CLINICAL ORAL IMPLANTS RESEARCH

Short Communication

Buccal and lingual bone level alterations after immediate implantation of four implant surfaces: a study in dogs

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Abstract

Objectives: Bone formation and maintenance around implants placed immediately after tooth extraction may be affected by implant surface treatment and compromise long-term esthetic results. This study morphometrically evaluated buccal bone loss and bone-to-implant contact (BIC) of four implant systems placed immediately after tooth extraction in a dog model.

Material and Methods: The premolars of eight beagle dogs were bilaterally extracted with a full-thickness flap, and root-form dental implants were placed on the root extraction socket. Implants (n = 16 each) with different surface treatments were placed from sites 1 to 4 and alternated between animals to allow evaluation of the same number of implants at sites and evaluation time points. Implant surface treatments were as follows: anodized, discrete crystalline deposition, SLActive, and microblasted. The left and right side provided implants that stayed for 2 and 4 weeks, respectively. Submerged healing was allowed and bone-to-implant contact (BIC) and buccal bone loss were morphometrically measured. Linear mixed models ($P < 0.05$) were used to assess differences between groups, across time, and their interaction.

Results: Buccal bone loss was observed to approximately double between 2 and 4 weeks ($P = 0.01$). BIC also increased between 2 and 4 weeks, by 20–25% ($P = 0.01$). These changes were statistically similar for each surface.

Conclusion: When placed immediately after tooth extraction, the evaluated histomorphometric parameters vary only with time.

Progressive alveolar bone loss occurring after tooth extraction may compromise the selection of implant dimensions that would provide adequate function and esthetics (Lundgren et al. 1992; Paolantonio et al. 2001; Scarano et al. 2000). Nontraumatic extraction followed by implant stabilization in the extraction socket (commonly achieved over the last 5 mm of the implant apical region) (Lundgren et al. 1992; Paolantonio et al. 2001; Scarano et al. 2000) becomes an opportunity to allow implants to heal surrounded by the socket walls in a defect-like scenario. Such approach, known as immediate implantation, would result in woven bone formation bridging the gap between implant and socket wall, allowing structural continuity between bone in intimate contact with surface and new bone formed because of socket healing (Coelho et al. 2010; Lundgren et al. 1992; Paolantonio et al. 2001; Scarano et al. 2000).

It has been shown that immediate implantation could not only decrease the time for prosthetic loading, but also has shown the potential to maintain alveolar bone morphology, or reduce bone alteration after extraction (Lundgren et al. 1992; Paolantonio et al. 2001; Scarano et al. 2000). Conversely, some studies have described pronounced buccal plate loss following immediate implant placement relative to the lingual plate loss (Araujo et al. 2005). Whereas controversy can be found in the literature, it seems clear from a recent consensus report that hard- and soft-tissue alterations should be expected with type I immediate implant placement and that the best indicated region is the premolar given its reduced esthetic relevance and favorable anatomy (Hammerle et al. 2012).

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Early osseointegration events are positively affected by implant surface topography/chemistry modifications. (Albrektsson & Wennerberg 2004a,b; Coelho et al. 2009) When early healing is considered, moderately rough surfaces (Sa between 1 and 2 μm) (Wennerberg & Albrektsson 2009b) result in higher bone-to-implant response compared to as-machined surfaces (Albrektsson & Wennerberg 2004a,b; Mendes et al. 2009; Shibli et al. 2007; Wennerberg & Albrektsson 2009a, 2010). A plethora of information regarding long-term survival of commonly used implant systems with surface modifications is available (Froberg et al. 2006; Heydenrijk et al. 2002; Schropp et al. 2003). However, controlled evaluation of their effects on marginal bone-level alteration in a clinically challenging scenario such as immediate implantation is missing.

