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Dental implant treatment strategies for failing and missing teeth in the maxillary aesthetic region

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Dental implant treatment strategies for failing and missing teeth in the maxillary aesthetic region

Wouter Gerard van Nimwegen

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CHAPTER

01

General introduction

General introduction

Prior to the introduction of dental implants, patients with failing or missing teeth in the aesthetic region were commonly treated with a removable partial denture or a fixed dental prosthesis. Nowadays, patients often prefer an implant-based solution, but implant placement in the maxillary aesthetic region is considered a difficult and complex treatment by dental professionals.¹ This is because the region where teeth fail or are missing is subject to issues that interfere with a favourable outcome of implant-based rehabilitations. Some of the main issues are mentioned below.

In case of failing teeth in the aesthetic region, extraction of these teeth is often preceded by a history of dental trauma, endodontic treatment and retreatment. At the time these teeth fail, periapical inflammation and root resorption often have occurred, accompanied by bony defects of the buccal bone wall. These bony defects increase the risk of mid-buccal mucosal recession when an implant is placed immediately into an extraction socket and may require additional guided bone regeneration procedures during implant treatment.²

Following extraction, regardless whether an implant is placed or not, the absence of a tooth in the extraction socket results in a cascade of biological events that can lead to pronounced local bone remodelling, resulting in additional loss of bone and overlying soft tissues.³ These post-extraction alterations of hard and soft tissues are usually highly visible in the aesthetic region.

As a result, failing and missing teeth in the maxillary aesthetic region provide non-ideal conditions for implant placement. Whenever possible, an evidence-based choice should be made between available implant treatment protocols. However, current implant treatment protocols and clinical studies on implant treatment in the aesthetic region focus mainly on implant treatment for one failing or missing tooth, while sparse evidence is available how to best treat two adjacent failing or missing teeth.^{4,5}

Single failing or missing teeth in the maxillary aesthetic region

As mentioned before, in case of single failing or missing teeth in the aesthetic region, a variety of implant treatment protocols exist.⁶ When implants are placed within 24 hours after extraction of a failing tooth into the extraction socket, this treatment is called immediate implant placement (Fig. 1a-1g). When failing teeth have been extracted two or more months before implant placement, the implants are considered to be placed in healed sites. Healed sites display soft and hard tissue healing, but defects of hard and soft tissue can also be found. When implants are placed into healed sites, this treatment is referred to as delayed implant placement. Delayed implant placement offers the advantage of placing implants into healed and pathogen free sites, but additional guided bone regeneration procedures are often required during implant treatment to create enough bone for primary stability and osseointegration of the implants.

Besides timing of implant placement, a variety of implant loading protocols is applied.⁷ In case of immediate loading, a provisional restoration is attached to the implant within 24 hours after implant placement (Fig. 1e). If the provisional restoration is attached after osseointegration of the implant, this procedure is referred to as delayed loading. Aside from the timing of loading (immediate or

delayed), loading protocols are divided into occlusal and non-occlusal loading. In case of occlusal loading, the provisional restoration is in contact with the opposing dentition in centric occlusion. If the provisional restoration is placed non-loading, no contact in centric occlusion exists between the provisional restoration and the opposing dentition.

Whether immediate or delayed implant placement, immediate or delayed loading, and occlusal or non-occlusal loading protocols are chosen for the individual patient is, among others, dependent on the amount of bone and keratinized soft tissue that is available after extraction of teeth, whether or not primary stability of the implant can be achieved as well as the skills and preferences of the dental professional. The following implant treatment options are commonly used by dental professionals in case of a single failing or missing tooth in the maxillary aesthetic region:

- Extraction of the failing tooth, immediate implant placement and non-occluding provisional implant restoration, placement of the final implant restoration after 3 months;
- Extraction of the failing tooth, immediate implant placement and localized guide bone regeneration procedure, delayed occluding provisional implant restoration placed after 3 months, placement of the final implant restoration after 6 months;
- Extraction of the failing tooth, ridge preservation procedure, delayed implant placement and immediate non-occluding provisional implant restoration placed after 3 months, placement of the final implant restoration after 6 months;
- Missing tooth, healed site present, delayed implant placement and localized guide bone regeneration procedure, delayed occluding provisional implant restoration placed after 3 months, placement of the final implant restoration after 6 months;
- Missing tooth, healed site present, guided bone regeneration procedure (extensive bone augmentation of the alveolar ridge), delayed implant placement after 3 months, delayed occluding provisional implant restoration after 6 months, placement of the final implant restoration after 9 months.

In recent years, there has been a tendency towards immediate implant placement in combination with immediate placement of a non-occluding provisional restoration (option 1), if primary stability of the implant can be achieved and bony defects of the buccal bone plate are absent or present as small solitary defects. The combination of immediate implant treatment and immediate non-occlusal loading greatly reduces treatment time compared to delayed implant treatment and eliminates the need of wearing an interim removable prosthesis.⁴ If primary stability cannot be achieved in the presence of large bony defects, or in case failing teeth have already been extracted in the past, implant treatment shifts to other treatment options with higher morbidity and longer treatment time (options 2-5).

Clinical studies on immediate implant placement have so far shown excellent short-term results with regard to implant survival (1-year: 97.1%) and peri-implant marginal bone loss (1 year: 0.81 ± 0.48 mm).⁸ Long-term clinical studies on immediate implant placement with follow-up periods of >1 year are scarce, however.⁹⁻¹³ Thus, it is not yet set whether the long-term results of immediate implant

placement are as favourable as the short-term results.

An important disadvantage of immediate placed implants, is that they are prone to mid-buccal mucosal recession. Clinical studies have reported that advanced recession (>1mm) of the mid-buccal mucosa commonly occurs, even in low-risk cases¹⁴, and that it seems to continue up to several years.¹² The use of a connective tissue graft in addition to immediate implant placement and provisionalization, is thought to compensate for the recession of the mid-buccal mucosa^{9,15}, although conflicting results have been reported.¹⁶ Amongst others, it is unknown whether a connective tissue graft actually contributes to a gain in volume of the peri-implant mucosa, since no volumetric studies exist on this topic.

