HUMAN RANDOMIZED CONTROLLED TRIAL

Immediate single-tooth implant placement with simultaneous bone augmentation versus delayed implant placement after alveolar ridge preservation in bony defect sites in the esthetic region: A 5-year randomized controlled trial

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Abstract

Background: It is unclear if an intact buccal bony plate is a prerequisite for immediate implant placement in post-extraction sockets. The aim of this 5-year randomized controlled trial was therefore comparison of peri-implant soft and hard tissue parameters, esthetic ratings, and patient-reported satisfaction of immediate implant placement in post-extraction sockets with buccal bony defects of \( \geq 5 \) mm in the esthetic zone, with delayed implant placement after ridge preservation.

Methods: Patients presenting a failing tooth in the esthetic region and a buccal bony defect of \( \geq 5 \) mm after extraction were randomly assigned to immediate (Immediate group, \( n = 20 \)) or delayed (Delayed group, \( n = 20 \)) implant placement. Second-stage surgery and placement of a provisional restoration occurred 3 months after implant placement in both groups, followed by definitive restorations 3 months thereafter. The follow-up was 5 years. Marginal bone level (primary outcome), buccal bone thickness, soft tissue parameters, esthetics, and patient-reported satisfaction were recorded.

Results: Mean marginal bone level change was \(-0.71 \pm 0.35\) mm and \(-0.54 \pm 0.41\) mm in respectively the Immediate group and the Delayed group after 5 years (\( P = 0.202 \)). This difference, and in other variables, was not significant.

Conclusions: Marginal bone level changes, buccal bone thickness, clinical outcomes, esthetics, and patients’ satisfaction following immediate implant placement, in combination with bone augmentation in post-extraction sockets with buccal bony defects of \( \geq 5 \) mm, were comparable to those following delayed implant placement after ridge preservation in the esthetic zone.

KEYWORDS
alveolar bone loss, bone transplantation, dental implants
1 | INTRODUCTION

The outcomes of immediate implant placement in the esthetic zone are favorable.\textsuperscript{1,2} However, it was reported in systematic reviews that immediate implant placement must preferably only done in a carefully selected group of patients to minimize risks.\textsuperscript{3–7} These authors state that data are limited and are based on studies with short follow-up periods without reporting full scale evaluation parameters. These data must include information of buccal mucosa and bone levels. In a recent consensus report of the XV European Workshop in Periodontology these statements were confirmed.\textsuperscript{8}

Kan et al.\textsuperscript{9} and Jung et al.\textsuperscript{10} recommended delayed implant placement combined with bone grafting and/or soft tissue grafting when a buccal bone defect is found at implant placement. However, there is also some evidence that favorable treatment outcomes are possible for implants placed in post-extraction sockets with buccal plate defects.\textsuperscript{11–15} Although it might not be essential to have an intact buccal plate at immediate implant placement, a stable buccal bone thickness, and mid-buccal mucosa level are important outcomes after the placement of implants. Both outcome parameters should preferably be part of evaluation, starting with pre-operative measurements at baseline.\textsuperscript{7} Only Slagter et al.\textsuperscript{13,14} (both manuscripts reported on the same study group) and Liu et al.\textsuperscript{16} analyzed thickness of buccal bone and level of mid-buccal mucosa in a study group with buccal plate defects. Yet, the follow-up periods of most studies were limited, being 9 months in the Sarnachiaro et al.\textsuperscript{12} study, 12 months in the Slagter et al.\textsuperscript{13,14}, Liu et al.\textsuperscript{16} and Pohl et al.\textsuperscript{15} studies, and 13-36 months (median 22 months) in the Noelken et al.\textsuperscript{11} study. Only the Kamperos et al.\textsuperscript{17} retrospective study analyzed immediate implant placement in buccal defect sites over 5 years. However, the results of the latter study were restricted to esthetic scores.

Full-scale evaluation of implants inserted in post-extraction sockets with buccal plate dehiscence’s in the maxillary esthetic region, with a medium-term evaluation period, is underreported. The aim of this 5-year randomized controlled trial was therefore a comparison of changes in bone level, thickness of buccal bone, changes in mucosa level, esthetic ratings by professionals and patient-reported satisfaction of immediate implant placement in post-extraction sockets with buccal bony defects of $\geq$ 5 mm and delayed implant placement after ridge preservation in the esthetic region.

