CLINICAL ORAL IMPLANTS RESEARCH

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Dimensions of buccal bone and mucosa at immediately placed implants after 7 years: a clinical and cone beam computed tomography study

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Key words: bone, clinical study, cone beam computed tomography, dental implant, immediate implant, mucosa

Abstract

Objective: The objective of this study was to evaluate the dimensions of buccal bone and soft tissue at immediately placed implants over a 7-year period.

Material and methods: Twenty-four patients, that participated in a clinical prospective study and received implants immediately placed into extraction socket, were enrolled for this study. Residual bone defects were grafted with xenogenic bone substitute and covered by means of collagen membrane. Baseline examination included measurements of full-mouth plaque and bleeding scores, width of keratinized mucosa, and dimensions of residual bone defects at the buccal aspect. Seven years after implant placement, full-mouth plaque score, full-mouth bleeding score, width of keratinized mucosa, and probing pocket depth were assessed and cone beam computed tomography images acquired. Dimensions of buccal bone and soft tissue were evaluated on the cross-sectional cone beam computed tomography reconstructions. Differences between two time-points were tested using the two-sided *t*-test. Correlation analysis was used to investigate the influence of baseline bone defect dimensions on the bone dimensions measured at the 7-year follow-up.

Results and conclusions: Fourteen patients attended the follow-up examination. In five implants almost no buccal bone was detected, whereas in the remaining nine implants the buccal bone was found covering the rough implant surface. No correlation was found between initial bone defects and bone dimensions at the follow-up examination. The sites without radiographically detectable buccal bone at the 7-year control presented with 1 mm more apical mucosal level in comparison to implants with intact buccal bone.

In recent years, there has been rising interest for immediate implant placement after tooth extraction (protocol type I) (Hämmerle et al. 2004). By reducing the number of surgical sessions and overall treatment time, this protocol is supposed to decrease patient discomfort. The survival rates of implants placed in extraction sockets appear to be similar to implants placed in healed sites, with majority of clinical studies reporting survival rates of over 95% (Chen & Buser 2009).

Evidence from recent animal (Araujo et al. 2005; Botticelli et al. 2006; Vignoletti et al. 2009a, 2009b) and clinical (Botticelli et al. 2004; Covani et al. 2004, 2007; Chen et al. 2005) studies has shown that type I implant placement is not able to prevent the physiological remodeling process of alveolar ridge after tooth loss (Schropp et al. 2003; Araujo & Lindhe 2005). Up to date, there is very little evidence about the amount of alveolar ridge remodeling at immediately placed implants over a period of several years. Most of the human studies on immediate implants were based on measurements at re-entry, reporting on dimensional changes of alveolar ridge up to 6 months following tooth extraction.

The alveolar ridge dimension is widely considered as a primary factor in determining soft-tissue contour around implants (Grunder et al. 2005). A recently published systematic review explored the critical buccal bone dimensions around implants for an optimal

result of the peri-implant mucosa (Teughels et al. 2009). The investigators concluded that there is insufficient evidence to set a threshold for minimal buccal bone dimension needed to achieve an optimal esthetic soft-tissue result.

The introduction of cone beam computed tomography (CBCT) has broadened the diagnostic and therapeutic possibilities in dentistry. While providing an adequate three-dimensional image quality for dentomaxillofacial examinations (Suomalainen et al. 2009; Fatemitabar & Nikgoo 2010), CBCT allows shorter scan times and at lower radiation doses compared to conventional CT (Rustemeyer et al. 2004; Ludlow et al. 2006; Ludlow & Ivanovic 2008).

The aim of this study was to evaluate the dimensions of bone and soft-tissue at the buccal aspect of immediately placed implants in humans over a 7-year period.

Material and methods

Study population

Between June 2002 and April 2003, 24 patients of the Department of Restorative Dentistry and Biomaterials Sciences, Harvard School of Dental Medicine, Boston, MA, USA participated in a clinical prospective study (Lang et al. 2007). Each patient received one implant immediately placed into an extraction socket located in the segment from second premolar to second premolar of maxilla or mandible. The experimental sites had healthy adjacent teeth on either side.

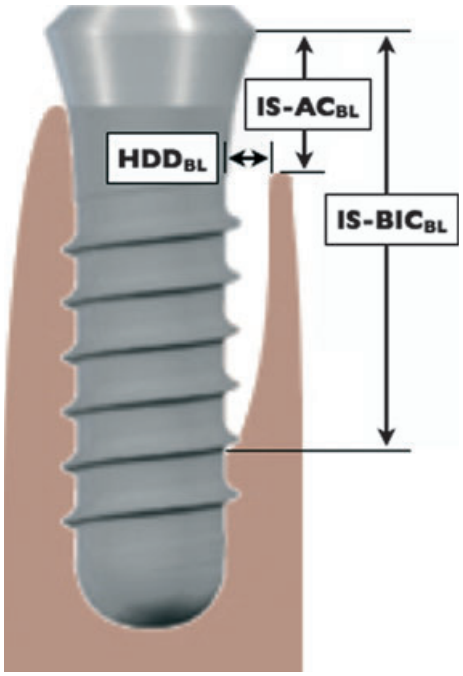

Fig. 1. Baseline intrasurgical measurements of the residual bone at the mid-buccal aspect of the implants.