Horizontal and vertical resorption of the buccal bone wall after extraction of teeth, is seen as the most important factor to mid-buccal mucosal recession. When immediate implant placement is applied, the gap between the buccal bone wall and the implant surface is usually grafted with demineralized bovine bone or a mixture of demineralized bovine bone and autogenous bone. Grafting with demineralized bovine bone reduces the horizontal resorption of the buccal bone wall after implant placement¹⁷ and is considered an essential part of any immediate implant treatment protocol.¹⁸

Another factor to mid-buccal mucosa recession are bony defects of the buccal bone wall that are rather frequently present after extraction of failing teeth. These bony defects are often small two- or three walled defects that, when left untreated, can lead to very localized mid-buccal mucosal recession. In case of immediate implant placement, under the restriction that primary stability of the implant is achieved, the implant-gap and bony defects are usually grafted with demineralized bovine bone, autogenous bone or a mixture of both as well as that a collagen membrane is placed to allow for guided bone regeneration. A 1-year clinical study showed that, when such an approach was applied, the outcome of immediate placed implants was comparable to that of delayed implant placement.¹⁹

Two failing or missing teeth in the maxillary aesthetic region

In case of two failing or missing neighbouring teeth in the aesthetic region, two single implants can be placed adjacent to each other. However, literature on implant treatment with two adjacent implants in the aesthetic region is scarce²⁰⁻²⁵ and long-term studies have not yet been conducted. The existing studies have yet to provide clear guidelines on how to treat patients with two adjacent implants in the aesthetic region. For example, it is unknown whether the existing implant treatment protocols for single implants also comply with placement of two adjacent implants as no comparative studies are available to test these protocols with adjacent implants.

In addition, placement of two adjacent implants can be accompanied by problems with regard to maintaining inter-implant bone crest height²⁰ and inter-implant papilla height²¹, which in turn can lead to the existence of a black triangle between the implant restorations (Fig. 2).

An alternative to implant treatment with two adjacent implants is the placement of a single implant-supported cantilever restoration in the aesthetic region (Fig. 3). In case of a missing lateral and central upper incisor, this treatment option is unavoidable when the horizontal distance

of the edentulous space is too limited for placement of two adjacent implants. Although single implant-supported cantilever restorations have been shown to provide a good treatment option for missing lateral and central incisors in terms of patient satisfaction and peri-implant marginal bone loss after 1 year²⁶, concerns about the stability of peri-implant papillae remain and long-term results are lacking.

General aim and outline of the thesis

The general aim of this thesis was to assess the outcome of a variety of treatment strategies for one failing tooth and two failing or missing teeth in the maxillary aesthetic region. The specific aims were:

- To retrospectively assess the treatment outcome of immediately placed and provisionalized single implants in the aesthetic region, with a follow-up period of >1 year following placement of the final implant restoration (**Chapter 2**);
- To assess the 1-year changes in mid-buccal mucosal volume of immediately placed and provisionalised implants in the aesthetic region, with or without the application of a connective tissue graft (**Chapter 3**);
- To assess the 1-year change in buccal bone thickness in relation to changes in mid-buccal mucosal volume in immediately placed and provisionalized implants in the aesthetic region, with or without the application of a connective tissue graft (**Chapter 4**);
- To compare the 5-year clinical, radiographic and patients' satisfaction parameters of two adjacent implant restorations in the aesthetic region, treated with a scalloped implant platform or a conventional flat implant platform (**Chapter 5**);
- To conduct a systematic review on the outcome of single implant-supported two-unit cantilever restorations in the anterior and posterior maxilla and mandibula (**Chapter 6**);
- To conduct a 5-year prospective comparative pilot study of patients with a missing central and lateral upper incisor treated with either one single implant-supported two-unit cantilever restoration or two single implant-supported restorations in the aesthetic region (**Chapter 6**);
- To present an implant treatment proposal on how to replace two failing or missing teeth in the aesthetic region, and to present a case series study which implemented this implant treatment proposal in case of two failing or missing central upper incisors (**Chapter 7**).

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Figure 1a-1g: Immediate implant placement and provisionalization

Photographs by courtesy of drs. R.J. Goené and drs. A.C.L. van Daelen

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Figure 1a. Preoperative photograph of a failing tooth in region 11.

Figure 1b. Extraction of the failing tooth in region 11.

Figure 1c. Immediate placement of the implant into the extraction socket in region 11.

Figure 1d. Postoperative photograph of the implant in region 11.

Figure 1e. Postoperative photograph of the provisional implant restoration in region 11.

Figure 1f. Photograph of the final implant restoration in region 11.

Figure 1g. Photograph of the final implant restoration in region 11, 5 years in function.

Figure 2. Photograph of a black triangle visible between two single implant restorations (region 11 and 21).

Figure 3. Photograph of a single implant in region 11 with an implant-supported cantilever restoration (region 11 and 12).

CHAPTER

02

Immediate implant placement and provisionalization of single teeth in the aesthetic region: A 1-7 year retrospective study

This chapter is an edited version of the manuscript:
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Abstract

Purpose: To assess the outcome of immediate single-tooth implant placement and provisionalization in the aesthetic region regarding hard and soft peri-implant tissue parameters and patient-related outcome measures in a dental referral practice.

Materials and methods: All consecutively treated patients with single-tooth immediate implant placement and provisionalization between the period January 1st, 2006 and April 1st, 2013 in a dental referral practice in Amsterdam, the Netherlands, were included in the study. Fifty-one patients of a total of 64 could be examined at follow-up ($T_{\text{follow-up}}$). Standardized radiographs were present from implant placement ($T_{\text{placement}}$), after placement of the final implant restoration ($T_{\text{restoration}}$) and new ones were made at the follow-up appointment ($T_{\text{follow-up}}$). Next to this, soft-tissue parameters, patients' satisfaction and professionals' aesthetic scores were measured at $T_{\text{follow-up}}$.

Results: Implant survival was 96.9% after a mean follow-up period of 4 years following implant placement. At $T_{\text{restoration}}$, mean ($\pm$ SD) marginal bone loss was 0.25 ± 0.19 mm. Between $T_{\text{restoration}}$ and $T_{\text{follow-up}}$, an additional mean ($\pm$ SD) marginal bone loss of 0.06 ± 0.10 mm was found. Mean ($\pm$ SD) implant probing depths were 2.9 ± 0.8 mm at proximal sides and 2.0 ± 0.8 mm midbuccally at $T_{\text{follow-up}}$. Plaque, bleeding and gingiva-scores were low. Patients' satisfaction was rated very high: 9.0 (SD 0.7). Professionals' aesthetic score (PES-WES) was 16.49 (SD 1.86).

Conclusions: From this study can be concluded that immediate placement of implants into fresh extraction sites followed by immediate provisionalization resulted in a high survival rate, minimum peri-implant bone loss, good aesthetics and satisfied patients after a mean follow-up period of 4 years.