2 | MATERIAL AND METHODS

2.1 | Study design

Details of study design, inclusion criteria, exclusion criteria, calculation of sample size, patient characteristics, and 1-year results were described by Slagter et al.\textsuperscript{15} Forty patients were enrolled and allocated to:

1) An Immediate group: immediately placed implant and delayed provisionalization;
2) A Delayed group: delayed implant placement after ridge preservation and delayed provisionalization.

The ethics committee of the University Medical Center Groningen approved the study (NL32240.042.10) and the study was registered (ISRCTN57251089; www.trialregister.nl:NL8255). Outcomes were reported according to the CONSORT 2010 checklist.\textsuperscript{18} A the 5-years evaluation the study was not judged anymore being clinical research with test subjects as meant in the Medical Research Involving Human Subjects Act (WMO) because evaluation was part of a routine control visit, without extra data collection. Nevertheless informed consent was asked orally from the patients to include their data. The study was conducted in accordance with the Helsinki Declaration of 1975, as revised in 2013.

2.2 | Surgical procedure

The surgical procedure was described in detail by Slagter et al.\textsuperscript{13} In both groups, the failing teeth were carefully removed and bone grafts were harvested from the tuberosity region.

Preparation of the alveolus in the Immediate Group was done at the palatal side guided by a surgical template for ideal positioning. A the tuberosity bone graft was placed in the socket under the periosteum to cover the buccal plate defect. A mixture of tuberosity bone and deproteinized bovine bone substitute\textsuperscript{*} was used to fill the remaining space between the last bur and the tuberosity bone graft. After this, a tapered dental implant\textsuperscript{†} was placed. A soft tissue graft, also from the tuberosity region, was placed to seal the implant site according to the Raghoebar et al.\textsuperscript{19} method. Three months thereafter, the implant was uncovered and an implant-level impression was made for manufacturing a provisional restoration.

The alveolus in the Delayed Group was augmented in the same manner as in the Immediate Group.

\textsuperscript{*} Bio-Oss, Geistlich, Wolhusen, Switzerland

\textsuperscript{†} NobelActive, Nobel Biocare AB, Gothenburg, Sweden
however without implant placement. Three months after ridge preservation, the implant was placed. Three months thereafter, the implant was uncovered and an implant-level impression was made for the provisional restoration.

## 2.3 Prosthetic procedure

A screw-retained provisional restoration was placed the same day of uncovering the implant. After 3 months, porcelain fused to zirconia definitive crowns were manufactured for both groups. The restoration was either glass-ionomer cement- or screw-retained. Abutment screws were torqued at 32 Ncm. Prosthetic procedures were performed by a single dental laboratory and an experienced prosthodontist (HJAM).

## 2.4 Outcome measures

Outcome measures were described in detail by Slagter et al.\(^\text{13}\) In short, the following outcome items were evaluated:

- Survival rate. The implants’ and restorations’ survival rate were defined as the percentage still in function five years after definitive restoration placement.\(^\text{20}\)
- Marginal bone level and buccal bone thickness. Standardized digital peri-apical radiographs were made immediately after implant placement (baseline = T0), and one (T1), and sixty (T60) months after definitive restoration placement.\(^\text{21}\)

Change in marginal bone level (MBL) was the primary outcome. Changes in MBL were calculated at T1 and T60 in relation to the level at baseline. Thickness of buccal bone at the time of tooth extraction and 1 month and 5 years after placing the definitive restoration were calculated on CBCT’S. The upper 5 mm section of the implant starting at the implant neck towards the apical point were defined as area of interest (locations: M1, M2, M3, M4, M5). Details of the methods for analyzing buccal bone thickness and outcomes of the 1-year follow-up can be found in Maes et al.\(^\text{22}\) Slagter et al.\(^\text{23}\) Slagter et al.\(^\text{24}\) Meijer et al.\(^\text{24}\)

## 2.4.1 Changes in interproximal and mid-buccal peri-implant mucosal level

Standardized digital photographs were taken before extraction of the failing tooth (Tpre) and after 1 month (T1) and 60 months (T60), following the technique as published by Meijndert et al.\(^\text{21}\) The interproximal and mid-buccal changes were compared with the original gingival level of the failing tooth.

## 2.4.2 Clinical outcomes

Clinical variables assessed at Tpre, T1, and T60 were papilla volume,\(^\text{25}\) amount of plaque,\(^\text{26}\) amount of bleeding,\(^\text{27}\) Gingival Index,\(^\text{28}\) and probing pocket depth.

