding on probing was seen (grade 1) [24]. The peri-implant mucosa has been recognised as scar tissue with impaired resistance to bacterial colonisation [45]. Bleeding processes are counted as peri-implant mucositis [25, 46], which was reported in around 50% of the implants [46]. We measured bleeding processes according to Mühlemann and defined four grades [24], whereas in current literature only a yes/no answer were given. Though, considering the possible iatrogenic-induced, limited and short-time damage that is possible by single probing [47, 48] it seems to be more reasonable to count only a reaction of grades 2 and 3 as a proof of a higher affection to bleed. In accordance to the international findings, changes in the peri-implant bone level are an essential parameter to describe the actual state of the implant and the success of implant placement [49]. In this study, panoramic radiographs were consulted. The potential to evaluate changes and the possibility to achieve accurate and reproducible values on the basis of radiographs is a reliable method [25, 36] with some limitations. Based on the two-dimensional availability, only the mesial and distal areas of the implant can be interpreted. While looking at the peri-implant loss of bone, the observed results follow with a medium bone loss of 0.051 mm during first 6 months and a bone gain with a mean of +0.016 mm. These results indicate a physiological average bone reformation during first year after implant placement. A considerable difference was found in correlation between implants placed in the posterior areas of the mandible and maxilla. At 6-month examination, we noted for the posterior mandible a mean bone loss of 0.007 mm compared to maxilla, where we established a mean bone loss of 0.031 mm ($p=0.004$). At the 1-year follow-up the difference of bone loss between posterior mandible and maxilla were 0.007 and 0.03 mm ($p<0.0001$), respectively.

An important aspect in the follow-up study of the dental implants is the possibility to compare data between different studies [50]. Despite of all restrictions, the method of implant-related survival calculation is mostly available in other studies [37, 38] and therefore appropriate for comparison among different studies. In the present study, after a length of stay of 1 year, the survival rate is 99.7% which is in accordance with the literature [39–44]; the survival rate of the implants coated with CaP is comparable to that of conventional implants. Therefore, the respective coating must be critically reconsidered due to lack of significant advantages after 1 year. To elucidate a possible and promising influence of the coating on long-term survival, further data are needed.

In the present study, the success rates according to Albrektsson [20] and Buser [21] were 99.7% and similar to the survival rate. These values are due to the one implant loss. No implant reached the critical bone loss of >0.2 mm/year.

Conclusion

The comparison of the clinical and paraclinical outcomes in this study with the results of aftercare examinations of other

implant systems indicates a promising 1-year survival and success rate for the studied CaP system. This applies to the partial edentulous jaws and should be interpreted with respect to the critical patient selection in this study (rate of major and minor augmentations, early loading). Long-time reports are further needed in order to support the use of CaP-coated implants.

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The authors declare that they have no conflict of interest.

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