Introduction

Advances in dental implant technology, implant surgery techniques and the increasing focus on aesthetics have created a shift in treatment outcomes from implant survival to success in the aesthetic region.¹ Implant success, rather than survival, is dependent on the establishment and maintenance of healthy hard and soft peri-implant tissues, particularly in the aesthetic region.^{2,3} Therefore, the interest in hard and soft tissue dynamics related to immediate single tooth implant placement in the aesthetic region has gained increasing interest.^{4,5} Currently, there is a tendency towards placing implants in the aesthetic region immediately after extraction of a failing tooth, combined with immediate provisionalization.^{6,7} Immediate implant placement and immediate provisionalization have already been identified as a reliable techniques, permitting a reduction in overall treatment time while offering satisfying aesthetic results.^{8,9} Furthermore, a systematic review demonstrated that immediate implant placement with immediate provisionalization of dental implants in the aesthetic region resulted in an excellent short-term treatment outcome in terms of implant survival and marginal bone loss.¹⁰ However, it is unknown whether outcomes of longer follow-up periods are comparable to the results of 1-year studies. At present, only a few studies reporting on medium-term treatment outcomes are available.¹¹⁻¹³ Furthermore, these studies lack assessments of aesthetics by professionals and patients. The aim of the present retrospective study was to assess medium-term treatment outcome of flapless immediate single-tooth implant placement and provisionalization in the aesthetic region regarding hard and soft peri-implant tissues parameters and patient-related outcome measures in a dental referral practice.

Materials and methods

Study design

The design of current study is a retrospective analysis of all patients treated with immediately placed and provisionalized implants between the period January 1st, 2006 and April 1st, 2013 in a dental referral practice in Amsterdam, The Netherlands (Fig. 1a-c). Inclusion criteria for immediate placement and provisionalization were:

- Failing tooth is a incisor, cuspid or first bicuspid in the maxilla with adjacent natural teeth;
- Adequate oral hygiene;
- No significant soft tissue loss at failing tooth or adjacent teeth;
- Distance of the contact point to bone level at the neighbouring teeth ≤ 5 mm;
- Level of mid-buccal marginal bone located ≤ 3 mm apically at the zenith of the tooth to be extracted;
- Primary stability of implant achieved after implant placement;
- Follow-up period of at least 1 year after placement of the final implant restoration.

Surgical and prosthetic protocol

All patients were treated following the same treatment protocol by one surgeon (RJG) and one prosthodontist (ACLVD). One hour before implant surgery, patients started prophylactic antibiotic therapy (amoxicillin 3 grams or clindamycin 600 gram in case of amoxicillin allergy) and oral disinfection composed of a 0.12% chlorhexidine mouthwash, twice daily for 14 days.

All surgeries were performed under local anaesthesia. A flapless, minimal traumatic extraction technique was used in order to prevent damage to the surrounding bony architecture. First, the attached periodontal ligament of the failing tooth was carefully detached by an incision in the sulcus. Periotomes and mini elevators were used to extract the failing tooth. Afterwards, the remnants of the periodontal ligament were carefully removed with curettes. No mucoperiosteal flap was raised. After the failing tooth had been removed, the integrity of the facial bone wall was verified with a periodontal probe. If the labial bone plate was found to be intact, the osteotomy preparation was initiated. First, a pointed starter drill was used to create a notch approximately 4 mm away from the apex up to the palatal wall, thereby positioning the osteotomy slightly more palatal than the failing tooth. A twist drill was then placed in the notch, advancing closely to and parallel to the palatal wall. The osteotomy preparation was continued with Quad Shaping Drills (BIOMET 3i, Palm Beach Gardens FL, USA) followed by placement of a corresponding Depth/Direction Indicator to check the depth and horizontal positioning of the implant to be placed. With the depth/direction indicator in place, a mixture of autogenous bone (collected from the flutes of the Quad Shaping Drills) and a xenograft (Endobon® 0.5-1.0 mm granules, BIOMET 3i, Palm Beach Gardens FL, USA), was placed in the void space between de Depth/Direction Indicator and the labial bone plate. The depth/direction indicator was then carefully removed, and the implant (Osseotite®, BIOMET 3i, Palm Beach Gardens FL, USA) was placed in the newly created osteotomy with adequate primary stability (>35

N cm). The shoulder of the implant was placed at a depth of 3 mm apical to the midbuccal soft tissue level of the extracted tooth.

A platform-switched provisional cylinder (PreFormance Temporary Cylinder®, BIOMET 3i, Palm Beach Gardens FL, USA) was then inserted into the implant and secured with a titanium abutment screw. A customized provisional restoration, fabricated from a presurgical impression of the extracted tooth, was mounted on the cylinder out of occlusion, with no centric contact or lateral excursions. The buccal aspect of the provisional restoration was deliberately under contoured to avoid any apical displacement of the buccal soft tissue. After placement of the provisional restoration, a periapical radiograph was taken. At the two-week follow-up appointment soft tissue healing was assessed. At the 3 month follow-up appointment, the provisional restoration was modified, if necessary. After 6 months of uneventful osseointegration and soft-tissue healing the provisional restoration was duplicated by mounting it on a lab-analogue in a putty-index, then replaced by a sandblasted impression coping. Flowable composite was added to duplicate the exact tissue contour. This patient specific impression coping was mounted on the implant, and the seating was confirmed radiographically. The impression was then poured and a soft-tissue model that exactly replicates the mucosal contours was fabricated. Four weeks later the provisional restoration was removed and a customized platform switched Zirconia abutment (Atlantis®, DENTSPLY, Mannheim, Germany) was positioned on the implant. After a periapical radiograph was then taken to confirm proper seating, the abutment was tightened to 25 Ncm of torque. Next, the final implant restoration was cemented.

Outcome measures

Between the period January 1st, 2006 and April 1st, 2013 all consecutive patients (n=64) (Table 1) who received single-tooth immediate implant placement and immediate provisionalization in the aesthetic zone in a dental referral practice (Tendens Tandartsen, Amsterdam, The Netherlands) were selected for examination of their medical records. Two patients (n=2) lost their implant within 3 months after implant placement. Sixty-two patients were selected for clinical examination (n=62) and were invited by letter and telephone call to attend the clinic between October 2014 and August 2015 for a recall visit by one and the same observer (WGVN). Nine patients (n=9) were unable to attend due to travel distance to the dental referral practice and two patients (n=2) due to advanced age. Fifty-one patients (n=51) with final implant restorations ≥ 1 year in function agreed to participate in the study (for details see section "Results").