## 2.4.3 Peri-implant mucositis and peri-implantitis

The incidence of peri-implant mucositis and peri-implantitis was calculated and determined according to the definition reached by consensus at the 2017 World Workshop on the Classification of Periodontal and Peri-Implant Diseases and Conditions.\(^\text{28}\)

## 2.4.4 Esthetic assessment

Esthetic outcome (Pink Esthetic score/White Esthetic Score (PES/WES))\(^\text{29}\) was assessed from the digital photographs.

## 2.4.5 Patient satisfaction

Overall patient satisfaction was assessed from a Visual Analogue Scale (VAS), with possible scores ranging 0, being completely dissatisfied, to 10, being completely satisfied.

## 2.5 Statistical analysis

Differences between groups were analyzed with one-way analyses of variance (ANOVA) for continuous data and with a Fisher’s exact test in case of categorical data. Possible significant differences between the groups’ BBT medians were analyzed with the Mann-Whitney U test. A P-value of 0.05 was seen as statistical significant.

## 3 RESULTS

### 3.1 Patients

Twenty patients were included in both the Immediate (mean age 44 ± 14 years) and Delayed (mean age 49 ± 16...
All patients had bony defects of the labial socket wall in the vertical direction after removing the failing tooth. In terms of the classification for bony defects according to Benic & Hämmerle, both class 2 and class 3 defects were found. The mean size of the defect length was $8.35 \pm 2.18$ mm and $8.65 \pm 1.76$ mm in respectively the Immediate group and the Delayed group.

### 3.2 Survival rate

No implants and no restorations were lost. This results in an 100% survival rate for implants and restorations in both groups. Also no technical complications happened during the 5-years evaluations.

### 3.3 Changes in marginal bone level and buccal bone thickness

Mean marginal bone level changes at the approximal sites separately and of the approximal sites combined (mean change of mesial and distal side) are shown in Table 1. The largest MBL change occurred in the period from placement of the implant until T1 in both groups. After 1 month with the definitive restoration only minor changes were observed in both groups, without significant differences between the groups (Immediate group: $-0.64 \pm 0.38$ mm
### TABLE 1
Changes in marginal bone level from implant placement (baseline) to 1 month (T1) and to 60 months (T60) and changes in marginal soft tissue level from pre-operative (Tpre) to 1 month (T1) and to 60 months (T60) after definitive crown placement

| Variable                  | T1 Mean (SD) | T1 Mean (SD) | P-value* | T60 Mean (SD) | T60 Mean (SD) | P-value* |
|---------------------------|--------------|--------------|----------|----------------|----------------|----------|
|                           | Immediate    | Delayed      |          | Immediate      | Delayed        |          |
| Marginal bone level       |              |              |          |                |                |          |
| changes in mm (± SD)      |              |              |          |                |                |          |
| Mesial of implant         | −0.49 (0.46) | −0.45 (0.41) | 0.692    | −0.64 (0.38)   | −0.50 (0.45)   | 0.336    |
| Distal of implant         | −0.71 (0.51) | −0.48 (0.47) | 0.342    | −0.77 (0.43)   | −0.58 (0.41)   | 0.171    |
| Mesial and distal side    | −0.59 (0.34) | −0.47 (0.41) | 0.692    | −0.71 (0.35)   | −0.54 (0.41)   | 0.202    |
| Marginal soft tissue      |              |              |          |                |                |          |
| level changes in mm (± SD)|              |              |          |                |                |          |
| Mesial of implant         | −0.15 (0.18) | −0.18 (0.16) | 0.790    | −0.30 (0.32)   | −0.22 (0.26)   | 0.416    |
| Distal of implant         | −0.17 (0.16) | −0.23 (0.17) | 0.460    | −0.38 (0.53)   | −0.36 (0.21)   | 0.870    |
| Mid-facial of implant     | −0.13 (0.28) | −0.30 (0.49) | 0.186    | −0.27 (0.57)   | −0.45 (0.59)   | 0.362    |

*one-way analysis of variance (ANOVA).