Marginal bone level is one important outcome evaluated in clinical studies, and its long-term stability indicates that osseointegration has been successfully established and maintained (Abrahamsson & Berglundh 2009). Considering that immediate implantation imposes, a challenging scenario for early healing events and buccal bone formation, because of its thinly anatomical configuration, it is hypothesized that implant surface treatments may have an effect on buccal bone maintenance, as previously shown for moderately rough relative to a smooth surface (Coelho et al. 2010). Therefore, this study aimed to evaluate the effect of four implant surfaces on buccal bone levels and bone-to-implant contact (BIC) immediately following tooth extraction in a dog model.

Materials and methods

This study utilized screw-root form endosseous implants (10 mm in length) with surface treatment from four different implant systems: Tiunite (anodized surface, 4.3 mm diameter, NobelReplace, Nobel Biocare, Yorba Linda, CA, USA), Straumman (SLA active, 4.1 mm siMWRWEStraumman, Basel Switzerland), Nanotite (discrete crystalline deposition (DCD), 4 mm diameter, Biomet 3i, Palm Beach, FL, USA), and Unitite (Nanoss Surface, 4.3 mm diameter, SIN Sistema de Implantes, SP, Brazil). (n = 16 per group).

Following approval of the bioethics committee for animal experimentation at the Universidade Federal de Uberlandia, Brazil, eight beagle dogs (approximately 2 years old) were acquired for the study and allowed to acclimate for 2 weeks prior to surgery. All surgical procedures were performed under general anesthesia. The preanesthetic procedure comprised an intramuscular (IM) administration of acepromazine maleate (0.2 mg/kg), diazepam (0.5 mg/kg), and fentanyl (4 mg/kg). Anesthetic induction was then achieved through ketamine (3 mg/kg), and general anesthesia was then obtained and maintained by 1–2% halothane.

Bilateral extractions of all premolars were performed. A full-thickness muco-periosteal flap was made, and teeth were sectioned in the bucco-ligual direction to allow nontraumatic individual root extraction by means of root elevators and forceps. One implant of each group was placed per mandible hemiarch, thus two of each surface per animal allows for equal observations of buccal bone levels and bone-to-implant contact (BIC) at 2 and 4 week time points. To enable evaluation of the four surfaces in an equal distribution throughout premolar extraction sockets, implant groups were alternated through sites 1 to 4, from mesial to distal (first premolar through fourth) resulting in a symmetrical distribution of implants per animal hemiarch, per site, and time *in vivo*.

Implant placement procedures followed each manufacturer's instructions. A gap of approximately 1 mm was left between the implant and the buccal plate, and drilling direction avoided invasion of the lingual plate during osteotomy or after implant placement. Healing cover screws were adapted to the implant internal connection (no increase in total device height was added by healing caps), and the flap was repositioned and sutured with resorbable material (Ethicon Johnson, Miami, FL, USA). Postsurgical medication included IM administration of antibiotics (kefazolin 30 mg/kg every 12 h for 3 days) and anti-inflammatory (0.2 mg/kg per day for 3 days). The euthanasia was performed by anesthesia overdose, 4 weeks after implant placement.

At necropsy, the mandibles were retrieved by sharp dissection, the soft tissue was removed by surgical blades, and initial clinical evaluation was performed to determine implant stability. The implants in bone were then separated from the mandible, allowing blocks with a minimum of 5 mm distance from the implant mesial and distal regions. The bone blocks were kept in 10% buffered formalin solution for 24 h and gradually dehydrated in a series of alcohol solutions ranging from 70 to 100% ethanol. Following dehydration, the samples were embedded in a methacrylate-based resin (Technovit 9100; Kultzer & Co, Wehrhein, Germany) according to the manufacturer's instructions. The sections, performed in a buccal-lingual direction, were then reduced to a final thickness of ~30 μm by means of a series of diamond blade sectioning and SiC abrasive papers (400, 600, 800, 1200, and 2400) in a grinding/polishing machine (Metaserv 3000; Buehler, Lake Bluff, IL, USA) under water irrigation. (Donath & Breuner 1982) The sections were then toluidine blue stained and referred to optical microscopy evaluation.