Survival rate

Survival rate was defined as the percentage functional implants at follow-up. The criteria for successful osseointegration according to Smith & Zarb¹⁴ were adopted. Patients not examined at T_{follow-up} were counted as having functional implants, unless their dental record revealed otherwise.

Radiographic assessments

To calculate changes in marginal bone level (MBL), a digital periapical radiograph was taken using a paralleling technique, immediately following placement of the implant and provisional restoration

(baseline, $T_{\text{placement}}$), after placement of the final implant restoration ($T_{\text{restoration}}$) and at follow-up during a routine examination between October 1st 2014 and July 1st 2015 ($T_{\text{follow-up}}$).

The periapical radiographs of $T_{\text{placement}}$, $T_{\text{restoration}}$ and $T_{\text{follow-up}}$ were analysed using the known implant diameter and length as a reference. The interface of the implant and the abutment was used as a reference line, from which all distances were measured. The following linear measurements were assessed to the nearest 0.01 mm: the vertical distance between the reference line and the first bone to implant level, measured at the mesial and distal implant side facing the neighbouring teeth. Measurements were performed twice by one examiner (WGVN), after which the average of both measurements was used.

Clinical assessments

The following clinical variables were assessed at $T_{\text{follow-up}}$:

- *Plaque*: assessed per implant using the modified plaque index;¹⁵
- *Bleeding*: assessed per implant using the modified sulcus bleeding index;¹⁵
- *Gingiva*: assessed per implant using the gingival Index;¹⁶
- *Implant probing depth / pocket probing depth*: assessed at three sites per implant/adjacent tooth (mesial, buccal, and distal) using a manual standardized pressure periodontal probe (Click-Probe®, Kerr, Bioggio, Switzerland) measuring to the nearest 1 mm.

All data were retrieved by one examiner (WGVN).

Aesthetic assessments

The aesthetic outcome was assessed on standardized digital photographs (Nikon 7000 twinflash and 105 mm Nikkor macrolens, Nikon Corporation) taken at $T_{\text{follow-up}}$. Peri-implant mucosa and implant restoration aesthetic outcomes were determined using the Pink Esthetic Score and White Esthetic Score index (PES-WES).¹⁷ The measurements were performed by one experienced prosthodontist (KS).

Patients' satisfaction

Patient satisfaction was measured using the questionnaire used by Meijndert et al.¹⁸ Patients examined at $T_{\text{follow-up}}$ received the questionnaire at home and were asked to fill in questions relating to overall score (numeric scale 0-10), colour of the implant restoration and mucosa and the shape of the implant restoration and mucosa (numeric scale 0-4).

Statistical analysis

All analyses were performed at implant/tooth level, except for patients' satisfaction. Descriptive statistics were applied to describe the means and standard deviations ($\pm$ SD) of variables used in current study.

Results

Patients

Patient and treatment characteristics of the study group are depicted in Table 1.

Survival rate

Two implants ($n=2$) were lost within 3 months following implant placement due to a failure of osseointegration. In both patients retreatment was successfully carried out with a two-stage implant technique: a provisional restoration was placed after a submerged healing phase of 3 months and the final implant restoration was placed 6 months following implant placement. Patients not examined at $T_{\text{follow-up}}$ were counted as still having functional implants, unless their dental record revealed otherwise. This resulted in a survival rate of 96.9% after a mean follow-up period of 4 years (range 1-7 years).

Change in marginal bone level

Table 2 shows the mean ($\pm$ SD) MBL changes at the proximal sides of the implant facing the adjacent teeth. An MBL change of -0.25 ± 0.19 mm was observed between $T_{\text{placement}}$ and $T_{\text{restoration}}$ (6 months). At $T_{\text{follow-up}}$, the total MBL change was -0.31 ± 0.20 mm after a mean period of 4 years (range 1-7 years). Between $T_{\text{restoration}}$ and $T_{\text{follow-up}}$, only a slight MBL change of -0.06 ± 0.11 mm was observed.

Clinical outcomes

Table 3 shows the mean ($\pm$ SD) implant probing depths of the implants and the mean pocket probing depths of their neighbouring teeth. Implant probing depths were 2.9 ± 0.8 mm on proximal sides and 2.0 ± 0.8 mm on the mid-buccal side. Pocket probing depths of the adjacent teeth were 2.5 ± 0.8 mm at the proximal side facing the adjacent implant, 1.6 ± 0.6 mm on the mid-buccal side and 2.3 ± 0.6 mm at the proximal side facing the adjacent tooth. Plaque, gingiva and bleeding scores were low.

Aesthetic assessments

The PES-WES scores are depicted in Table 4. Both PES and WES were high. The mean ($\pm$ SD) PES score was 7.35 ± 1.23 and the mean WES score was 9.14 ± 0.94 , resulting in a mean combined PES-WES score of 16.49 ± 1.86 .

Patients' satisfaction

Patient satisfaction at $T_{\text{follow-up}}$ was divided in an mean ($\pm$ SD) overall score of 9.0 ± 0.7 on a 0-10 numeric scale ($0 = \text{very dissatisfied}$, $10 = \text{very satisfied}$) and mean scores of 3.4 ± 0.8 and 3.2 ± 0.9 for the colour and shape of the peri-implant mucosa and mean scores of 3.5 ± 0.8 and 3.8 ± 0.5 for the colour and shape of the implant restoration on a 0-4 numeric scale ($0 = \text{very dissatisfied}$, $4 = \text{very satisfied}$).