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**FIGURE 2** Example of peri-apical radiograph and Cone Beam Computed Tomograph of a patient of the Immediate group with implant in position 11 depicted 5 years after treatment

Mesially and $-0.77 \pm 0.43$ mm distally versus Delayed group: $-0.50 \pm 0.45$ mm mesially and $-0.58 \pm 0.41$ mm distally; $P = 0.336$ and $P = 0.171$ for respectively the mesial sides and the distal sides (Figure 2). At T60, the least peri-implant bone change in the Immediate group was $-0.15$ mm and the largest bone change was $-1.45$ mm. In the same time period in the Delayed group, bone change varied from 0.00 to -1.38 mm.
## 3.4 Changes in interproximal and mid-buccal peri-implant mucosal level

Changes in soft tissue level from pre-operative up to 5 years after placing the definitive restorations are shown in Table 1. Five-year mid-buccal mucosa level changes were $-0.27 \pm 0.57$ mm and $-0.45 \pm 0.59$ mm in the Immediate group and Delayed group respectively, without a significant difference ($P = 0.362$) (Figure 3). At T60, the least mid-buccal mucosa level change in the Immediate group was 0.00 mm and the largest mid-buccal mucosa level change was -2.40 mm. In the same time period in the Delayed
group, mid-buccal mucosa level change varied from 0.00 to -1.90 mm.

3.5 | Clinical outcomes

In both groups, low plaque and bleeding indexes were seen and a healthy peri-implant mucosa, without significant differences between the groups (Table 3). And also pocket probing depths were stable throughout the evaluation period without significant differences (Table 3).

3.6 | Peri-implant mucositis and peri-implantitis

The incidence of peri-implant mucositis was 38.9% and 11.8% in, respectively, the Immediate group and the Delayed group without a significant difference between the groups ($P = 0.070$). None of the patients in both groups developed peri-implantitis.

3.7 | Esthetic assessment

Both groups’ PES/WES scores were acceptable throughout the follow-up (Table 3). The total esthetic outcome was $14.8 \pm 2.20$ in the Immediate group and $14.5 \pm 2.10$ in the Delayed group ($P = 0.679$).

3.8 | Patient satisfaction

Overall patient satisfaction (Table 3) was high and comparable between the groups throughout the follow-up ($P = 0.389$).

4 | DISCUSSION

As well immediate implant placement, in combination with a bone augmentation procedure, and delayed implant placement after ridge preservation in post-extraction sockets with buccal bony defects of $\geq 5$ mm in the esthetic zone, were accompanied by minor peri-implant bone loss, good peri-implant parameters and high patient satisfaction. At the 5-year evaluation, no significant differences were noted for all outcomes between both procedures.

Buser et al. $^{31}$ recommended a fully intact buccal bone wall with a thickness of at least 1 mm when considering immediate implant placement. Jung et al. $^{10}$ recommended delayed implant placement combined with a bone grafting and/or soft tissue grafting approach when a buccal bone defect is noted at implant placement. Possible risk factors for immediate placement in less favorable cases would be orofacial flattening of the soft tissue profile and recession of the facial mucosa. However, the results of our study do not support these statements because favorable 5-year outcomes were observed with immediate implant placement combined with bone augmentation.

So far as known, prospective studies reporting full-scale outcomes with an evaluation period of at least 5 years after immediate dental implant placement in anterior maxillary sites with labial bony defects have not been published yet. The results of our study are therefore best be compared with: the prospective Noelken et al. $^{11}$ study with an evaluation period of 13 to 36 months, although their implants were immediately provisionalized and splinted to neighboring teeth; the retrospective Kamperos et al. $^{17}$ study which dealt with esthetic outcomes after 5 years; and for the control group with the Eghbali et al. $^{32}$ being a five-year prospective study on implant delayed placement after alveolar ridge preservation. Noelken et al. $^{11}$ reported a 100% implant survival, stable approximal bone levels and normal peri-implant probing depths. CBCT scans, however, revealed a small longitudinal zone of incomplete bone coverage in the midline, measuring 0.5 to 1.0 mm in width in a number of cases. The buccal bone thickness of the present study was greater, in comparison. This could possibly be because of the fact that the Noelken et al. $^{11}$ study only included patients with a complete loss of the labial bone wall while the present study also had patients demonstrating partial loss ($\geq 5$ mm). Presumably, an augmentation procedure is more successful if part of the augmented material can be condensed between the residual wall and the implant surface. The Kamperos et al. $^{17}$ study’s PES values from both the immediate and delayed implant placement groups are in line with the present study’s PES results. The 5-year Eghbali et al. $^{32}$ study placed the dental implants and connective tissue grafts 4 months after alveolar ridge preservation, then a provisional restoration was manufactured 3 months later, with the definitive restoration being manufactured and placed 3 months after that. Their procedure and implant system were the same as in the Delayed group of the present study. The implant survival of that study was 100% after 5 years. Mean marginal bone loss was 0.47 mm, the mid-facial recession amounted to 0.12 mm and the PES values were high, thus very similar outcomes to ours.