Baseline parameters and surgical procedures

The following clinical variables were assessed before the surgical procedure:

- Full-mouth plaque score (FMPS) at six sites per tooth/implant (O'Leary et al. 1972).
- Full-mouth bleeding on probing score (FMBS) at six sites per tooth/implant (Ainamo & Bay 1975).
- Width of the keratinized mucosa (KM) at the mid-buccal aspect of the experimental site.

A mucoperiostal flap was elevated at the experimental site and adjacent teeth. After the tooth extraction, a dental implant (Straumann® Dental Implant System; Straumann AG, Basel, Switzerland) with a 1.8 mm machined collar length was placed into the extraction socket. The implants were placed according to the standard procedures for this implant system (Buser et al. 2000) with the implant shoulder 2–3 mm apical to the mid-buccal mucosal margin.

Subsequently, the following intra-surgical measurements of the residual bone defect were performed at the mid-buccal aspect of the implant (Fig. 1):

- Distance (mm) from the implant shoulder to the alveolar crest (IS-AC$_{BL}$).
- Distance (mm) from the implant shoulder to the first bone-to-implant contact (IS-BIC$_{BL}$).
- Horizontal defect depth (mm) from the implant surface to the most coronal aspect of the alveolar crest in a direction perpendicular to the long axis of the implant (HDD$_{BL}$).

The residual infrabony defects with HDD$_{BL}$ of at least 0.5 mm and bone dehiscences with exposed rough implant surface were grafted with xenogenic bone substitute mineral (Bio-Oss® Spongiosa granules, size 0.25–1 mm; Geistlich AG, Wolhusen, Switzerland) and covered by means of a resorbable collagen membrane (Bio-Gide®; Geistlich AG) (Fig. 2). No grafting material was placed over the intact buccal bone. All implants healed transmucosally and definitive porcelain-fused-to-metal (PFM) cement-retained crowns were inserted 4–6 months after implant placement.

During the first 3 years, all patients participated in a maintenance care program with annual follow-up examinations and professional dental hygiene treatments once every 6 months. Thereafter, they were referred to private dentists.

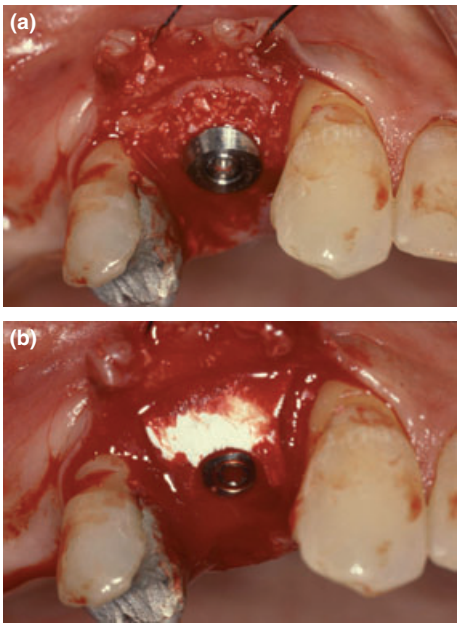

Fig. 2. Application of (a) xenogenic bone substitute and (b) collagen membrane.

Seven-year follow-up examination

This clinical study was approved by the Harvard Medical School Committee on Human Studies (CHS Nr. M17684-102). Between September 2009 and May 2010, the 24 patients were recalled by single letter and a phone call. Informed consent was obtained from all patients.

The same clinical variables (FMPS, FMBS, KM) as at the baseline examination were assessed. In addition, probing pocket depth (PPD$_{7y}$) was measured at six sites around the implants (Ramfjord 1959).

CBCT analysis

Prior to CBCT imaging, a layer of flowable light-curing composite resin (Permaflo®; Ultradent Products, South Jordan, UT, USA) was applied onto the soft-tissues around the implant and the adjacent teeth. The radiopaque material was used as a contrast for the visualization of the soft-tissues on the CBCT image (Fig. 3).

The CBCT images were acquired with an i-CAT Platinum CBCT scanner (Imaging Sciences, Hatfield, PA, USA). For the scan procedure, the occlusal planes were oriented parallel to the horizontal plane. The scans were made with the following technical parameters: 120 kV, 5, 18.54 mA, a voxel

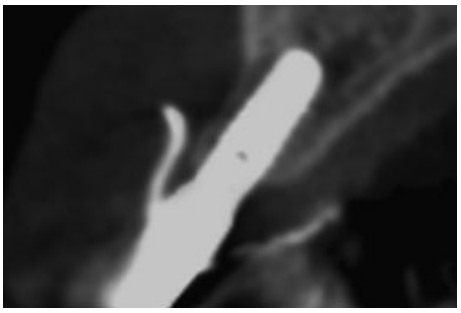

Fig. 3. Mid-buccal cross-sectional cone beam computed tomography slice showing the radio-opaque contrast material used for soft-tissue visualization.

size of 0.3 mm, a field height of 6 cm, and a scanning time of 9 s. The composite resin material was removed immediately after the scan procedure.