Discussion

Current study reported a 96.9% survival rate of flapless immediately placed and provisionalized implants in the aesthetic region after a mean period of 4 years following implant placement. No comparable studies report on this technique in a dental referral practice with this implant system. Three medium-term studies with other implant systems were available for comparison.¹¹⁻¹³ A recent study reported a survival rate of 94.6% after a period of 5 years.¹³ The other studies reported survival rates of 95.8% after a mean period of 3.4 years¹¹ and 100% after a mean period of 4 years.¹²

Mean MBL change in present study was -0.25 ± 0.19 mm between implant placement and placement of the final implant restoration after a period of 6 months. After the final implant restoration was attached, only a minor MBL change of -0.06 ± 0.11 mm occurred. The total MBL change was -0.31 ± 0.20 mm after a mean period of 4 years. Two comparable studies reported higher total mean MBL changes of -0.9 ± 1.1 mm after a mean period of 3.4 years¹¹ and -0.72 ± 0.27 mm mesially and -0.63 ± 0.21 mm distally after a mean period of 4 years¹². A third comparable study reported a total mean MBL change of $+0.43 \pm 0.63$ mm after a period of 5 years.¹³ The higher MBL loss in two compared studies^{11,12} might partially be explained by the cementation of the provisional restorations in compared studies, whereas in current study the provisional restoration was screw-retained. Cementation of the provisional restoration increases the risk of MBL loss due to residual cement that can cause an inflammatory response of peri-implant tissues¹⁹. Furthermore, current study and the study which showed a gain in MBL¹⁴ both used platform-switched implants whereas other comparable studies did not.^{11,12} The difference in MBL change between current study and the study that presented a gain in MBL¹⁴ might be explained by a difference in determination of first implant to bone level after implant placement. This can be particularly difficult with immediately placed implants in fresh extraction sockets due to the socket grafting materials used to fill up the implant-gap.

Implant probing depths of the peri-implant soft tissue and pocket probing depths of the adjacent teeth were very low. This may partially be due to the excellent hygiene maintained by patients and periodical examinations of the patients by dental hygienists, mostly once or twice a year. No comparable studies reported on peri-implant probing depths.

PES-WES scores reported in current study were very high, mean PES was 7.35 ± 1.23 and mean WES was 9.14 ± 0.94 . Belser et al.¹⁷ described a mean PES of 7.8 ± 0.88 and a mean WES of 6.9 ± 1.47 after a follow up of 2-4 years after early single implant placement and Slagter et al.²⁰ described a mean PES of 7.5 ± 1.59 and a mean WES of 8.10 ± 0.90 1 year after immediate single implant placement and provisionalization. Specifically; WES scores in current study were higher than reported in earlier mentioned studies.^{17,20} This may be due to the fact that the final implant restoration was sometimes fabricated simultaneously with other crowns and veneers for neighbouring teeth, resulting in a more harmonious dental situation.

Immediate placement and provisionalization are known to be associated with high subjective satisfaction rates.²¹ This corresponds with patients' satisfaction perceived by the patients in current study. The overall high satisfaction score of 9.0 ± 0.7 on a 0-10 numeric scale can be partially explained by the immediate, chair-side, fabrication of the provisional restoration and the excellent

aesthetics of the final implant restoration. Overall, patients rated the colour and shape of the implant restorations higher than the colour and shape of the peri-implant mucosa. This corresponds with the objective PES-WES scores, whereas PES was rated lower, 7.35 ± 1.23 , than the WES of 9.14 ± 0.94 . Considering only three medium-term studies reporting on implant survival and marginal bone loss were available for comparison with present study, long-term prospective research reporting on hard and soft peri-implant tissues parameters and patient-related outcome measures is needed to confirm the findings in current study.

Conclusions

From this study can be concluded that placement of implants into fresh extraction sites followed by immediate provisionalization resulted in a high survival, minimum peri-implant bone loss, good aesthetics and satisfied patients after a mean follow-up period of 4 years.

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Conflict of interest

The authors have stated explicitly that there is no conflict of interest in connection to this article.

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Figure 1a. Preoperative photograph of tooth to be extracted (region 21).

Figure 1b. Postoperative photograph of provisional implant restoration (region 21).

Figure 1c. Photograph of the final implant restoration (region 21)

(photographs courtesy of drs. R.J. Goené and drs. A.C.L. van Daelen)

Table 1. Characteristics of the study group

	All consecutive patients	Patients examined at follow-up
Number of participants	64	51
Age (mean/ range)	50 / 23-92	48 / 23-75
Gender (male/female)	32 / 32	26 / 25
Tooth gap position (I ₁ / I ₂ / C / P ₁)	34 / 18 / 4 / 4	25 / 15 / 4 / 3

Table 2. Mean and standard deviation ($\pm$ SD) of the change in marginal bone level in mm.

Location		T _{place} * - T _{rest} **	T _{place} - T _{follow-up} ***	T _{rest} - T _{follow-up}
		Mean $\pm$ SD	Mean $\pm$ SD	Mean $\pm$ SD
Implants (n=51)	Marginal bone level facing the adjacent teeth	-0.25 $\pm$ 0.19	-0.31 $\pm$ 0.20	-0.06 $\pm$ 0.11

*T_{place}: after implant placement

**T_{rest}: after final implant restoration

***T_{follow-up}: at follow-up appointment

Table 3. Mean and standard deviation ($\pm$ SD) of implant probing depths and pocket probing depths (mm) measured around implants and adjacent teeth at proximal sides and mid-buccally at T_{follow-up}*.

Location		Mean $\pm$ SD	Location		Mean $\pm$ SD
Implants (n=51)	Proximal sides facing adjacent teeth (n=102)	2.9 $\pm$ 0.8	Adjacent teeth (n=102)	Proximal side facing adjacent tooth (n=102)	2.3 $\pm$ 0.6
	Mid-buccally (n=51)	2.0 $\pm$ 0.8		Mid-buccally (n=102)	1.6 $\pm$ 0.6
				Proximal side facing Implant (n=102)	2.5 $\pm$ 0.8

* T_{follow-up}: at follow-up appointment

Table 4. Pink Esthetic Score and White Esthetic Score at Tfollow-up*.

PES						
Items PES	Total score (0-10)	Mesial papilla	Distal papilla	Curvature of facial mucosa	Level of facial mucosa	Root convexity, Soft tissue colour & Texture
Mean	7.35	1.12	1.06	1.78	1.73	1.67
SD	1.23	0.48	0.54	0.42	0.45	0.52
Maximum**	10	2	2	2	2	2
Minimum***	5	0	0	1	1	0
WES						
Items WES	Total score (0-10)	Tooth form	Tooth volume & outline	Colour (hue/ value)	Surface Texture	Translucency/ Characterization
Mean	9.14	1.80	1.71	1.80	1.90	1.92
SD	0.94	0.40	0.46	0.40	0.30	0.27
Maximum**	10	2	2	2	2	2
Minimum***	6	1	1	1	1	1
PES-WES						
Mean	16.49					
SD	1.86					
Maximum**	20					
Minimum***	12					

* Tfollow-up: at follow-up appointment

** Maximum score reported

***Minimum score reported

CHAPTER 03

Immediate implant placement and provisionalization of single teeth in the aesthetic region, with or without a connective tissue graft: A 1-year randomized controlled trial and volumetric study

This chapter is an edited version of the manuscript:
van Nimwegen WG, Raghoobar GM, Zuiderveld EG, Jung RE, Meijer HJA, Mühlemann S.
Immediate placement and provisionalization of implants in the aesthetic zone with or without a
connective tissue graft: A 1-year randomized controlled trial and volumetric study.
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Abstract

Purpose: To volumetrically compare peri-implant mid-buccal mucosal changes in immediately placed and provisionalized implants in the aesthetic region, with or without a connective tissue graft.