The bone-to-implant contact (BIC) was determined through the whole perimeter of the implant at 50×–200× magnification (Leica DM2500M; Leica Microsystems GmbH, Wetzlar, Germany) by means of computer software (Leica Application Suite; Leica Microsystems GmbH, Wetzlar, Germany). The regions of mineralized bone-to-implant contact along the implant perimeter were subtracted from the total implant perimeter, and calculations were performed to determine the BIC. Linear buccal bone distances from the implant shoulder (most cervical region) were acquired by computer software for each specimen.

Surface and time effects were analysed with a linear mixed model procedure (IBM SPSS, v20, New York, NY, USA). While conceptually similar to a completely randomized two-way ANOVA, this analysis also modeled a random intercept that adjusts the residual error term for dependencies introduced by repeated measurements within the same animals. Statistical significance was set by P-levels <5%.

Results

No complications were observed during animal surgical procedures or follow-up including postoperative infection, or any other clinical concern. All implants were integrated with bone at the 4 weeks observation period.

Buccal bone loss is shown as a function of group and time *in vivo* in Fig. 1a and Table 1. Inspection suggests an overall increase from 2 to 4 weeks for all groups, and statistical analysis supports a main effect of time; averaged over surfaces bone loss increased from a mean (SD) of 0.7 mm (0.7) at 2 weeks to 1.2 mm (0.9) at 4 weeks (P = 0.01). Analysis failed to suggest effects of surface (P = 0.63) or an interaction of time and surface (P = 0.92). Thus, all surfaces showed a similar change, almost double, in bone loss between 2 and 4 weeks.

BIC is shown as a function of surface group and time *in vivo* in Fig. 1b and Table 1. Inspection again suggests an overall increase

