Immediate dental implant placement in the aesthetic zone
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Buccal bone measurements at dental implants the aesthetic region:

a 1 year follow-up cone-beam computed tomography study.

This chapter is an edited version of the manuscript:
KW Slagter, GM Raghoebar, NA Bakker, A Vissink, HJA Meijer.
Buccal bone measurements at dental implants the aesthetic zone: a 1 year follow-up cone beam computed tomography study. Submitted.
Abstract

Background: Sufficient buccal bone thickness (BBT) is important for optimal aesthetic results of implant treatment in the aesthetic zone. BBT measurements can be done with cone beam computed tomography (CBCT), but studies are scarce.

Aim: To assess the mean amount of BBT as a function of time after implant placement and relate it to immediate and delayed placed implants in the aesthetic zone with a 1 year follow-up using CBCT-scans.

Materials and Methods: After 1 month and 1 year of definitive crown placement, BBT was measured on CBCTs of 80 patients, part of 2 randomized clinical trials. Patients were divided in 4 study groups according bony defect (<5 or ≥5 mm) and timing of implant placement (immediate or delayed). Area of interest was the upper 5mm section of the implant, beginning at the neck of the implant towards the apical direction and measured in steps of 1 mm along the axis of the implant.

Results: BBT 1 year after placement of the definitive crown, varied for the immediate placed implants of study group 1 from 1.52(sd:0.89) to 2.04(sd:0.77) mm (i.e., at the level of the upper 5 mm of the implant); for study group 2 from 1.08(sd:0.55) to 1.44(sd:0.72) mm and for study group 3 from 1.00(sd:0.47) to 1.29(sd:0.72) mm. BBT varied from 0.71(sd:0.28) to 0.92(sd:0.57) mm for the delayed placed implants in study group 4. Mean loss of BBT between 1 month and 1 year was negligible and independent of the size of the buccal bone defect (<5 or ≥5 mm) prior to implant insertion and timing of implant insertion.

Conclusion: BBT at dental implants in the aesthetic zone measured on CBCTs, appears to be stable for immediate and delayed placed implants after placement of the definitive crown, independent of the size of buccal bone defect prior to implant insertion and timing of provisionalization.
Introduction

Single-tooth immediate implant placement in the aesthetic zone is a highly reliable treatment option for replacing a failing tooth. Particularly in the aesthetic zone, establishment and maintenance of healthy peri-implant hard and soft tissues is crucial. The presence of sufficient bone volume is the most important prerequisite to achieve primary stability in case of immediate implant placement in an extraction socket. Peri-implant bone preservation could be considered as one of the key factors in aesthetic outcome. The morphological assessment of bone volume is of great interest to clinicians. In the literature there is insufficient evidence to set a threshold for minimum buccal bone thickness to ensure the aesthetic outcome and the long-term stability. In the aesthetic zone there is data of buccal bone dimensions at different apical positions when the tooth is still in situ. Mean buccal bone thickness (BBT) varied from 0.6 mm to 0.8 mm, measured at different locations at central incisors and lateral incisors. The lack of clinical data regarding bone thickness at buccal aspect of dental implants is probably related to frequently encountered difficulties in standardization of the measurements. Cone-beam computed tomography (CBCT) has proven to be a useful tool that has been successfully employed for various dental procedures. The choice of an accurate and reliable imaging modality is clinically important in terms of postoperative monitoring of bone volume stability and to choose an adequate treatment approach. The CBCT might be used for evaluation of implant buccal bone dimension. The use of 3D image diagnostic and treatment planning software programs in combination with software programs for tracking and registration of the exact position of existing dental implants in radiographs can be of help. In view of the aforementioned, there is need for more studies which measure BBT at single tooth implants in the aesthetic zone on CBCT-scans. To the best of our knowledge, no clinical trials yet assessed the amount of implant buccal bone with a reproducible measure method on CBCT-scans at different apical positions along the implant axis. It is therefore not known how reliable the CBCT-scan is to assess BBT as a function of time after implant placement in the aesthetic zone.

The aim of the present study was to assess the mean buccal bone thickness (BBT) as a function of time and relate it to immediate and delayed placed implants in the aesthetic zone in after 1 month and 1 year follow-up using CBCT-scans.

Material and methods

To measure BBT on a CBCT-scan were 80 patients included with an immediate or delayed placed implant in the aesthetic region (region 13 to 23) of the maxilla (Figure 1). Patients were part of two randomized clinical trials. Both trials14,15 were approved by the local Medical Ethic Board (METC 2010.246) and registered in a trial register (www.isrctn.com: ISRCTN57251089) as well as that written informed consent was obtained from all patients. Patients were divided according the bony defect after removal of the failing tooth before implant placement. Due to sample size calculation, the two trials consisted each out of 20 patients per study group, with a total of 4 study groups (3 study groups with immediate implant placement and 1 study group with delayed implant placement).
Figure 1. Cohort flow diagram.