Materials and methods: Sixty patients were included. All implants were placed immediately after extraction. After randomization, in one group a connective tissue graft (test group, n=30) was inserted at the buccal aspect of the implant. The other group (control group, n=30) received no connective tissue graft. Clinical parameters, digital photographs and conventional impressions were obtained before extraction (T_{pre}) and at 12 months following placement of the final implant restoration (T_{12}). The casts were digitized by a laboratory scanner and a volumetric analysis was performed between T_{pre} and T_{12} .

Results: Twenty-five patients in each group were available for analysis at T_{12} . The volumetric change, transformed to a mean ($\pm$ SD) change in thickness, was -0.68 ± 0.59 mm in the test group and -0.49 ± 0.54 mm in the control group ($p=0.189$). The mid-buccal mucosa level was significantly different between both groups ($p=0.014$), with a mean ($\pm$ SD) change of $+0.20 \pm 0.70$ mm in the test group and -0.48 ± 1.13 mm in the control group. The Pink Esthetic Scores were similar between both groups.

Conclusions: The use of a connective tissue graft in immediately placed and provisionalized implants in the aesthetic region did not result in less mucosal volume loss after 12 months, leading to the assumption that a connective tissue graft cannot fully compensate for the underlying buccal bone loss, although a significantly more coronally located mid-buccal mucosa level was found when a connective tissue graft was performed.

Introduction

Different clinical protocols exist to replace a failing tooth in the aesthetic region by implant therapy.¹ In implant treatment type 1, implants may be placed immediately after extraction of the failing tooth and be provisionalized within 24 hours. Apart from a reduced treatment time, immediate implant placement and provisionalization (IIPP) is considered a predictable treatment option in terms of survival.² However, recent systematic reviews have shown that immediate implant placement bears a significant risk for mid-buccal mucosal recession as a result of resorption of the buccal bone wall.^{3,4} Furthermore, clinical studies have shown that in 11% of low-risk IIPP cases advanced ($\geq 1\text{mm}$) mid-buccal mucosal recession is taking place.⁵ Moreover, this mucosal recession seems to continue for a long period, up to 5 years after implant placement.^{6,7}

In order to reduce mid-buccal mucosa recession and volume loss of peri-implant tissues, it has been proposed to use a connective tissue graft (CTG).⁸ The CTG can either be harvested from the palate or the tuberosity region and is placed submucosally at the buccal aspect of the implant. Two randomized clinical studies concluded that placement of a CTG leads to less vertical loss of the mid-buccal mucosa level after 1 year, resulting in more stable peri-implant mucosa levels.^{8,9} However, these studies show limitations regarding the small number of patients⁹ and possible selection bias.⁸ Other studies reporting on CTG's and immediately placed and provisionalized implants mostly consist of case series and have shown inconclusive results.¹⁰

Until recent, studies have focused mainly on stability of mid-buccal mucosa levels as a parameter for aesthetic success. However, the introduction of volumetric analysis¹¹ enables us to objectively and volumetrically compare larger areas of preoperative and postoperative peri-implant tissue levels. Therefore, the aim of this randomized controlled clinical trial was to volumetrically compare the outcome of immediately placed and provisionalized implants, with or without a connective tissue graft. It was hypothesized that the use of a connective tissue graft leads to more volumetrically stable peri-implant tissues.

Materials and methods

Study design

This randomized controlled clinical trial (RCT) included 60 patients who were enrolled and treated at the department of Oral and Maxillofacial Surgery of the University Medical Center Groningen, University of Groningen, Groningen, the Netherlands. The RCT was approved by the Medical Ethical Committee (NL43085.042.13), registered in a trial register (www.trialregister.nl: TC3815) and the CONSORT 2010 checklist was used as a guideline to report on the outcomes. All eligible patients were informed about the features of the study and granted their informed consent before enrolment. Patients were included between December 2012 and July 2015. Randomization was carried out by an independent research-assistant with a 1:1 allocation ratio using sealed envelopes, to be opened after implant placement, resulting in two study groups of immediately placed and provisionalized implants in the aesthetic region (first bicuspid to first bicuspid in the maxilla) with:

- a connective tissue graft (CTG) harvested from the tuberosity region (test group).
- no soft tissue graft (control group);

Patients

All referred patients with a failing tooth in the aesthetic region were considered for inclusion. The fulfilment of the inclusion criteria was verified by clinicians at the screening session, including:

- ≥ 18 years of age;
- the failing tooth is an incisor, canine or first bicuspid in the maxilla;
- the failing tooth has adjacent and opposing natural teeth;
- adequate oral hygiene and absence of active and uncontrolled periodontal disease;
- sufficient mesial-distal and interocclusal space for placement of the implant and final implant restoration;
- sufficient interocclusal space to design a non-occluding provisional restoration;
- an intact buccal bone wall is present on the preoperative CBCT.

Exclusion criteria were:

- medical and general contraindications for the surgical procedure, expressed by ASA score $\geq$ III;¹²
- presence of periodontal disease, expressed by pocket probing depths of ≥ 4 mm and bleeding on probing (modified sulcus bleeding index score ≥ 2);
- smoking;
- earlier treatment with radiotherapy to the head and neck region;
- pregnancy;
- A post-extraction bony defect and a distance, measured in a vertical direction from the bony defect of the buccal bone wall to the mucosa at the cement-enamel junction of the adjacent teeth, that exceeded 5 mm (example given: 3 mm bony defect and 2mm mucosa). This distance was assessed with a periodontal probe (Williams Color-Coded Probe, Hu-Friedy, Chicago, Illinois, USA) to the nearest millimeter.