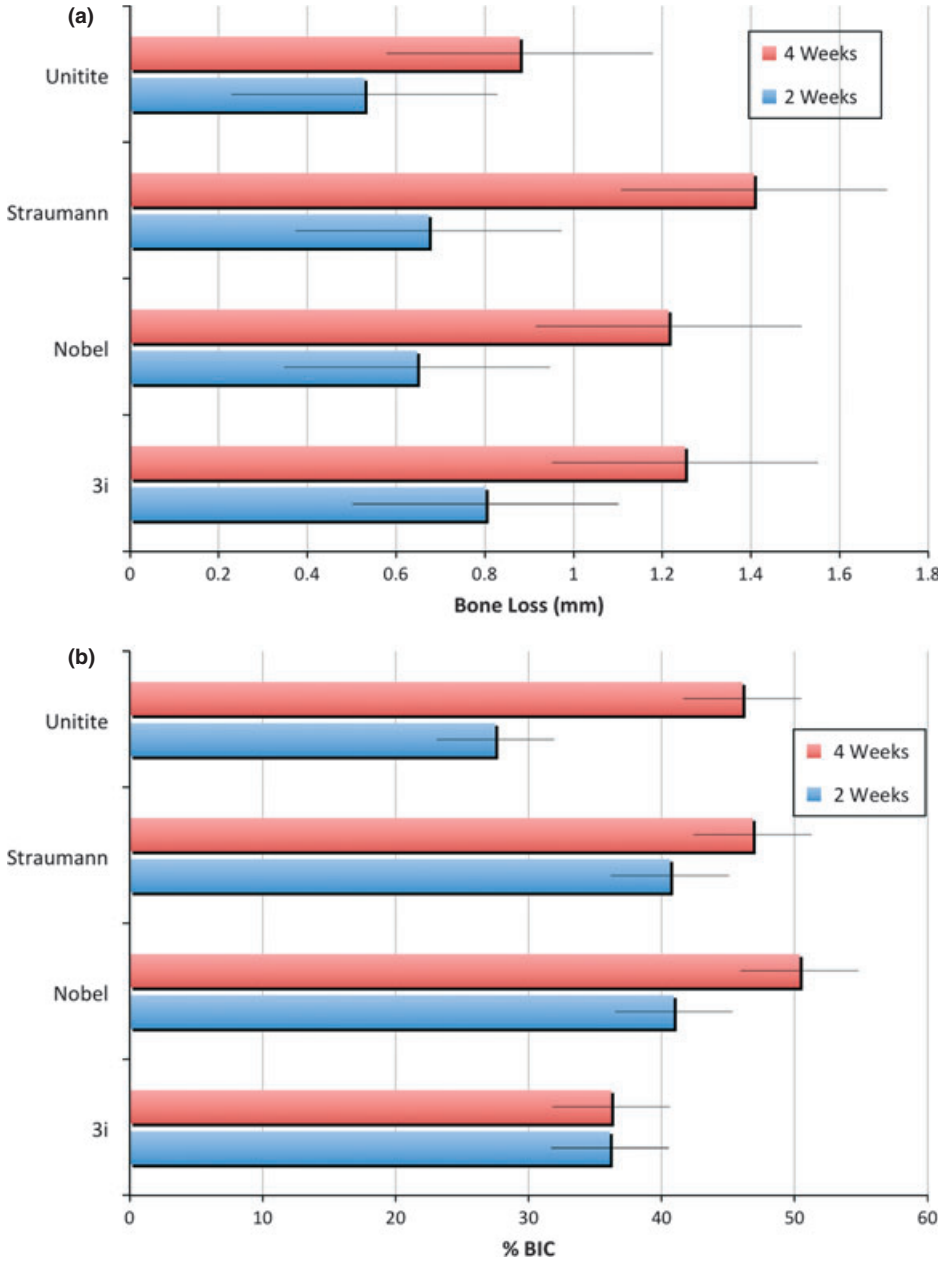

Fig. 1. Mean (SEM) bone loss (a) and % BIC (b) around implant systems after 2 and 4 weeks *in vivo*. Analysis showed increases in bone loss and % BIC with time ($P = 0.01$). While the increase in % bone-to-implant contact (BIC) over time does not appear the same for all systems, analysis failed to indicate an interaction ($P = 0.22$).

Fig. 2. Representative histologic bucco-lingual section for an implant in socket for the present study. Direct bone contact was observed at both 2 and 4 weeks at regions where direct engagement existed between bone and implant at both lingual (L) and buccal (B) aspects (red arrows), as well as in regions where a gap existed between implant and extraction socket wall (yellow arrows).

Table 1. **Mean values for buccal bone loss and bone to implant contact at 2 and 4 weeks and their standard error values**

	Buccal bone loss mean (SE)	Bone-to-implant contact mean (SE)
Unitite 2 weeks	0.51 (0.29)	33.2 (4.43)
Unitite 4	0.92 (0.29)	44.8 (4.43)
3i 2	0.78 (0.29)	37.9 (4.43)
3i 4	1.24 (0.29)	41.1 (4.43)
Nobel 2	0.63 (0.29)	40.3 (4.43)
Nobel 4	1.21 (0.29)	49.4 (4.43)
Straumann 2	0.70 (0.29)	40.2 (4.43)
Straumann 4	1.42 (0.29)	45.8 (4.43)

from 2 to 4 weeks for all groups, albeit one that is not as consistent between surfaces as above for buccal bone loss. Statistical analysis supported a main effect of time; averaged over surface BIC increased from a mean (SD) of 36.3% (12.0) at 2 weeks to 44.9% (14.1) at 4 weeks ($P = 0.01$). Analysis also suggested differences between surface averaged over time ($P = 0.08$). Inspection suggests a pair of lower BIC surfaces (3i and Unitite) with means (SD) of 36.2% (12.2) and 36.8% (15.9), and a pair of higher BIC surfaces, Nobel and Straumann, with means (SD) of 45.6% (14.3) and 43.7% (10.4). While there was no indication of an interaction between time and surface ($P = 0.22$), power of that test was only 0.38. We estimate that a doubling of the sample would provide power of 0.8 to detect this interaction. Thus, while all surfaces showed a similar increase, 20–25%, in BIC between 2 and 4 weeks, we reserve judgement on the question of whether this change truly describes all of these implant systems.