For the image evaluation the datasets were imported as 16-bit DICOM files in the ImplantMax 4.0 software (Saturn Imaging, Taipei, Taiwan). Bucco-oral cross-sectional images were reconstructed and used for the following measurements at the mid-buccal aspect of the study implants:

- Distance (mm) from the implant shoulder to the first bone-to-implant contact (IS-BIC_{7y}; Fig. 4a).
- Distance (mm) from the implant shoulder to the alveolar crest (IS-AC_{7y}; Fig. 4a).
- Distance (mm) from the mucosal margin to the implant shoulder (MM-IS_{7y}; Fig. 4a).
- Thickness (mm) of the buccal bone measured at the most coronal aspect of the alveolar crest as determined at implant placement (see Fig. 1) (BT_{7y}; Fig. 4b).
- Thickness (mm) of the soft-tissue 1 mm apical from the mucosal margin (MT_{7y}; Fig. 4b).

Axial slices parallel to the occlusal plane were used for the evaluation of the bucco-oral implant position. The localization of the buccal margin of the implant shoulder in relationship to the reference line connecting cervical buccal surfaces of the adjacent teeth was determined as being buccal or oral (Buser et al. 2004).

All the radiographic measurements were performed by two examiners. In cases of disagreement, the values were discussed until an agreement was reached. Every measurement was repeated three times and the mean was calculated.

Statistical analysis

The six PPD_{7y} measurements around each implant were averaged for the calculation of a mean PPD_{7y} per implant.

All the data were characterized using mean values, standard deviations (SD), medians and ranges (PASW Statistics 18.0; SPSS Inc, Chicago, IL, USA).

Non-parametric Spearman correlation analysis was used to investigate the influence of intra-surgical bone defect dimensions (IS-AC_{BL}, IS-BIC_{BL}, HDD_{BL}) on the bone dimensions measured at the 7-year follow-up (IS-AC_{7y}, IS-BIC_{7y}, BT_{7y}).

Paired *t*-test was applied to detect differences between baseline and 7-year follow-up measurements. To account for multiple testing, the level of significance was set at $P \leq 0.01$ according to Bonferroni.

Mann–Whitney *U*-test was selected to detect the difference of the level of mucosal margin (MM-IS_{7y}) between the groups of implants with and without buccal bone plate at the 7-year follow-up. The level of statistical significance was set at $P \leq 0.05$.

Results

A total of 14 patients, six women and eight men with a mean age of 67.1 years (range: 45–91 years) attended the 7-year follow-up examination. Six letters were returned because the patient had moved and four patients declined to attend, yielding a recall rate of 58%.

All implants were considered successful (Buser et al. 1997) and no signs of peri-implant soft-tissue inflammation were present. At the follow-up examination, one implant presented with a temporary crown. In this case, the PFM crown had been removed previously by a private dentist due to a fracture of veneering ceramic.

Twelve implants were originally placed in the maxilla and two in the mandible. Three implants were located at incisor sites and 11 at premolar sites. Twelve implants presented with a regular diameter (4.1 mm) and two with a narrow diameter (3.3 mm). The lengths of the implants were 8 mm ($n = 4$), 10 mm ($n = 5$) and 12 mm ($n = 5$). Guided bone regeneration (GBR) procedure after implant placement had been performed in 11 out of 14 cases (78.6%). In the remaining three cases (21.4%), no bone augmentation procedure had been performed.

The results of baseline and 7-year follow-up measurements for the 14 implants are presented in Table 1.

Clinical measurements

The FMPS and FMBS were higher at the 7-year follow-up compared to the baseline examination, reaching statistical significance only for the difference of FMBS ($P \leq 0.01$) (Table 1). The KM at the implants decreased by 1.2 ± 1 mm (SD) at the 7-year follow-up. This difference was statistically significant ($P \leq 0.01$) (Table 1).

Radiographic measurements

When comparing 7-year follow-up radiographic measurements and baseline clinical

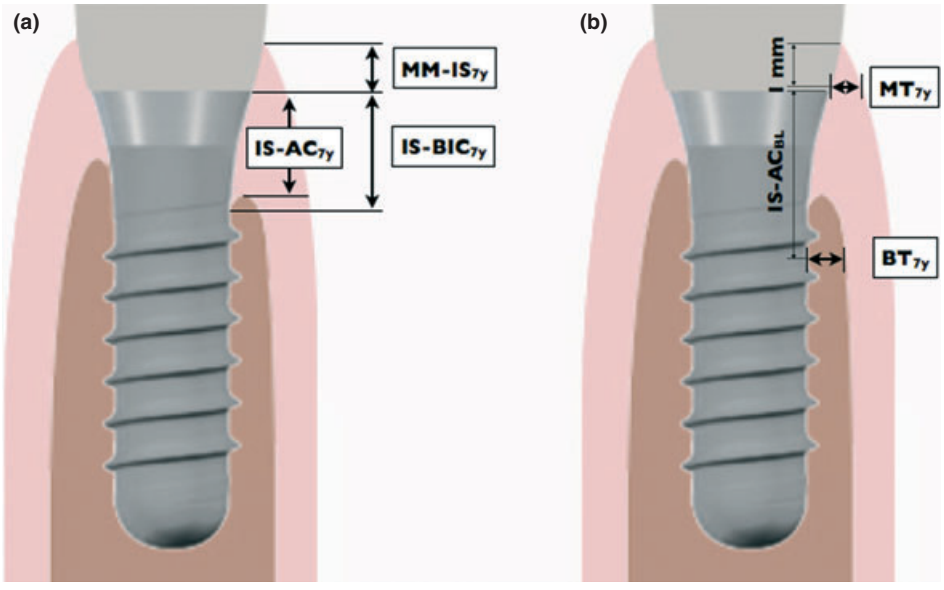

Fig. 4. Seven-year follow-up cone beam computed tomography (a) vertical and (b) horizontal measurements of bone and soft-tissue dimensions at the mid-buccal aspect of the implants.

