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Clinical Paper
Dental Implants

Immediate implant placement: the fate of the buccal crest. A retrospective cone beam computed tomography study

E. Groenendijk[1], T. A. Staas[2], F. E. J. Graauwmans[3], E. Bronkhorst[4], L. Verhamme[5,6], T. Maal[5], G. J. Meijer[3,4,5,6]

[1]Dental Implant Clinic, Den Haag, The Netherlands; [2]Dental Implant Clinic, 's-Hertogenbosch, The Netherlands; [3]Section Implantology & Periodontology, Department of Dentistry, Radboudumc, Nijmegen, The Netherlands; [4]Department of Preventive and Curative Dentistry, Radboudumc, Nijmegen, The Netherlands; [5]Department of Oral and Maxillofacial Surgery, Radboudumc, Nijmegen, The Netherlands; [6]3D Facial Imaging research Group, Radboudumc, Nijmegen, The Netherlands

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Abstract. This retrospective study aimed to analyse the fate of the buccal crest after immediate implant placement (IIP) through the use of cone beam computed tomography (CBCT). In 16 consecutive patients, an implant was placed in a more palatal position after extraction, thereby creating a gap of at least 2 mm between the implant and the buccal crest. Subsequently, this gap was filled with a bone substitute. Preoperatively, immediate postoperatively, and late postoperatively, a CBCT was made to measure the thickness of the buccal crest. After application of the bone substitute, the buccal crest increased in thickness from 0.9 mm to 2.4 mm (mean). At a mean of 103 weeks after IIP, late postoperative CBCT scans showed that the thickness of the buccal crest was compacted to 1.8 mm. In the same period, the height of the buccal crest increased by 1.6 mm (mean) to, on average, 1.2 mm above the implant shoulder. The aesthetic outcome was analysed using the White and Pink Esthetic Score (WES and PES). Both scored high: 8.4 and 11.8, respectively. Within the limitations of this study, the results of this IIP protocol are promising. Long-term prospective research on this topic on a large number of patients is necessary.

Key words: dental implant; immediate implant placement; implant position; cone beam computer tomography; buccal gap; buccal crest; aesthetics in dentistry.

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To achieve optimal functional and aesthetic results after implant installation in the anterior maxilla, correct implant positioning and establishment of an optimum volume of hard- and soft-tissues are crucial[1–3]. After tooth extraction, the socket walls collapse. In a horizontal direction, the reduction of the alveolar socket (3.79 ± 0.23 mm) is higher than vertically (1.24 ± 0.11 mm) at 6 months[4]. As a consequence, the oral mucosa retracts, thereby compromising aesthetics.

Current consensus is that immediate implant placement (IIP) itself does not prevent reported horizontal and vertical resorption of the buccal crest[5]. Applying bone substitutes is reported to be effective in limiting both horizontal and vertical ridge alterations. As a barrier material, they preserve the ridge volume in a maximal way[6–10]. Obviously, these measures

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should also be performed during IIP[11,12]. Even during bone augmentation procedures, the role of bone substitutes as barriers and stabilizers is indisputable[13–15].

Compared with the conventional approach, in which the socket is allowed to collapse over a 6- to 12-week period before implant installation, IIP allows immediate restoration, is less invasive and more cost effective, resulting in reduced overall treatment time and higher patient comfort. However, IIP is often associated with buccal bone loss and midfacial recession[3,16,17]. New insights advocate installing the implant in a more palatal position, as crestal bone resorption and midfacial soft-tissue recession are correlated with an implant placed too close to the buccal crest[18,19]. Creating a buccal gap of at least 2 mm results in new bone formation, coronal to the receding buccal bone wall[20,21]. Also, the thickness of the buccal crest itself plays an important role: the thinner it is, the more resorption occurs[22,23]. To create a gap of at least 2 mm, the use of implants with a smaller diameter is advocated. As radiographic data that give insight into the process of buccal bone remodelling after IIP are still lacking[24], the aim of this retrospective study was to analyse the fate of the buccal crest and the aesthetic outcome following IIP.

Materials and methods

In this retrospective study, 16 consecutive patients with one failing maxillary incisor in between natural neighbouring teeth were treated by one surgeon. Ethical approval for this retrospective evaluation was given.