Enrollment

Assessed for eligibility (n=80)

Excluded (n=0)
- Not meeting inclusion criteria (n=0)
- Declined to participate (n=0)
- Other reasons (n=0)

Randomized (n=80)

Allocated to intervention (n=40)
- Received allocated intervention (n=40)
- Did not receive allocated intervention (give reasons) (n=0)

Lost to follow-up (give reasons) (n=0)

Discontinued intervention (give reasons) (n=0)

Analysed (n=40)
- Excluded from analysis (give reasons) (n=0)

Allocation

Allocated to intervention (n=40)
- Received allocated intervention (n=40)
- Did not receive allocated intervention (give reasons) (n=0)

Follow-Up

Lost to follow-up (give reasons) (n=1, patient did not show up at appointments)

Discontinued intervention (give reasons) (n=0)

Analysis

Analysed (n=39)
- Excluded from analysis (give reasons) (n=0)
A research-nurse not involved in the study blindly allocated by a computerized random number the patients in:

Study A with patients with a buccal bony defect of <5 mm:
- Group 1 (n=20): immediate placed implant (NobelActive, Nobel Biocare AB, Goteborg, Sweden) and immediate provisionalization;
- Group 2 (n=20): immediate placed implant (NobelActive) and delayed provisionalization.

Study B with patients bony defect of ≥5 mm:
- Group 3 (n=20): immediate placed implant (NobelActive) and delayed provisionalization;
- Group 4 (n=20): delayed placed implant (NobelActive) and delayed provisionalization.

For the present study to measure changes in the BBT at the level of implants as a function of time, CBCT scans were made after one month and 1 year after placement of the definitive crown (iCAT 3D exam scanner, KaVo Dental GmbH, Biberach, Germany). This scanner was validated for measuring bone thickness by Fourie et al. The method error of this scanner is very small, i.e. 0.05 mm (95 CI 0.03-0.07). The standard used voxel size was 0.30 and FoV was 100 x100 mm on the CBCT scans. Bone measurements at implants on the CBCT-scans were done using 3D image diagnostic and treatment planning software (Nobelclinician, version 2.1 (Nobel Biocare - Guided Surgery Center, Mechelen, Belgium). To allow for reproducible measurements, a CBCT imaging and software protocol was developed and validated.

**Measuring procedure**

Acquired CBCT Digital Imaging and Communications in Medicine (DICOM) datasets were transferred to a computer. The CBCT images were exported in DICOM multi-file format and imported into a medical image computing program, Maxilim, version 2.3 (Medicim, Sint-Niklass, Belgium). With Multimodality Image Registration using Information Theory (MIRIT), which has an accuracy of a subvoxel, the exact position of the implant could be recognized, determined and implemented in the patients DICOM files. The implant and patient dataset were exactly aligned by the MIRIT method, so that the distance from the central axis of the implant to the outer contour of the buccal bone could be measured. Area of interest was the upper 5 mm section of the implant, beginning at the neck of the implant towards the apical direction. Exact dimensions along the implant axis of each implant configuration used in the study was provided by the manufacturer. Buccal bone measurements (in mm) were performed calculating the distance to the buccal bone outline minus the radius of the interior contour of the implant. These buccal bone measurements were done for 5 mm at each millimeter along the axis beginning at the neck of the implant (Mo) towards apical (M1, M2, M3, M4, M5) (Figure 2). Measurements were done (with time interval to prevent recollection) by two independent operators (HM and KS) in a random order. This after validation of the measurement procedure and an interobserver intraclass correlation coefficient of 0.96 (95%CI 0.93-0.98) and an intra-observer intraclass correlation coefficient of 0.93 (95%CI 0.88-0.96) for examiner one and an intra-observer intraclass correlation coefficient of 0.96 (95%CI 0.93-0.97) for examiner two.
Figure 2a. Measurements were performed at each millimeter along the axis of the implant for 5 mm, beginning at the neck of the implant.

Figure 2b. Actual measurements beginning at the neck of the implant of the axis of the implant for 5 mm towards apical.
Statistical analysis

Friedman’s test was used to compare between bone thickness measurements at different levels. In case of uncertainty of the significance because of the relatively small number of patients analysed and the large number of outcomes, Bonferroni correction was considered in case of a p-value 0.01<0.05. A p-value of 0.05 was considered to indicate statistical significance. All analyses were performed using SPSS (PASW Statistics 20.0, SPSS Inc.; IBM Corporation, Chicago, IL, USA).