Table 1. **Results of baseline, 7-year follow-up measurements and differences between two time-points for the 14 implants**

	Baseline			7-year follow-up			Differences			
Parameter	Mean ± SD	Median	Range	Mean ± SD	Median	Range	Mean ± SD	Median	Range	*P*-value[†]
FMPS (%)	12.5 ± 9.2	14.8	0 to 29	22.9 ± 17.1	17.2	0.7 to 63.7	10.4 ± 17.4	11	−23.2 to 47	0.044
FMBS (%)	5.8 ± 5.1	4.4	0 to 17.4	19.4 ± 13.1	15.7	2.4 to 46.2	13.6 ± 14.1	12.2	−7.3 to 46.2	0.003[*]
KM (mm)	3.6 ± 1	4	2 to 5	2.4 ± 0.8	2	1 to 4	−1.2 ± 1	−1	−3 to 0	<0.001[*]
mean PPD (mm)				3.1 ± 0.7	2.8	2.5 to 4.5				
Buccal PPD (mm)				2.7 ± 0.5	3	2 to 3				
IS-AC (mm)	1.9 ± 1	2	0 to 3	5 ± 4.7	2.2	1.1 to 13.4	3.1 ± 4.6	0.9	−1.7 to 11.4	0.026
IS-BIC (mm)	7.7 ± 2.4	8	4 to 13	5.2 ± 4.5	2.6	1.3 to 13.4	−2.6 ± 5.9	−5.2	−11.6 to 5.8	0.132
HDD (mm)	1.5 ± 0.8	1.8	0 to 2.5							
BT (mm)				0.4 ± 0.7	0	0 to 2.1				
MM-IS (mm)				0.8 ± 0.9	0.4	−0.3 to 2.8				
MM-BIC (mm)				6 ± 4.1	4	2 to 13.7				
MT (mm)				1.5 ± 0.5	1.6	0.8 to 2.1				

FMPS, full-mouth plaque score; FMBS, full-mouth bleeding score; KM, width of the keratinized mucosa; PPD, probing pocket depth; IS, implant shoulder; AC, alveolar crest; BIC, first bone-to-implant contact; HDD, horizontal defect depth; BT, bone thickness; MM, mucosal margin; MT, mucosal thickness; SD, standard deviation.
[*] $P \leq 0.01$.
[†] Student's *t*-test.

results, an increase of IS-AC [3.1 ± 4.6 mm (SD)] and a decrease of IS-BIC [−2.6 ± 5.9 mm (SD)] were detected ($P > 0.01$) (Table 1).

At the 7-year examination, mean thickness of the buccal bone measured at the most coronal aspect of the alveolar crest as determined at implant placement (BT_{7y}; Fig. 4b) measured 0.4 ± 0.7 mm (SD) (Table 1). In 10 out of 14 cases (71%), the most coronal aspect of the alveolar crest at the 7-year follow-up was located more apically than at the implant surgery, resulting in BT_{7y} values of 0 mm.

Correlation analysis did not show any significant correlation between the initial defect dimensions ($IS\text{-}AC_{BL}$, $IS\text{-}BIC_{BL}$, HDD_{BL}) and the 7-year radiographic bone results ($IS\text{-}AC_{7y}$, $IS\text{-}BIC_{7y}$, BT_{7y}) (Table 2).

For the 11 implants treated using GBR procedure $IS\text{-}BIC_{7y}$ measured 5.2 ± 4.8 mm (SD) (range: 1.3–13.4 mm), $IS\text{-}AC_{7y}$: 5.1 ± 5 mm (SD) (range: 1.1–13.4 mm), BT_{7y}: 0.3 ± 0.6 mm (SD) (range: 0–1.8 mm). In this group, IS-AC increased 3.2 ± 4.7 mm (SD) (range: −1.7 to 13.1 mm) and IS-BIC decreased by 2.9 ± 1.9 mm (SD) (range: −11.6 to 5.8) between two time-points ($P > 0.01$).

The implant shoulder was located submucosally in 12 out of 14 cases (85.7%). $MM\text{-}IS_{7y}$ amounted at 0.8 ± 0.9 mm (SD) and the vertical dimension of the buccal soft-tissue $MM\text{-}BIC_{7y}$ measured 6 ± 4.1 mm (SD) (Table 1). MT_{7y} 1 mm apical to the mucosal margin reached 1.5 ± 0.5 mm (SD) (Table 1).

With regard to the bucco-oral position, all implants were located in an oral position.

The radiographic evaluation revealed five implants (35.7%) with missing buccal bone at the 7-year examination (Fig. 5). Four out of these five sites had initially been treated using GBR procedures.