Study population

Patients were treated with IIP if they fulfilled the following criteria: presence of an intact extraction socket, sufficient occlusal support, absence of periodontal disease, and bruxism. Furthermore, adequate bone height apical from the socket of the failing tooth (at least 4 mm) must be present to ensure primary implant stability. IIP was contraindicated when smoking habits exceeded more than 10 units a day; pregnancy; drug or alcohol abuse; or when negative bone reactions could be inspected, such as in cases of severe osteoporosis, Paget's disease, renal osteodystrophy, immunosuppression, recent corticosteroid treatment, chemotherapy, or radiotherapy.

IIP Protocol

In cases of an empty socket immediately after avulsion, or if the failing tooth was still in situ, a CBCT scan (Scanora, Soredex, Tuusula, Finland) with a standard dose, 85 kV, 15 mA, and a small field of view (FOV) of 6 cm by 6 cm was made, to decide if IIP was feasible (Fig. 1A). An absolute prerequisite for IIP was the presence of sufficient palatal bone volume: (1) to offer the implant sufficient primary stability to allow immediate restoration; and (2) to create a minimum of 2 mm distance between the buccal implant contour and the inner buccal crest. Patients were instructed to take 2 g of amoxicillin 1 hour preoperative followed by 500 mg amoxicillin every 8 hours during 5 days postoperatively and to rinse with 0.12% chlorhexidine solution twice a day during 14 days post surgery. In addition, intact interdental septa and buccal crest had to be present. After atraumatic extraction, the socket was cleaned extensively using a bone excavator to remove remnants of the periodontal ligament and/or inflammation tissue and to promote bleeding. The keratinized gingiva remained intact as no flaps were raised. Then, the osteotomy was directed palato-apically in relation to the original apex. The drill protocol used was in accordance with the manufacturer's guidelines for NobelActive Internal implants (Nobel Biocare, Washington DC, USA). Before applying bone substitute with grain size 0.25–1.0 mm (Bio-Oss, Geistlich Pharma AG, Wolhusen, Switzerland), the last used drill was placed into the osteotomy in order to prevent congestion of the implant bed with bone substitute. After packing the granules, the drill was removed, creating a tunnel, through which the implant was installed (NobelActive™ Internal; Nobel Biocare, Washington DC, USA). The implant seat was positioned 3 mm deeper than the buccal gingival margin. Immediately after this flapless surgery a second small FOV, low-dose CBCT scan was made to evaluate the implant position (Fig. 1B). In case of inaccuracies in this stage corrections still could be made. Hereafter, a titanium temporary abutment (Nobel Biocare, Washington DC, USA) was positioned onto the implant that allowed the fabrication of a screw-retained temporary crown (Protemp, 3 M ESPE Dental Products, Delft, The Netherlands) under cofferdam. Six months later, either an individualized, screw-retained, zirconium-porcelain crown, or an individualized zirconium abutment (Procera, Nobel Biocare, Washington DC, USA) with a cemented porcelain facing, was placed. To evaluate the height and thickness of the buccal crest in time (Fig. 1C), also a late postoperative small FOV, low-dose CBCT scan was executed.

Radiographic measurements

Changes in buccal crest thickness and height were measured by importing the preoperative, immediate postoperative, and late postoperative CBCT data of each patient as Digital Imaging and Communications in Medicine (DICOM) files in the analysis software (version 2.3.0.3