Results

One patient from study group 2 did not show up at appointments and was therefore excluded from the study, which lead to evaluation of CBCT’s of 79 patients. Baseline characteristics and treatment specifications are presented in Table 1. The mean and standard deviation values of buccal bone thickness (BBT) at different levels 1 year after definitive crown placement are presented per study and study group in Table 2.

In study A, with bony defects of <5 mm, the BBT in mm varied at the different apical positions between 1.58(0.55)- 2.12(0.78) in group 1 (immediate placement and immediate provisionalization) and 1.10(0.70)- 1.46(0.82) in group 2 (immediate placement and delayed provisionalization) after 1 month with a significant difference at M1,M2,M3 and M4 (1-4mm apical). After 1 year the BBT in mm varied between 1.52(0.89)- 2.04(0.77) in group 1 and 1.08(0.55)- 1.44(0.72) in group 2 with a significant difference at M1,M2 and M3.

In study B, with bony defects of ≥5 mm, the BBT in mm varied at the different apical positions between 1.11(0.65)-1.29(0.60) in group 3 (immediate placement and delayed provisionalization) and 0.79(0.46)- 0.93 (0.59) in group 4 (immediate placement and delayed provisionalization) after 1 month with a significant difference at M1. After 1 year the BBT in mm varied between 1.00(0.47) – 1.29 (0.72) in group 3 and 0.71(0.28) – 0.92 (0.57) in group 4 with a significant difference at M0 (neck) and M1.
**Table 1.** Baseline characteristics and treatment specifications per study group.

<table>
<thead>
<tr>
<th>Variable</th>
<th>Immediate Group 1 (n=20)</th>
<th>Immediate Group 2 (n=20)</th>
<th>Immediate Group 3 (n=20)</th>
<th>Delayed Group 4 (n=20)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Age</td>
<td>Mean ± SD Range</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>39.4±16.9 (19-70)</td>
<td>42.3±14.2 (23-66)</td>
<td>43.7±13.9 (18-63)</td>
<td>48.6±16.4 (20-72)</td>
</tr>
<tr>
<td>Gender</td>
<td>Male: 5, Female: 15</td>
<td>Male: 8, Female: 12</td>
<td>Male: 11, Female: 9</td>
<td>Male: 7, Female: 13</td>
</tr>
<tr>
<td>Implant location</td>
<td>Incisor 1: 7</td>
<td>Incisor 2: 8</td>
<td>Canine: 5</td>
<td></td>
</tr>
</tbody>
</table>

**Table 2.** Buccal bone measurements and changes after 1 month and 1 year.

<table>
<thead>
<tr>
<th>Measurements 1 month</th>
<th>Group 1 (n=20)</th>
<th>Group 2 (n=19)</th>
<th>Level of sign.</th>
<th>Group 3 (n=20)</th>
<th>Group 4 (n=20)</th>
<th>Level of sign.</th>
</tr>
</thead>
<tbody>
<tr>
<td>M0 (at neck)</td>
<td>1.84 (0.91)</td>
<td>1.27 (0.82)</td>
<td>0.06</td>
<td>1.01 (0.55)</td>
<td>0.79 (0.46)</td>
<td>0.19</td>
</tr>
<tr>
<td>M1</td>
<td>2.05 (0.80)</td>
<td>1.39 (0.94)</td>
<td>0.03*</td>
<td>1.29 (0.60)</td>
<td>0.88 (0.57)</td>
<td>0.03*</td>
</tr>
<tr>
<td>M2</td>
<td>2.12 (0.78)</td>
<td>1.46 (0.82)</td>
<td>0.02*</td>
<td>1.19 (0.61)</td>
<td>0.93 (0.59)</td>
<td>0.18</td>
</tr>
<tr>
<td>M3</td>
<td>2.08 (0.63)</td>
<td>1.39 (0.76)</td>
<td>0.01*</td>
<td>1.26 (0.61)</td>
<td>0.92 (0.62)</td>
<td>0.08</td>
</tr>
<tr>
<td>M4</td>
<td>1.89 (0.54)</td>
<td>1.31 (0.75)</td>
<td>0.01*</td>
<td>1.25 (0.67)</td>
<td>0.85 (0.66)</td>
<td>0.06</td>
</tr>
<tr>
<td>M5</td>
<td>1.58 (0.55)</td>
<td>1.10 (0.70)</td>
<td>0.07</td>
<td>1.11 (0.65)</td>
<td>0.82 (0.71)</td>
<td>0.18</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Measurements 1 year</th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>M0 (at neck)</td>
<td>1.52 (0.89)</td>
<td>1.28 (0.85)</td>
<td>0.41</td>
<td>1.00 (0.47)</td>
<td>0.71 (0.28)</td>
<td>0.07</td>
</tr>
<tr>
<td>M1</td>
<td>1.94 (0.79)</td>
<td>1.37 (0.78)</td>
<td>0.04*</td>
<td>1.25 (0.53)</td>
<td>0.81 (0.46)</td>
<td>0.01*</td>
</tr>
<tr>
<td>M2</td>
<td>2.04 (0.74)</td>
<td>1.44 (0.72)</td>
<td>0.02*</td>
<td>1.28 (0.67)</td>
<td>0.92 (0.57)</td>
<td>0.08</td>
</tr>
<tr>
<td>M3</td>
<td>1.91 (0.64)</td>
<td>1.39 (0.63)</td>
<td>0.02*</td>
<td>1.29 (0.72)</td>
<td>0.90 (0.55)</td>
<td>0.06</td>
</tr>
<tr>
<td>M4</td>
<td>1.66 (0.71)</td>
<td>1.24 (0.58)</td>
<td>0.07</td>
<td>1.24 (0.70)</td>
<td>0.85 (0.58)</td>
<td>0.06</td>
</tr>
<tr>
<td>M5</td>
<td>1.57 (0.90)</td>
<td>1.08 (0.55)</td>
<td>0.43</td>
<td>1.14 (0.66)</td>
<td>0.77 (0.59)</td>
<td>0.06</td>
</tr>
</tbody>
</table>
Discussion