In the group of implant with presence of buccal bone, IS-AC remained stable [ΔIS-AC: 0 ±1.3 mm (SD) (range: −1.7 to 2.4 mm)] between baseline and 7-year examination (Table 3). In other five implants, IS-AC increased 8.7 ± 1.8 mm (SD) (range: 6.7–11.4 mm).

$MM\text{-}IS_{7y}$ for groups with and without buccal bone measured 1.2 ± 1 and 0.1 ± 0.3 mm, respectively, reaching statistical difference ($P = 0.044$) (Table 3). For both groups of implants with and without buccal bone mean MT_{7y} measured 1.5 ± 0.5 mm (SD) at follow-up appointment (Table 3).

Table 2. **Spearman correlation between intra-surgical bone defect dimensions and 7-year radiographic bone measurements**

	Correlation coefficient (*P*-value[†])		
Parameter	$IS\text{-}AC_{7y}$ ($n = 14$)	$IS\text{-}BIC_{7y}$ ($n = 14$)	BT_{7y} ($n = 14$)
$IS\text{-}AC_{BL}$	0.16 (0.58)	0.24 (0.94)	0.58 (0.06)
$IS\text{-}BIC_{BL}$	−0.28 (0.34)	−0.44 (0.11)	0.12 (0.67)
HDD_{BL}	−0.26 (0.37)	−0.06 (0.83)	−0.04 (0.90)

BL, baseline; 7y, 7-year follow-up; IS, implant shoulder; AC, alveolar crest; BIC, first bone-to-implant contact; HDD, horizontal defect depth; BT, bone thickness.
[†] Spearman correlation.

Discussion

In the present radiological study, at approximately one-third of the implants almost no buccal bone was detected. In the other two-thirds of the implants the buccal bone plate was covering the entire rough implant surface. Despite this difference all implants exhibited clinically successful tissue integration at the 7-year follow-up. The mucosal margin, however, was located 1 mm more apically in the group of implants without buccal bone.

In 78.6% of the study implants GBR of the residual defects had been performed. It is important to emphasize that a bone substitute material had been applied in residual infrabony defects and dehiscences and that no attempt was made to over-augment the buccal bone plate. In four of five cases without detectable buccal bone at the 7-year control, GBR procedure of the residual defects had been performed at implant surgery.

Several clinical studies with non-grafted (Covani et al. 2004, 2007; Chen et al. 2005, 2007;) and grafted (Gher et al. 1994; Botticelli et al. 2004; Chen et al. 2005, 2007) implants immediately placed into extraction sockets found a mean reduction of the buccal bone height of 0.5–1 mm at the reentry operation 4–6 months later. The greater amount of mean alveolar crest resorption in the present study may be explained by the longer-term follow-up. This mean value, however, masks the finding that in two-thirds of the implants the buccal bone seemed stable and in one-third it was almost completely absent.

No correlation was found between the size of the initial bone defects and the coverage of the buccal implant surface at the 7-year

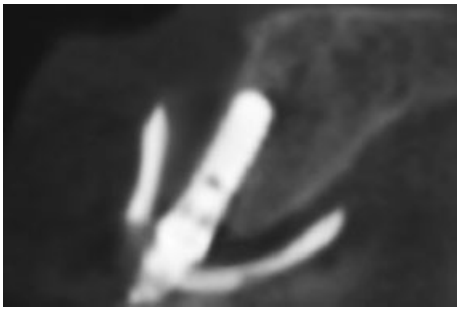

Fig. 5. Cross-sectional cone beam computed tomography slice of an implant showing no buccal bone at the 7-year examination.

follow-up. This is in agreement with a previous report investigating 21 non-grafted immediate anterior implants (Botticelli et al. 2004). After 4 months of healing, the investigators did not find any relationship between the buccal bone thickness at implant placement and the amount of vertical bone resorption. However, other clinical studies with larger sample sizes found a relationship between initial bone dimensions and resulting changes until reentry procedures (Spray et al. 2000; Chen et al. 2007).

The main limitation of the present study is the fact that clinical intra-surgical measurements were compared with CBCT findings. Due to the artifacts induced by metal objects, it is controversial whether or not CBCT represent a precise technique for the evaluation of peri-implant bone (Draenert et al. 2007; Razavi et al. 2010; Schulze et al. 2010). Nevertheless, the fact that a buccal bone plate was visible at most of the implants and not in one-third is a striking finding worth reporting.

The mucosal margin was located more apically in the group of implants without buccal bone. Despite the major difference of alveolar crest levels between implants with and without buccal bone, the difference of the mucosal margin between these two groups amounted to as little as 1 mm. These results suggest that other factors beside bone affect the mucosal level.

In a recent animal study, grafting of residual infrabony defects around immediately placed implants was evaluated (Araujo et al. 2010). The study also showed that implants with a more apical position of first bone-to-implant contact presented with a more apical mucosal level. These data are in agreement with the results of a study evaluating buccal bone and mucosa levels at 40 single tooth implants by means of clinical and CT examination (Nisapakultorn et al. 2010). It was shown that the buccal mucosal level at anterior single-tooth implants was influenced by multiple factors including peri-implant biotype, the level of the facial bone crest, the vertical position of the implant shoulder, and the level of the interproximal bone crest at the adjacent teeth. In another clinical study the esthetic outcome of 42 single-unit immediately placed implants was analyzed. The investigators reported that implants with a buccal shoulder position showed three times more recessions than implants with an oral shoulder position (Evans & Chen 2008).