Qualitative evaluation of the toluidine blue stained thin sections showed direct bone contact at 2 or 4 weeks at regions where direct engagement existed between bone and implant at buccal and lingual aspects (Fig. 2). A general trend was observed between implant groups presenting a gap between the extraction socket wall and implant outer diameter. In these cases, woven bone formation bridging such a gap was observed at 2 weeks (Fig. 3a), whereas at 4 weeks, initial lamellar bone formation replacing woven bone was observed for all groups at these regions (Fig. 3b).

Similar findings were observed for SLActive, discrete crystalline deposition, and anodized surfaces at either 2 or 4 weeks at regions

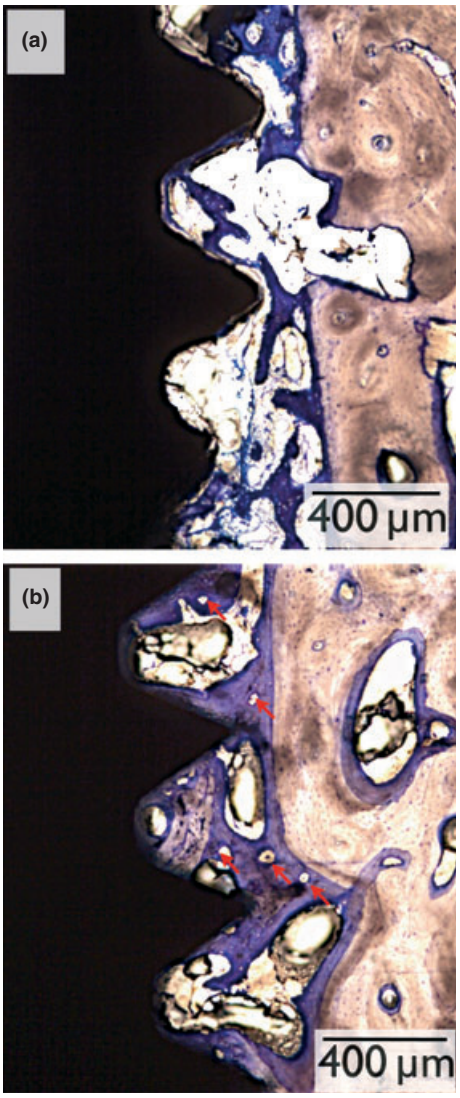

Fig. 3. For all implant systems, (a) woven bone formation between implant and extraction socket wall bridging implant surface and extraction socket wall was observed as early as 2 weeks *in vivo*. (b) Higher degrees of bone organization presenting initial woven bone remodeling sites replacing woven bone with lamellar bone was observed at 4 weeks *in vivo*.