There were no other 5-year studies available for buccal bone thickness comparisons. The BBT in the Immediate group of our study varied from 1.23 to 1.58 mm. The BBT of the Delayed group varied from 1.05 to 1.44 mm. It looks as if the BBT increases between the first month and 5 years after definitive restoration placement. However, this could probably be ascribed to maturation of the augmentation mix and replacement by newly generated bone, resulting in better visibility on the CBCT scan. A stable buccal bone...
**TABLE 3** Means of pre-operative and 1 month (T1) and 60 month (T60) clinical outcome measures (papillai index, gingival index, plaque index, bleeding index and pocket probing depth), esthetic evaluation and overall patient satisfaction (with standard deviations)

| Variable                          | Tpre Immediate | Delayed | P-value* | T1 Immediate | Delayed | P-value* | T60 Immediate | Delayed | P-value* |
|-----------------------------------|----------------|---------|----------|-------------|---------|----------|---------------|---------|----------|
| Papillavolume (papillaindex)      |                |         |          |             |         |          |               |         |          |
| mesial                            | 2.10 (0.97)    | 1.80 (1.01) | 0.183    | 2.15 (0.99) | 1.80 (1.06) | 0.818    | 2.28 (0.83) | 2.47 (0.72) | 0.812    |
| distal                            | 1.95 (0.89)    | 1.80 (1.01) | 0.669    | 2.00 (0.99) | 1.45 (1.15) | 0.281    | 2.22 (0.81) | 2.35 (0.70) | 0.816    |
| Health of gingiva (gingivalindex) | 0.05 (0.22)    | 0.25 (0.79) | 1.000    | 0.05 (0.23) | 0.00 (0.00) | 1.000    | 0.06 (0.24) | 0.06 (0.24) | 1.000    |
| Amount of plaque (plaqueindex)    | 0.05 (0.22)    | 0.00 (0.00) | 1.000    | 0.00 (0.00) | 0.00 (0.00) | NA       | 0.00 (0.00) | 0.06 (0.24) | 0.486    |
| Bleeding after probing (bleedingindex) | 0.65 (0.59)    | 0.95 (1.00) | 0.318    | 0.45 (0.61) | 0.35 (0.49) | 1.000    | 0.50 (0.71) | 0.18 (0.53) | 0.182    |
| Pocket probing depth (mm)         |                |         |          |             |         |          |               |         |          |
| mesial                            | 2.90 (1.55)    | 3.30 (1.63) | 0.431    | 3.15 (0.59) | 3.15 (0.67) | 1.000    | 3.72 (1.07) | 3.12 (0.86) | 0.076    |
| distal                            | 3.25 (1.02)    | 3.45 (1.54) | 0.631    | 3.60 (0.68) | 3.25 (0.64) | 0.102    | 3.83 (1.38) | 3.35 (1.27) | 0.293    |
| buccal                            | 1.65 (0.75)    | 2.25 (1.12) | 0.053    | 2.90 (0.79) | 3.20 (0.89) | 0.267    | 3.17 (0.62) | 2.76 (0.75) | 0.093    |
| palatal                           | 2.15 (0.81)    | 3.05 (1.93) | 0.062    | 2.80 (0.41) | 2.85 (0.59) | 0.757    | 2.61 (0.61) | 2.71 (0.59) | 0.643    |
| Esthetic evaluation               |                |         |          |             |         |          |               |         |          |
| PES                               | 7.00 (2.05)    | 6.90 (1.32) | 0.631    | 7.80 (1.66) | 7.40 (1.59) | 0.711    | 7.44 (1.85) | 7.53 (1.33) | 0.878    |
| WES                               | 5.00 (2.33)    | 5.40 (1.65) | 0.702    | 7.99 (1.73) | 7.60 (1.09) | 0.682    | 7.39 (1.15) | 7.00 (1.37) | 0.368    |
| PES/WES                           | 11.60 (3.33)   | 11.10 (3.46) | 0.433    | 16.20 (2.20) | 15.10 (1.71) | 0.383    | 14.8 (2.20) | 14.5 (2.10) | 0.679    |
| Overall patient satisfaction      | NA              | NA       | NA       | 79.4 (14.1) | 80.7 (12.3) | 0.758    | 77.7 (17.2) | 82.4 (14.3) | 0.389    |

Abbreviations: NA = not applicable.