In this study the vertical dimension of the supracrestal buccal soft-tissue was more than three times larger in the absence of a buccal bone plate. The observation of longer soft-tissue at implants placed in extraction sockets has been reported in previous animal studies (Schultes & Gaggl 2001; Rimondini et al. 2005; Vignoletti et al. 2009a, 2009b; de Sanctis et al. 2010). In a clinical study, the vertical dimension of peri-implant mucosa was measured by bone sounding around 45 maxillary anterior implants at 1 year of function (Kan et al. 2003). Vertical dimension of the buccal mucosa amounted at 3.6 mm. However, due to the buccal crown contour bone sounding may lead to an underestimation of the soft-tissue dimensions. A human autopsy case report evaluated the buccal soft tissue height at twelve immediately loaded implants after 14 months of function (Romanos et al. 2010). The buccal soft-tissue height measured 6.5 and 4.8 mm at maxillary and mandibulary specimens, respectively. The previously cited CT study evaluating 40 single tooth implants in the anterior maxilla reported mean value of 4.8 mm with a large inter-individual variation for the vertical dimension of the facial soft-tissue (Nisapakultorn et al. 2010). The magnitude of the data from these studies is in agreement with the mean value of the present trial.

In the present study the mean thickness of the buccal soft-tissue 1 mm apical from the margin measured 1.5 mm for both groups with and without buccal bone at the 7-year examination. Two clinical studies evaluated buccal mucosal thickness by either using an ultrasonic device or an endodontic file (Chang et al. 1999; Jung et al. 2008). The measurements reached approximately 2–3 mm. The discrepancy with the data from the present study may be due to factors like different clinical procedures, methods of measurement, implant position, or implant shoulder diameter.

Due to the cross-sectional nature of the evaluation of the facial mucosa level, it was not possible to quantify its change over time. Nevertheless, since all implants were placed at the same vertical position with the implant shoulder 2–3 mm apical to the mucosal margin, the distance from mucosal margin to the implant shoulder at the follow-up examination is expected to reflect changes over time. The level of the marginal mucosa was 0.8 mm above the implant shoulder. Therefore, a mean recession of the mid-buccal soft-tissue of approximately 1.5 mm over 7 years may be extrapolated. The reduction of the width of the KM of 1.2 mm between implant placement and the 7-year follow-up compares well with the extrapolated value of soft-tissue recession. In a recent review the majority of the articles reported a mean recession of the facial mucosa of approximately 1 mm (Chen & Buser 2009). This is in agreement with the extrapolated values of the present 7-year follow-up study.

Table 3. **Baseline and follow-up results for implants with and without radiographically detectable buccal bone at the 7-year examination**

	Buccal bone detectable (n = 9)			No buccal bone detectable (n = 5)		
Parameter	Mean ± SD	Median	Range	Mean ± SD	Median	Range
IS-AC$_{BL}$ (mm)	1.8 ± 1.1	2.0	0–3	2.2 ± 0.8	2.0	1–3
AC-BIC$_{BL}$ (mm)	6.8 ± 2.4	7.0	2–10	4.0 ± 2.0	3.0	2–7
IS-BIC$_{BL}$ (mm)	8.6 ± 2.3	9.0	5–13	6.2 ± 1.9	6.0	4–9
HDD$_{BL}$ (mm)	1.6 ± 0.7	2.0	0.5–2.5	1.3 ± 0.8	1.5	0–2
IS-AC$_{7y}$ (mm)	1.7 ± 0.6	1.4	1.1–2.8	10.9 ± 1.6	10.8	9.4–13.4
IS-BIC$_{7y}$ (mm)	2.0 ± 0.6	2.0	1.3–2.8	10.9 ± 1.6	10.8	9.3–13.4
BT$_{7y}$ (mm)	0.6 ± 0.8	0	0–2.1	0	0	0
		*				
MM-IS$_{7y}$ (mm)	1.2 ± 1.0	1.1	−0.2–2.8	0.1 ± 0.3	0.3	−0.3–0.3
MM-BIC$_{7y}$ (mm)	3.2 ± 0.9	2.7	2.0–4.8	11.1 ± 1.7	11.1	9.4–13.7
MT$_{7y}$ (mm)	1.5 ± 0.5	1.3	0.9–2.4	1.5 ± 0.5	1.7	0.9–2.4

BL, baseline; 7y, 7 year follow-up; IS, implant shoulder; AC, alveolar crest; BIC, first bone-to-implant contact; HDD, horizontal defect depth; BT, bone thickness; MM, mucosal margin; MT, mucosal thickness; SD, standard deviation.
*$P \leq 0.05$.

The fact that a buccal bone plate was visible at most of the implants and not in one-third is the most striking finding of the present study. More research is needed to further explore this issue and to optimize adjunctive procedures during implant placement. The small sample size and the high drop-out rate are considerable limitations, which have to be taken into account when interpreting the findings of the present study.