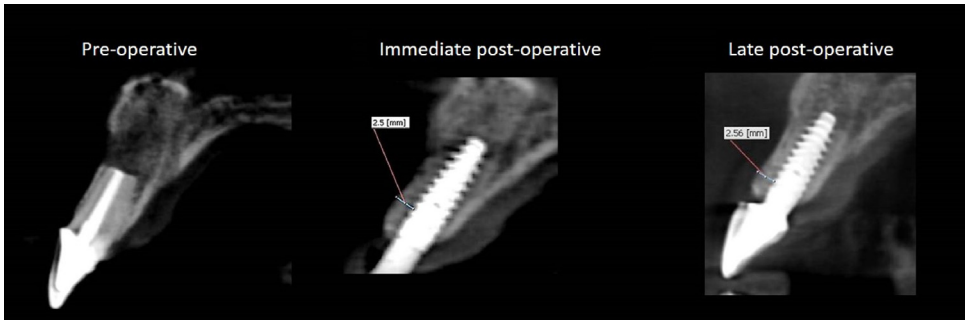

Fig. 1. (A) CBCT: the preoperative cross-section shows a root after apicoectomy; a thin buccal crest is still present. (B) CBCT: immediately postoperative cross-section; a clear, thickened, buccal bone crest can be observed. (C) CBCT: late postoperative cross-section; hard-tissue remodelling was performed at the buccal crest after incorporation of the bone substitute material.

Table 1. Distribution and radiological measurements on the preoperative, direct postoperative and late postoperative CBCT scans per case.

Case	Age	Tooth	MBT1	MBT2	MBT3	MBT3–MBT1	MBT3–MBT2	MBH1	MBH3	MBH3–MBH1	Weeks Late Post-op CBCT
1	49	11	1.0	2.2	2.4	1.4	0.2	−0.2	0.9	1.1	202
2	60	11	0.8	2.1	2.2	1.4	0.1	−2.8	1.1	3.9	163
3	17	22	1.4	2.3	2.4	1.0	0.1	1.1	1.5	0.4	103
4	59	12	1.0	2.0	0.9	−0.1	−1.1	−0.3	1.0	1.3	60
5	72	11	1.3	2.9	2.0	0.7	−0.9	0.9	1.5	0.6	73
6	57	11	0.7	2.6	2.2	1.5	−0.4	0.7	1.9	1.2	60
7	17	22	1.1	2.3	1.7	0.6	−0.6	−1.2	1.0	2.2	98
8	60	11	0.5	2.2	1.4	0.9	−0.8	−0.8	0.6	1.4	117
9	55	21	0.8	2.8	2.1	1.3	−0.7	−3.0	1.4	4.4	75
10	29	12	1.0	2.6	1.8	0.8	−0.8	−3.2	−0.4	2.8	125
11	27	11	1.6	2.0	1.9	0.3	−0.1	−0.8	0.4	1.2	43
12	22	11	0.8	2.3	1.9	1.1	−0.4	0.7	1.4	0.7	125
13	40	21	0.5	2.2	0.9	0.4	−1.3	−0.4	1.1	1.5	76
14	63	11	1.0	2.5	2.1	1.1	−0.4	0.9	1.5	0.6	60
15	51	21	0.7	3.2	2.4	1.7	−0.8	−0.6	1.3	1.9	119
16	27	21	0.6	2.3	1.2	0.6	−0.9	0.3	1.4	1.1	148

MBT1, preoperative midbuccal crest thickness in mm; MBT2, direct postoperative midbuccal crest thickness in mm; MBT3, late postoperative midbuccal crest thickness in mm; MBT3-MBT1, difference in late postoperative and preoperative crest thickness; MBT3-MBT2, difference in late postoperative and direct postoperative crest thickness; MBH1, preoperative midbuccal crest height in mm; MBH3, late postoperative midbuccal crest height in mm; MBH3-MBH1, difference in late postoperative and preoperative crest height; Weeks CBCT, number of weeks post surgery.

Maxilim, Medicim NV, Mechelen, Belgium). These were superimposed, based on voxel-based alignment using the palate and the anterior nasal spina as orientation. As a field-of-view of 6 cm by 6 cm was applied, only the area of interest was radiated, thereby avoiding the area of the submandibular glands and the eyeballs. This technique is advocated to optimally register the dimensions of the buccal crest[25]. In total, three sagittal sections were defined: centrally at the placed implant (the midbuccal cross section), as well as 1 mm to the mesial side and 1 mm to the distal side. The width of the buccal crest was measured 1 mm below the most coronal point of the buccal crest, thereby ensuring that the thickness of the buccal crest was measured at the same position at all time points. By comparing the preoperative, immediate postoperative, and late postoperative dimensions with each other, the change in buccal crest thickness could be calculated. The height of the buccal crest was also determined at the midbuccal aspect of the implant, 1 mm to the distal side and 1 mm to the mesial side. Differences in bone height were calculated by subtracting the late postoperative height from the preoperative height. It was not possible to measure the immediate postoperative top of the buccal crest exactly, because of a lack of homogeneity of the bone substitute in this stage.