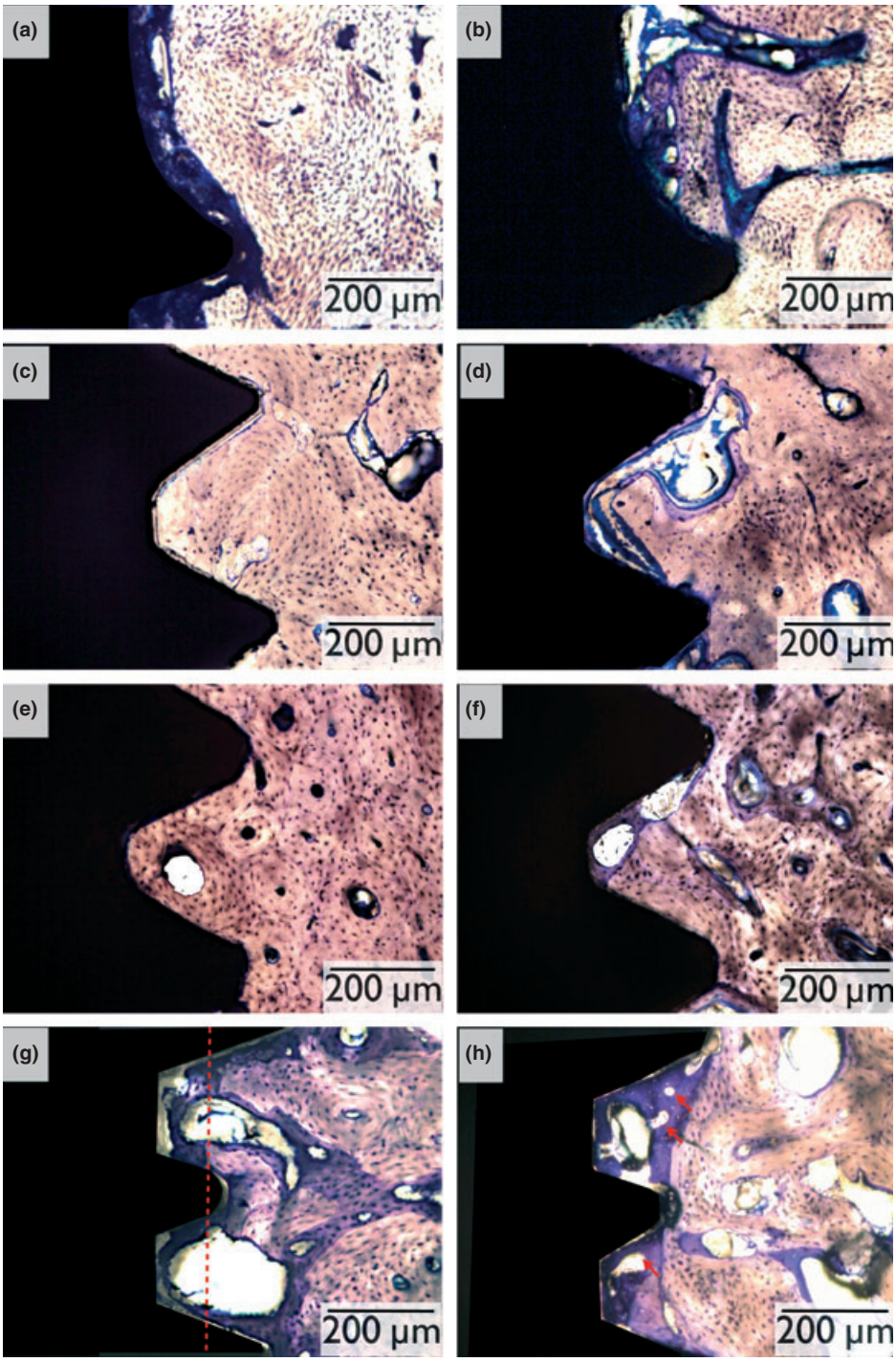

Fig. 4. Histologic section at 2 and 4 weeks *in vivo* for SLActive (a and b, respectively), Nanotite (c and d, respectively), and TiUnite (e and f, respectively) at regions where direct engagement between implant and bone occurred immediately following implantation. (a, c, e) Depicts interfacial remodeling along with initial new bone formation observed at 2 weeks; b, d, and f shows further remodeling along with new bone formation in close proximity and at the implant surface observed at 4 weeks *in vivo*. (g) The red dashed line represents the outer dimension of the final drill relative to the implant threads in the Unitite implant group. Such configuration allowed the formation of healing chambers, which presented initial woven bone filling at 2 weeks *in vivo*; (h) Initial remodeling replacing woven bone by lamellar bone at the healing chamber regions was observed at 4 weeks *in vivo* (red arrows).

where direct engagement between implant and bone occurred immediately following implantation. At regions close to and at the implant surface, interfacial remodeling along with initial new bone formation was observed at 2 weeks (Fig. 4a,c,e for SLActive, DCD, and anodized, respectively), whereas at 4 weeks further remodeling in tandem with new bone formation was observed (Fig. 4b,d,f for SLActive, DCD, and anodized, respectively). The same trend was observed in the Unitite group at regions where the interplay between the implant outer diameter and extraction socket resulted in intimate contact, leading to the same early bone healing qualitatively observed events. Owing to interplay between this implant macrogeometric configuration and socket dimensions, specific areas of the implant inner diameter were not in direct contact with the bone resulting in the formation of healing chambers. Where healing chambers were formed, an intramembranous-type healing mode was observed with woven bone formation at 2 weeks (Fig. 4g) followed by its initial replacement by lamellar bone at 4 weeks (Fig. 4h).