Conclusions

Within the limitations of the present clinical study it can be concluded that after 7 years of function at immediately placed implants:

- In one-third of the sites almost no buccal bone was detected, whereas in the remaining implants the buccal bone was found covering the rough implant surface.
- No correlation was found between initial bone defects and bone dimensions at the 7-year follow-up.
- The sites without radiographically detectable buccal bone presented with 1 mm more apical mucosal level in comparison to implants with intact buccal bone.

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References

Ainamo, J. & Bay, I. (1975) Problems and proposals for recording gingivitis and plaque. *The International Dental Journal* **25**: 229–235.

Araujo, M.G., Linder, E. & Lindhe, J. (2010) Bio-oss® collagen in the buccal gap at immediate implants: a 6-month study in the dog. *Clinical Oral Implants Research* **22**: 1–8.

Araujo, M.G. & Lindhe, J. (2005) Dimensional ridge alterations following tooth extraction. An experimental study in the dog. *Journal of Clinical Periodontology* **32**: 212–218.

Araujo, M.G., Sukekava, F., Wennstrom, J.L. & Lindhe, J. (2005) Ridge alterations following implant placement in fresh extraction sockets: an experimental study in the dog. *Journal of Clinical Periodontology* **32**: 645–652.

Botticelli, D., Berglundh, T. & Lindhe, J. (2004) Hard-tissue alterations following immediate implant placement in extraction sites. *Journal of Clinical Periodontology* **31**: 820–828.

Botticelli, D., Persson, L.G., Lindhe, J. & Berglundh, T. (2006) Bone tissue formation adjacent to implants placed in fresh extraction sockets: an experimental study in dogs. *Clinical Oral Implants Research* **17**: 351–358.

Buser, D., Martin, W. & Belser, U.C. (2004) Optimizing esthetics for implant restorations in the anterior maxilla: anatomic and surgical considerations. *The International Journal of Oral & Maxillofacial Implants* **19** (Suppl.): 43–61.

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.

Buser, D., von Arx, T., ten Bruggenkate, C. & Weingart, D. (2000) Basic surgical principles with iti implants. *Clinical Oral Implants Research* **11** (Suppl.): 59–68.

Chang, M., Wennstrom, J.L., Odman, P. & Andersson, B. (1999) Implant supported single-tooth replacements compared to contralateral natural teeth. Crown and soft tissue dimensions. *Clinical Oral Implants Research* **10**: 185–194.

Chen, S.T. & Buser, D. (2009) Clinical and esthetic outcomes of implants placed in postextraction sites. *The International Journal of Oral & Maxillofacial Implants* **24**(Suppl.): 186–217.

Chen, S.T., Darby, I.B., Adams, G.G. & Reynolds, E.C. (2005) A prospective clinical study of bone augmentation techniques at immediate implants. *Clinical Oral Implants Research* **16**: 176–184.

Chen, S.T., Darby, I.B. & Reynolds, E.C. (2007) A prospective clinical study of non-submerged immediate implants: clinical outcomes and esthetic results. *Clinical Oral Implants Research* **18**: 552–562.

Covani, U., Bortolaia, C., Barone, A. & Sbordone, L. (2004) Bucco-lingual crestal bone changes after immediate and delayed implant placement. *Journal of Periodontology* **75**: 1605–1612.

Covani, U., Cornelini, R. & Barone, A. (2007) Vertical crestal bone changes around implants placed into fresh extraction sockets. *Journal of Periodontology* **78**: 810–815.

Draenert, F.G., Coppenrath, E., Herzog, P., Muller, S. & Mueller-Lisse, U.G. (2007) Beam hardening artefacts occur in dental implant scans with the newtom cone beam ct but not with the dental 4-row multidetector ct. *Dentomaxillofacial Radiology* **36**: 198–203.

Evans, C.D. & Chen, S.T. (2008) Esthetic outcomes of immediate implant placements. *Clinical Oral Implants Research* **19**: 73–80.

Fatemitabar, S.A. & Nikgoo, A. (2010) Multichannel computed tomography versus cone-beam computed tomography: linear accuracy of *in vitro* measurements of the maxilla for implant placement. *The International Journal of Oral & Maxillofacial Implants* **25**: 499–505.

Gher, M.E., Quintero, G., Assad, D., Monaco, E. & Richardson, A.C. (1994) Bone grafting and guided bone regeneration for immediate dental implants in humans. *Journal of Periodontology* **65**: 881–891.

Grunder, U., Gracis, S. & Capelli, M. (2005) Influence of the 3-d bone-to-implant relationship on esthetics. *The International Journal of Periodontics and Restorative Dentistry* **25**: 113–119.

Hämmerle, C.H., Chen, S.T. & Wilson, T.G., Jr (2004) Consensus statements and recommended clinical procedures regarding the placement of implants in extraction sockets. *The International Journal of Oral & Maxillofacial Implants* **19**(Suppl.): 26–28.

Jung, R.E., Holderegger, C., Sailer, I., Khraisat, A., Suter, A. & Hammerle, C.H. (2008) The effect of all-ceramic and porcelain-fused-to-metal restorations on marginal peri-implant soft tissue color: a randomized controlled clinical trial. *The International Journal of Periodontics and Restorative Dentistry* **28**: 357–365.