Aesthetic measurements

In order to measure the aesthetic outcomes, both the implant site and contralateral site were photographed in all patients using a Nikon D7000 camera (16.2 megapixel). Evaluation was performed by means of a White Esthetic Score[26] (WES) and the Pink Esthetic Score[27] (PES).

Statistical methods

In this pilot study for all measurements, the median, mean and standard deviation were calculated. Radiological differences were tested with a paired *t*-test. For the aesthetic parameters, reliability, the Duplo error and structural measurement error were determined. Also an intra- and interobserver test was carried out using the Cohen's kappa coefficient. Statistics were calculated for all clinical parameters using SPSS (SPSS Inc., Chicago, IL).

Table 2. Overview of mean, standard deviation (SD) and distribution in CBCT measurements of the midbuccal aspect of the alveolar crest in mm ($n = 16$).

	Mean	SD	Max	Min
Preoperative thickness	0.925	0.315	1.6	0.5
Immediate postoperative thickness	2.406	0.338	3.2	2.0
Late operative thickness	1.844	0.501	2.4	0.9
Late postoperative versus preoperative thickness	0.919	0.489	1.7	−0.1
Late postoperative versus immediate postoperative	−0.550	0.447	0.2	−1.3
Preoperative height	−0.544	1.405	1.1	−3.2
Late postoperative height	1.100	0.547	1.9	0.4
Late postoperative versus preoperative height	1.644	1.160	4.4	0.4

Results

In 16 patients (four male and 12 female), IIP of one maxillary incisor was indicated. Seven implants were installed at position 11, five at position 21, two at position 12, and two at position 22. A lateral incisor was replaced by an implant with a diameter of 3.5 mm, a central incisor was replaced by an implant with a diameter of 4.3 mm. In all cases, primary implant stability was achieved with a insertion torque ranging from 40 to 110 newton centimetre (N cm), with an average of 65 N cm. In nine cases, persistent periapical pathology was the reason for extraction, four patients suffered from a crown or root fracture, and in three cases, a recent trauma related to avulsion was encountered. The ages of the patients ranged from 17 to 72 years with a mean age of 44 years. The patients were treated by one practitioner. The late postoperative CBCT was made after a period that ranged between 43 and 202 weeks (median 101 weeks) after IIP.

Radiographic measurements

The distribution and radiological measurements on the preoperative, direct postoperative, and late postoperative CBCT scans per case are shown in Table 1. An overview of mean, standard deviation (SD), and distribution in CBCT measurements of the midbuccal aspect of the alveolar crest in mm are listed in Table 2. No difference in measurements for thickness (ΔD) and height (ΔH) were observed between the midfacial value and those values established 1 mm to the mesial side and 1 mm to the distal side. Therefore, only the data for the midbuccal values are presented (Tables 1 and 2, Fig. 2). The immediate postoperative buccal crest thickness showed an increase of 1.5 mm (mean) from 0.9 mm to 2.4 mm (mean). During the evaluation period, a horizontal reduction of the buccal crest occurred, resulting in a final thickness of 1.8 mm (mean). The observed dimensional changes (ΔD) were statistically significant ($P < 0.001$) for all cross-sections.

The buccal crest height increased by 1.6 mm (mean), to an average of 1.2 mm coronal on the implant shoulder. This observed increase in height was statistically significant ($P < 0.001$).

Aesthetic measurements

The WES and PES scores after 60–202 weeks (mean 107 weeks), maximum, minimum, range, standard deviation (SD) and mean scores are shown in Tables 3 and 4, respectively.

The WES scores (Table 3), revealed a total score of 8.4 (out of 10). The PES scores (Table 4) displayed a total score of 11.8 (out of 14). With respect to intra-observer reproducibility the correlation was high (Cohen's kappa coefficient for WES was 0.865; for PES 0.940).