Surgical and prosthetic protocol

All implants were placed under a prophylactic antibiotic regime, starting one day prior to surgery (amoxicillin 500 mg, 3 times daily for 7 days or clindamycin 300 mg, 4 times daily for 7 days in case of amoxicillin allergy). Furthermore, patients used a 0.2% chlorhexidine mouthwash (2 times daily for 7 days) for oral disinfection. All surgical procedures were performed by one experienced oral and maxillofacial surgeon (G.R.). First, a sulcular incision was made to separate the attached periodontal ligament from the failing tooth. Next, periostomes were used to atraumatically extract the tooth without raising a mucoperiosteal flap. After extraction, the implant bed was prepared on the palatal side of the extraction socket according to the manufacturer's instructions. Then, an implant drill was placed in the implant preparation to serve as a space maintainer. The gap between the implant drill and the buccal bone wall was filled using a 1:1 mixture of autogenous bone, harvested from the flutes of the implant drill, and anorganic bovine bone (Geistlich Bio-Oss®, Geistlich Pharma AG, Wolhusen, Switzerland). Afterwards, the implant (NobelActive, Nobel Biocare AG, Gothenburg, Sweden), was placed 3 mm apical of the cement-enamel junction of the adjacent teeth. Primary implant stability was achieved by final insertion torque ≥ 45 Ncm. An implant-level impression was taken for the fabrication of a screw-retained provisional restoration. In the test group, a CTG was harvested from the tuberosity region and placed submucosally on the buccal bone wall through an envelope technique. In both groups, a provisional restoration free of occlusal and eccentric contacts was placed during the same day. After 3 months, a final implant restoration was fabricated. In case the screw access hole was located palatally, a screw-retained implant restoration was fabricated by means of a veneered zirconia abutment (NobelProcera, NobelBiocare AB). If the location of the screw access hole did not allow a screw-retained implant restoration, a customized zirconia abutment (NobelProcera, NobelBiocare AB) was fabricated and a veneered zirconia restoration (NobelProcera, NobelBiocare AB) was cemented (Fuij Plus Cement, GC Europa, Leuven, Belgium). All prosthetic procedures were executed by two experienced prosthodontists and all provisional and final implant restorations were fabricated by one experienced dental technician.

Outcome measures

The primary outcome measure of this study was volumetric change, transformed to a mean linear change in thickness (mm), from baseline (T_{pre}) to 12 months after placement of the final implant restoration (T_{12}). Secondary outcome measures were gingival biotype, plaque scores, bleeding scores, mucosal inflammation, mid-buccal mucosa level, Pink Esthetic Scores (PES) and patient satisfaction. All clinical measurements were performed by one examiner (E.Z.). The photographic assessments and aesthetic assessment of soft tissues were performed by two calibrated examiners (E.Z. and L.d.H.). The volumetric measurements and analysis were done by one examiner (W.v.N.). A software calibration session was conducted before the volumetric analysis to ensure reproducibility.

Volumetric measurements

Hydrocolloid impressions (Cavex, Cavex Holland BV, Haarlem, The Netherlands) were taken at T_{pre} and T_{12} . Thereafter, the impressions were poured in dental stone type IV (Sherahard-rock, Shera

Werkstoff-Technologie, Lemförde, Germany) and the stone casts were optically scanned with a laboratory optical scanner (IScan D301i, Imetric, Courgenay, Switzerland) resulting in digital STL files (Standard Tessellation Language). For each patient the digital surface models representing the two study time points were imported into the volume analysis software (Swissmeda/SMOP, Zürich, Switzerland). The best-fit algorithm was used to help superimpose the digital surface models based on unchanged neighbouring tooth surfaces as reference. Thereafter, the study-relevant area of interest was defined with anatomical reference structures using the border of the mesial and distal papilla adjacent to the implant restoration, the apically located mucogingival line and the coronally located margin of the implant restoration (Fig 1). The area of interest located at the margin of the implant restoration was shifted 1-2 mm more apically in all patients to avoid an invalid superimposition as a result of mid-buccal mucosa recession. As a result, the area of interest was of variable size (mm²) between patients.^{13,14}

After the area of interest was defined, the volumetric analysis software (Swissmeda/SMOP) calculated a mean dimensional change (mm³) for each patient. In order to allow for a direct comparison between patients and study groups, the mean dimensional change per area was transformed to a mean linear change in thickness in mm.^{13,14} After the volumetric analysis was completed, the volumetric analysis was run again for 10 randomly selected patients by an independent examiner (S.M.) to calculate inter-operator reliability (Intraclass Correlation Coefficient).

Photographic assessment of mid-buccal gingiva level

Standardized digital photos¹⁵ (Canon EOS 650 with ring flash, Canon Inc., Ota, Tokyo, Japan) were taken at T_{pre} and T₁₂. A periodontal probe (Williams Color-Coded probe) was used for calibration of the photographs. The change in mid-buccal mucosa level was measured by a full screen-analysis using Adobe Photoshop (Adobe Photoshop CS5.1, Adobe Systems Inc., San Jose, USA).

Clinical assessments

The following clinical parameters were assessed:

- gingival biotype at T_{pre}, measured at the mid-buccal aspect of the marginal gingiva of the failing tooth, using a periodontal probe¹⁶ (Williams Color-Coded Probe);
- implant probing depth at T₁₂, measured to the nearest 1 mm using a periodontal probe (Williams Color-Coded Probe) at the mid-buccal aspect of the implant;
- plaque scores at T₁₂, using the modified plaque index;¹⁷
- bleeding scores at T₁₂, using the modified sulcus bleeding index;¹⁷
- mucosal inflammation at T₁₂, using the gingival-index.¹⁸

Aesthetic assessment of mid-buccal soft tissues

Standardized digital photographs¹⁵ (Canon EOS 650 with ring flash) of the aesthetic region were taken at T₁₂ to assess the PES as described by Fürhauser et al.¹⁹ The PES consists of 7 topics regarding mesial papilla fill (0-2 points), distal papilla fill (0-2 points), level of gingival margin (0-2 points), contour (0-2 points), alveolar process (0-2 points), colour (0-2 points) and texture (0-2 points),

resulting in a total score (0-14 points) with 0 = lowest score and 14 = highest score.

Patient satisfaction

Assessment of patient satisfaction was performed at T_{12} with a self-administered patient questionnaire regarding overall satisfaction and satisfaction of colour and shape of the mucosa using a Visual Analogue Scale (VAS, left = very dissatisfied (0), right = very satisfied (10)).

Statistical analysis

An a priori analysis was performed to determine the minimum sample size for both study groups (G*power version 3.1).²⁰ A mean linear change in thickness of 0.5 mm from T_{pre} to T_{12} was considered as a clinically relevant difference between both groups with an expected average standard deviation of 0.56 mm as derived from literature.¹⁴ A two-sided test with an α error probability of 5% and a power of 80% was then carried out, resulting in a sample size of 21 patients per study group. To deal with withdrawal of patients, the number of patients per study group was set at 30.