Kan, J.Y., Rungcharassaeng, K., Umezu, K. & Kois, J.C. (2003) Dimensions of peri-implant mucosa: an evaluation of maxillary anterior single implants in humans. *Journal of Periodontology* **74**: 557–562.

Lang, N.P., Tonetti, M.S., Suvan, J.E., Pierre Bernard, J., Botticelli, D., Fourmousis, I., Hallund, M., Jung, R., Laurell, L., Salvi, G.E., Shafer, D. & Weber, H.P. (2007) Immediate implant placement with transmucosal healing in areas of aesthetic priority. A multicentre randomized-controlled clinical trial i. Surgical outcomes. *Clinical Oral Implants Research* **18**: 188–196.

Ludlow, J.B., Davies-Ludlow, L.E., Brooks, S.L. & Howerton, W.B. (2006) Dosimetry of 3 cbct devices for oral and maxillofacial radiology: Cb mercuray, newtom 3g and i-cat. *Dentomaxillofacial Radiology* **35**: 219–226.

Ludlow, J.B. & Ivanovic, M. (2008) Comparative dosimetry of dental cbct devices and 64-slice ct for oral and maxillofacial radiology. *Oral Surgery, Oral Medicine, Oral Pathology, Oral Radiology, and Endodontology* **106**: 106–114.

Nisapakultorn, K., Suphanantachat, S., Silkosessak, O. & Rattanamongkolgul, S. (2010) Factors affecting soft tissue level around anterior maxillary single-tooth implants. *Clinical Oral Implants Research* **21**: 662–670.

O'Leary, T.J., Drake, R.B. & Naylor, J.E. (1972) The plaque control record. *Journal of Periodontology* **43**: 38.

Ramfjord, S.P. (1959) Indices for prevalence and incidence of periodontal disease. *Journal of Periodontology* **30**: 51–59.

Razavi, T., Palmer, R.M., Davies, J., Wilson, R. & Palmer, P.J. (2010) Accuracy of measuring the cortical bone thickness adjacent to dental implants using cone beam computed tomography. *Clinical Oral Implants Research* **21**: 718–725.

Rimondini, L., Bruschi, G.B., Scipioni, A., Carrassi, A., Nicoli-Aldini, N., Giavaresi, G., Fini, M., Mortellaro, C. & Giardino, R. (2005) Tissue healing in implants immediately placed into postextraction sockets: a pilot study in a mini-pig model. *Oral Surgery, Oral Medicine, Oral Pathology, Oral Radiology, and Endodontology* **100**: e43–e50.

Romanos, G.E., Traini, T., Johansson, C.B. & Piattelli, A. (2010) Biologic width and morphologic characteristics of soft tissues around immediately loaded implants: studies performed on human autopsy specimens. *Journal of Periodontology* **81**: 70–78.

Rustemeyer, P., Streubuhr, U. & Suttmoeller, J. (2004) Low-dose dental computed tomography: significant dose reduction without loss of image quality. *Acta Radiologica* **45**: 847–853.

de Sanctis, M., Vignoletti, F., Discepoli, N., Munoz, F. & Sanz, M. (2010) Immediate implants at fresh extraction sockets: an experimental study in the beagle dog comparing four different implant systems. Soft tissue findings. *Journal of Clinical Periodontology* **37**: 769–776.

Schropp, L., Kostopoulos, L. & Wenzel, A. (2003) Bone healing following immediate versus delayed placement of titanium implants into extraction sockets: a prospective clinical study. *The International Journal of Oral & Maxillofacial Implants* **18**: 189–199.

Schultes, G. & Gaggl, A. (2001) Histologic evaluation of immediate versus delayed placement of implants after tooth extraction. *Oral Surgery, Oral Medicine, Oral Pathology, Oral Radiology, and Endodontology* **92**: 17–22.

Schulze, R.K., Berndt, D. & d'Hoedt, B. (2010) On cone-beam computed tomography artifacts induced by titanium implants. *Clinical Oral Implants Research* **21**: 100–107.

Spray, J.R., Black, C.G., Morris, H.F. & Ochi, S. (2000) The influence of bone thickness on facial marginal bone response: stage 1 placement through stage 2 uncovering. *Annals of Periodontology* **5**: 119–128.

Suomalainen, A., Kiljunen, T., Kaser, Y., Peltola, J. & Kortesniemi, M. (2009) Dosimetry and image quality of four dental cone beam computed tomography scanners compared with multislice computed tomography scanners. *Dentomaxillofacial Radiology* **38**: 367–378.

Teughels, W., Merheb, J. & Quirynen, M. (2009) Critical horizontal dimensions of interproximal and buccal bone around implants for optimal aesthetic outcomes: a systematic review. *Clinical Oral Implants Research* **20**(Suppl. 4): 134–145.

Vignoletti, F., de Sanctis, M., Berglundh, T., Abrahamsson, I. & Sanz, M. (2009a) Early healing of implants placed into fresh extraction sockets: an experimental study in the beagle dog. II: ridge alterations. *Journal of Clinical Periodontology* **36**: 688–697.

Vignoletti, F., de Sanctis, M., Berglundh, T., Abrahamsson, I. & Sanz, M. (2009b) Early healing of implants placed into fresh extraction sockets: an experimental study in the beagle dog. III: soft tissue findings. *Journal of Clinical Periodontology* **36**: 1059–1066.