Discussion

Placement of a bone substitute simultaneous with IIP significantly reduces the horizontal buccal bone changes[12]. As the process of physiological remodelling of the original bone itself is not affected by the presence of a bone substitute[28], the postoperative buccal crest consists of a combination of original buccal crest, the applied bone substitute and newly formed bone. Therefore, application of a bone substitute in an extraction socket provides positive dimensional changes[29], as the bone substitute particles retain their radiographically detectable status.

Owing to the procedure of installing the implant in a more palatal position and filling the created gap with a bone substi-

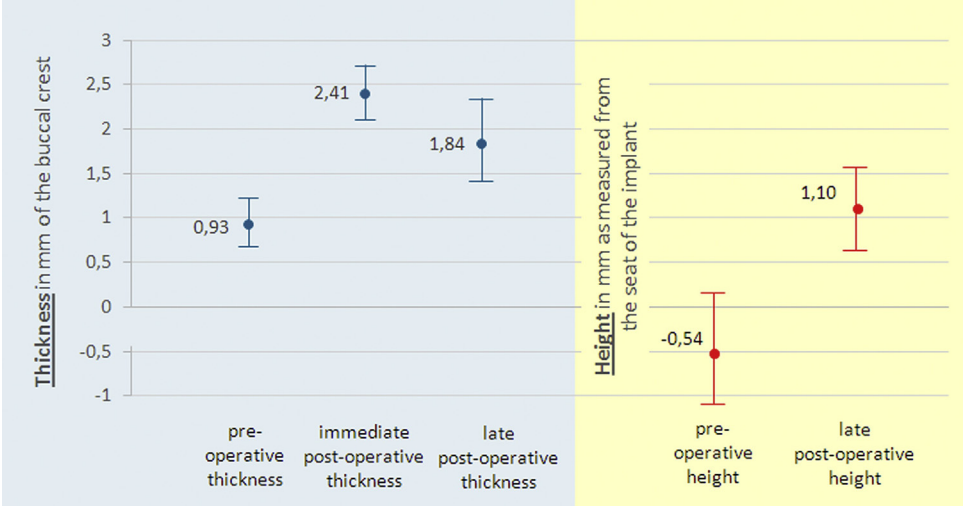

Fig. 2. Changes in thickness (mm) of the buccal crest are depicted in the blue background; preoperatively, immediately postoperatively and late postoperatively. Changes in height (mm) of the buccal crest is displayed in the yellow background; preoperatively and late postoperatively.

Table 3. WES-scores after 60–202 weeks (mean 107 weeks): maximum, minimum, range, standard deviation (SD), and mean scores (n = 16). All five sub-scores were evaluated as 0, 1, or 2. The total score is cumulative with a range of 0–10.

	Maximum	Minimum	Range	SD	Mean
Tooth shape	2	0	2.0	0.619	1.375
Tooth volume/outline	2	0	2.0	0.632	1.500
Colour/hue value	2	0	2.0	0.619	1.625
Surface texture	2	2	0.0	0.0	2.0
Translucency	2	1	1.0	0.342	1.875
Total score WES	10	3	7.0	1.668	8.375

Table 4. PES scores after 60–202 weeks (mean 107 weeks): maximum, minimum, range, standard deviation (SD) and mean scores (n = 16). All five sub-scores were evaluated as 0, 1 or 2. The total score is cumulative with a range of 0–14.

	Maximum	Minimum	Range	SD	Mean
Mesial papilla	2	1	1.0	0.3416	1.875
Distal papilla	2	1	1.0	0.5123	1.563
Soft-tissue contour	2	0	2.0	0.6021	1.688
Soft-tissue level	2	1	1.0	0.4031	1.813
Alveolar process contour	2	0	2.0	0.6292	1.563
Soft-tissue colour	2	0	2.0	0.6292	1.438
Soft-tissue texture	2	0	2.0	0.5774	1.750
Total score PES	14		7.0	1.7212	11.813

tute, the buccal crest thickness increased immediately postoperatively from 0.9 mm to 2.4 mm. During the evaluation period of between one to four years, a reduction occurred that resulted in a final, average buccal crest thickness of 1.8 mm. This horizontal bone reduction of 0.6 mm (mean) can be explained by settling of the bone substitute or resorption of the buccal bundle bone, as a result of remodelling. Owing to the IIP, the buccal crest bone height increased by 1.6 mm (mean), to an average of 1.2 mm above the implant seat. This observation is in agreement with the gain of height that was found in the ridge preservation studies from Iasella et al.[30] and Vance et al.[31], who already reported a gain of vertical average height of 1.3 mm and 0.7 mm respectively.