Discussion

Although high success rates have been observed with classical protocols for implant placement, (Branemark 1983; Branemark et al. 1969, 1977), new endosseous dental implant designs and treatment options have been suggested in attempt to reduce final prosthetic rehabilitation treatment time (Coelho et al. 2009). Whereas the bone morphologic changes occurring after teeth extraction have been described, (Araujo et al. 2005), investigations on the effects of various surgical protocols and implant surfaces on immediate implantation bone healing kinetics are under development.

According to the present findings, the four commercially available implant surfaces evaluated after immediate implantation resulted in minimal buccal bone level alteration. Given that buccal bone loss, overall values were below 1.5 mm at 4 weeks, as previously observed (Araujo et al. 2006a) and that increased loss has been observed at 12 weeks with a surface other than those investigated herein (Araujo et al. 2005), comparisons should be made with caution, and investigation of temporal changes before and after 4 weeks with commonly used implant surfaces is warranted. However, evidence from a recent systematic review has pointed that most of the marginal bone-loss occurs during the first year after type I immediate implant placement and is in the magnitude of generally <1 mm (Lang et al. 2012). Also, despite the differences in investigated surfaces physico/chemical properties (Kang et al. 2009; Zinelis et al. 2012) and macrogeometric configurations, an overall trend toward increased BIC from 2 to 4 weeks was observed for all surfaces.

As to the effect of the interplay between socket dimension and implant macrogeometry, our findings are in agreement with previous studies of implants placed in extraction sockets (Araujo et al. 2005, 2006a,b) and healed alveolar ridges (Berglundh et al. 2003; Leonard et al. 2009b; Vignoletti et al. 2009). In essence, implants presenting an intimate contact with bone walls resulted in extensive remodeling along with woven bone formation especially observed at 4 weeks (appositional bone healing). In contrast, representative micrographs of the Unitite implant where implant macrogeometry and socket dimensions allowed the formation of healing chambers showed initial woven bone formation already at 2 weeks and its initial replacement with lamellar bone at 4 weeks (intramembranous healing) (Berglundh et al. 2003; Bonfante et al. 2011; Leonard et al. 2009a; Vignoletti et al. 2009). At the cervical areas where a gap was formed between implant and socket walls, initial woven bone formation at 2 weeks and its initial replacement with lamellar bone at 4 weeks were observed for all groups, irrespective of surface treatment (Coelho et al. 2010).

The resulting gap between the implant and the buccal alveolar wall was of approximately 1 mm and comparisons between groups were balanced in terms of implant number, site, and time *in vivo*. At 4 weeks, early bone healing was observed as previously reported for self-containing defects around immediate implants (Araujo et al. 2005, 2006a,b; Botticelli et al. 2004, 2008; Hammerle et al. 2004; Scarano et al. 2000; Vignoletti et al. 2009). As evidence supporting the need for augmentation procedures and specific techniques at immediate implants is insufficient, (Esposito et al. 2010) no regenerative technique such as the use of bone substitutes and guided bone regeneration were used in attempt to isolate implant surface effect on buccal bone loss and BIC at early times *in vivo*. Clinically, no differences in complication rates have been reported when using organic bovine bone substitute along with guided bone regeneration compared with guided bone regeneration alone in postextractive immediate implant sites (De Angelis et al. 2011).

Whereas all implant surfaces were biocompatible and osteoconductive in the immediate implantation scenario, different implant groups did not influence bone-to-implant contact and buccal bone level, and in fact, these parameters were only affected by time *in vivo*, where the former increased and the later decreased from 2 to 4 weeks *in vivo*, respectively.

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