*Fisher’s Exact test for the papilla, gingiva, plaque and bleeding indices; one-way analysis of variance (ANOVA) for pocket probing depth; one-way analysis of variance (ANOVA) for esthetic evaluation and patient satisfaction.
thickness is an important outcome after immediate placement of implants in the esthetic region. For future studies evaluating immediate implant placement, it should be kept in mind that BBT is probably the primary outcome of preference instead of approximal bone levels. The importance of buccal bone thickness and a stable mucosa level in the esthetic region was also strengthened by a number of authors all evaluating surgical procedures on hard and soft tissues to enhance esthetics.33–40

Immediate implant placement is said to increase the risk of soft tissue recession.41 Soft tissue level change mid-buccally was limited, being $-0.27 \pm 0.57$ mm and $-0.45 \pm 0.59$ mm in the Immediate group and the Delayed group, respectively. Most of the recession occurred in the period up to the first months and was more or less stable thereafter. Then, the recession between 1 year and 5 years post treatment was $-0.12$ and $-0.11$ mm for the Immediate and Delayed group, respectively (see Slagter et al.13 for the 1-year results). Cosyn et al.42 performed a 5-year follow-up study of immediate implant placement, with the same implant system, in sites without large bony deficiencies. In this study, a recession of $0.53 \pm 0.53$ mm was reported, which is also limited. These positive limited recession outcomes were reconfirmed by the 10-year results of the same study group.43 The statement in the systematic review41, performed in 2012, that immediate implant placement, either or not in sites with large labial bone wall deficiencies, is associated with soft tissue recession has not been confirmed, therefore, by the more recent clinical studies with mid-term to long-term evaluation periods.42,43

Avila-Ortiz and co-authors (2020) proposed the term “peri-implant phenotype concept”, elucidating the role of peri-implant keratinized mucosa width, peri-implant mucosal thickness, peri-implant supracrestal tissue height and peri-implant bone thickness on the stability of soft tissues.44 It could well be that the efforts to create enough buccal bone thickness in the present study paid off in reducing mucosal recession after the initial period of soft tissue healing and maturation. Possibly, the development of new procedures are accountable for less mid-facial recession. Unfortunately, soft-tissue level at the time-point of tooth extraction was not taken as a starting point in other studies, meaning that initial recession could not be calculated.

Derks and Tomasi published a systematic review in which a prevalence of 43% for peri-implant mucositis was mentioned and 22% for peri-implantitis.45 Our study found lower values, but one should note that the systematic review included highly heterogenous population and treatment groups.

Both procedures tested here resulted in the same good bone and soft tissue outcomes and the professionals and patients were equally satisfied so, if larger future RCTs report similar results from a general practice setting, implant teams can discuss the methods with the patient and apply the individual preference. Immediate placement of dental implants in post-extraction sites with large labial wall deficiencies in the maxillary esthetic zone seems to be equally reliable treatment as alveolar ridge preservation with delayed placement. The fact that the procedure applied to the Immediate group requires 3 months less treatment time than the Delayed group should be taken into account.
Some limitations of the current study must be mentioned. First, initial group size calculation revealed that 19 patients would be necessary in each group.\textsuperscript{13} At the 5-years evaluation, 18 patients could be analyzed in the Immediate group and 17 patients in the Delayed group. This means that conclusions have lost some power with respect to the primary outcome. Next, the study was carried out in a university setting. This means that highly experienced professionals treated the patients. Also, participants were strictly selected. This could mean that results of our study may be different from those achieved in a general practice.

5 CONCLUSIONS

Taking into account the limitations, it is concluded that changes in mean marginal bone level following immediate implant placement, in combination with a bone augmentation procedure, are comparable to those when implants are placed 3 months following alveolar ridge preservation in post-extraction sockets with buccal bony defects of $\geq$ 5 mm in the esthetic region. Hard and soft tissue outcomes, including buccal bone thickness, were favorable with both procedures and professionals and patients were satisfied with esthetics.

CONFLICT OF INTEREST

The study was supported by an unrestricted grant from Nobel Biocare Services AG, Gothenburg, Sweden (by means of implant materials, research grant: 2012-1135). The authors report no conflict of interest.

AUTHORS CONTRIBUTION

All the authors contributed substantially to the conception, design, data interpretation, and critical revision of study and manuscript and approved the final version for publication. Kirsten W. Slagter and Henny J.A. Meijer were involved in collecting data and drafting of the manuscript. Henny J.A. Meijer and Arjan Vissink were involved in the data analysis.

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