The increase in height of the buccal crest corroborated the clinical findings: also an increase in the midfacial soft tissue level was noticed (Fig. 3A,B). The presented IIP protocol resulted in a higher PES score than was reported for the ''early treatment'' protocol[26,32], implicating that 6 weeks after extraction the implant is placed, or the ''conventional treatment'' protocol[33], in which the implant is placed 12 weeks after tooth removal. Also when first augmentation is executed using mandibular block grafts covered with bovine hydroxyapatite and a resorbable collagen membrane, the aesthetic results are less[34].

Reported WES and PES scores (respectively mean 8.4 and 11.8) are higher than in other studies concerning immediate implantation. Cosyn et al.[35] described mean WES and PES scores of respectively 8.2 and 10.5 after 3 years, while Raes et al.[36] published WES and PES scores of respectively 7.2 and 10.3 after 1 year. Noelken et al.[37] noted a PES score of 11.3 after 2 years. The difference in aesthetic outcome between these studies and our study may be explained by differences in implant position and selected implant diameter.

No differences in thickness (ΔD) or in height (ΔH) were observed for the sagittal cross-sections, as measured at the midfacial level, 1 mm more to the mesial or 1 mm more distally. Therefore, in future research, only the mid-buccal cross-sections need to be calculated. In order to compare IIP protocols in the aesthetically sensitive anterior maxilla, long-term clinical trials should routinely include the surgical and restorative protocols used, as well as the three-dimensional implant position, buccal hard-tissue thickness and height at baseline, and over time.

Within the limitations of this study, it was concluded that the results of immediate implant placement in such a way that a buccal gap of 2 mm or more is filled with a bone substitute showed promising results. Further long-term, prospective, clinical research on this topic is necessary.

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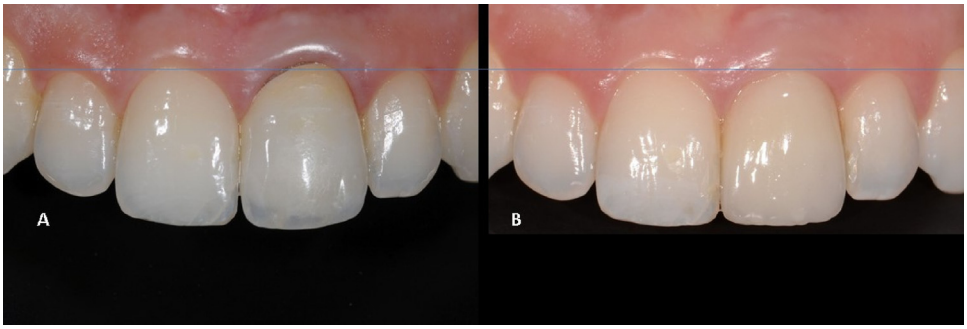

Fig. 3. (A) Tooth 21 is considered as lost due to a root fracture. (B) Implant crown region 21 three years after IIP. The Figure shows stable peri-implant soft-tissue and a mid-facial gain around implant crown region 21 (reference line in blue). (For interpretation of the references to colour in this figure legend, the reader is referred to the web version of this article.)

Medical Center (Radboudumc) in Nijmegen, the Netherlands.

Competing interests

None.

Ethical approval

Ethical Approval was given by Concernstaf Kwaliteit en Veiligheid, Commissie Mensgebonden Onderzoek, Radboud universitair medisch centrum, Geert Grooteplein (route 629), Nijmegen, www.radboudumc.nl; www.cmoregio-a-n.nl; reference number: 2016-2897.

Patient consent

Written consent has been obtained to publish clinical photographs.

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Address:
Edith Groenendijk
Stadhouderslaan 12
2517 HW Den Haag
The Netherlands
E-mail: edith@implantologiedenhaag.nl