A successful aesthetic outcome is suggested to be dependent on establishment of an optimal 3D implant position within the available bone dimensions and the maintenance of adequate buccal bone over the buccal implant surface but the amount of buccal bone is not known. The position of the implant in relation to the bucco-oral dimension of the alveolar ridge is thought to influence the degree of bone remodeling following implant placement. When there is no buccal bone present due to a bony defect after extraction, the position and depth of the placed implant could be different compared to an intact extraction socket or healed site. In the study of El Nahass and Naiem (2015) a mean buccal bone thickness, in relation to natural incisors still in situ, of 0.57 mm and 0.84 mm was found in the first 4 mm towards apically. This means that due to the surgical procedure with the slightly palatal placement of the implant and augmentation of the buccal space in the extraction socket between implant and buccal wall, more thickness of buccal bone is present at dental implants compared to natural teeth.

The reason behind the 6 measurements (M0-M5) performed after 1 month and 1 year after placement of the definitive crown is to investigate the buccal bone thickness at different apical positions, clinically relevant with dental implants in the aesthetic zone. No measurements for BBT at different positions along a dental implant are known in the literature. Although measured in a different study design, a mean value of 0.16 (0.21) mm BBT is found in an immediate implant group of Raes et al. and 2.12 (0.92) mm BBT found by Degidi et al. These numbers are in line for the immediate placed implants in this study. For delayed placed implants, only a mean amount of 0.20 (0.22)mm is described by Raes et al. This number is lower then the mean amount of BBT in this study.

Loss of buccal bone is inevitable, mainly as a consequence of the disappearance of bundle bone. Therefore information on the original buccal bone contour prior to removal of the tooth should be provided to measure the amount of change before and after implant placement. On post-operative CBCTs it is not known how much of the original contour has been changed after dental implant treatment. It would be interesting to include preoperative dimensions on CBCT-scans in relation to the actual position of the placed implant on a post-operative CBCT'scan. More insight would be gained on alterations in BBT due to the surgical procedure and occurring during the follow-up period. Consequently, implant positioning in relation to the bucco-oral dimensions of the alveolar ridge, which is thought to influence the degree of bone remodeling, could then be evaluated.

Limitations of the study

Some limitations have to be addressed. The interpretation of the buccal bone adjacent to dental implants on the resolution of the CBCT is insufficient in comparison with light microscopy. In the case of very thin buccal bone, CBCT images seem not always reliable due to background scattering and problems with standardization of the measurements. The quality and accuracy of a three-dimensional (3D) model derived from a CBCT is dependent on scanner related factors such as type of scanner, field of view (FoV), artifacts and voxel size. In addition, patient related factors such as patient position and metal artifacts, and operator related factors as the segmentation process or interpretation of the CBCT are of influence.
Conclusion

Buccal Bone Thickness at dental implants in the aesthetic zone measured on CBCTs, appears to be stable for immediate and delayed placed implants after placement of the definitive crown, independent of the size of buccal bone defect prior to implant insertion and timing of provisionalization.
References