An assessment of continuous variables was carried out using the Shapiro-Wilk test and normal Q-Q-plots. Differences in means between groups were calculated using the independent t-test or the Mann-Whitney test. Categorical variables were analysed using the Chi-Square test or Fisher's exact test. For within-group statistical comparison, the Wilcoxon test was used. The inter-observer reliability of the volumetric measurements was calculated using the Intraclass Correlation Coefficient (ICC, two-way mixed, single measures). All analyses were carried out with SPSS using a p-value of 0.05 to determine statistical significance (SPSS Statistics 23.0, SPSS Inc.; IBM Corporation, Chicago, Illinois, USA).

Results

Patients

This study included a total of 60 patients, consisting of 30 patients in a test group and 30 in a control group. Details regarding patient characteristics at baseline are shown in Table 1. The allocation process and follow-up is shown in Figure 2. All included patients received their assigned treatment. One implant was lost in both groups due to early failure of osseointegration, resulting in a 1-year implant survival rate of 96.7%. In both groups, four patients were excluded from final analysis due to irregularities in the stone casts, taken at T_{pre} and/or T_{12} .

Volumetric measurements

The mean ($\pm$ SD) area of measurements for the evaluation of volume changes between T_{pre} and T_{12} was $11.97 \pm 4.43 \text{ mm}^2$ in the test group and $13.45 \pm 3.56 \text{ mm}^2$ for the control group, respectively. The

mean volumetric changes in this time period were $9.32 \pm 7.19 \text{ mm}^3$ in the test group and $7.77 \pm 7.26 \text{ mm}^3$ in the control group. To allow for comparison between groups, the volumetric changes were transformed to mean linear measurements in mm. The resulting change in thickness between T_{pre} and T_{12} is shown in Table 2. Both groups displayed a loss of volume at T_{12} , being $-0.68 \pm 0.59 \text{ mm}$ in the test group and $-0.49 \pm 0.54 \text{ mm}$ in the control group. Although the test group displayed slightly more mucosal volume loss with a mean (SE) difference of 0.19 (0.16) mm, no statistical significance was found ($p=0.24$). The inter-operator reliability (ICC), measured for 10 randomly selected patients, was 0.821 ($p=0.001$).

Photographic measurements

The change in mid-buccal mucosa level is shown in Table 3. A mean ($\pm$ SD) change of $+0.20 \pm 0.70 \text{ mm}$ in the test group and $-0.48 \pm 1.13 \text{ mm}$ in the control group were reported between T_{pre} - T_{12} . The change in mid-buccal mucosa levels was significantly different between both groups with a mean (SE) difference of 0.68 (0.27) mm ($p=0.014$). In addition, only 2 out of 25 patients (8%) displayed advanced cases of mid-buccal mucosa recession ($\geq 1 \text{ mm}$) in the test group against 8 out of 25 patients (32%) in the control group.

Clinical measurements

The implant probing depth at T_{12} is shown in Table 4. Both groups displayed probing depths of $\leq 3 \text{ mm}$ with a mean (SE) difference of 0.16 (0.29) mm between both groups ($p=0.813$). Plaque scores at T_{12} were very low (98%: no plaque). Bleeding on probing scores showed no peri-implant bleeding in 50% of all patients, peri-implant isolated bleeding spots in 38% of all patients and confluent lines of bleeding in 12% of all patients. A gingival index score of 0 was found in 96% of all patients at T_{12} . No significant differences in plaque scores, bleeding scores and gingival index scores were found between groups at T_{12} .

Aesthetic measurements

The Pink Esthetic Scores at T_{12} are displayed in Table 5. The aesthetics of the gingival margin level were rated significantly higher in the test group than the control group ($p=0.034$), although the texture of the peri-implant soft-tissues was scored significantly lower in the test group ($p=0.039$). No significant difference was found in total score between both groups.

Patient satisfaction

Patient satisfaction at T_{12} regarding an overall score and soft tissue aesthetics are displayed in Table 6. Total satisfaction showed a mean ($\pm$ SD) score of 8.38 ± 2.28 in the test group (range 0.8-10) and 8.84 ± 1.23 in the control group (range 5-10) with a mean (SE) non-significant difference of 0.46 (0.52) between both groups ($p=0.861$). Patient satisfaction regarding colour and shape of peri-implant mucosa showed comparable scores with no significant differences between test and control group ($p=0.711$ and $p=0.892$), respectively.

Discussion

The aim of this RCT was to volumetrically compare the outcome of immediately placed and provisionalized implants in the aesthetic region, with or without a connective tissue graft. It was hypothesized that the use of a CTG graft leads to more stable peri-implant mucosal soft tissues. Volume measurements at T_{12} showed non-significant differences between both groups, with the test group displaying the most mucosal volume loss. In contrast, mid-buccal mucosa levels were significantly more stable in the test group than the control group between T_{pre} and T_{12} . These findings reject the hypothesis that the use of a CTG leads to less mucosal volume loss, although mid-buccal mucosa levels seem more stable after 1 year follow-up when a CTG was applied.

Physiological bone resorption of the buccal bone wall, after extraction and immediate implant placement, has to be considered as an important factor to the volume loss in both groups.²¹ Also, it is unknown whether shrinkage or thickening of the CTG in the present study had any influence on the mucosal volume loss. De Bruyckere et al.²² reported that mucosal thickness, measured with an ultrasound device, increased after 12 months follow-up when a CTG was placed 3 months after implant placement. This might imply that a CTG remains stable after placement and that the mucosal volume loss is mostly related to underlying buccal bone loss. This leads to the assumption that the use of a CTG cannot fully compensate for alterations of the buccal bone wall following immediate implant placement and provisionalization.

In recent years, post extraction buccal bone wall thickness has been recognized as a risk factor to buccal bone loss and a risk factor to soft-tissue alterations. The study of Chappuis et al.²¹ showed that in case of a post-extraction thin wall phenotype (less than 1mm), significantly higher bone alterations were found. Additionally, clinical studies have shown that the anterior maxilla is dominated by thin wall biotypes.²³⁻²⁵ Due to the fact that the present study was designed and commenced before these studies, post extraction thickness of the facial bone wall has not been incorporated as a risk factor. Therefore, further research with Cone Beam Computed Tomography (CBCT) data is needed to determine the exact role of buccal bone alterations in relation to the use of a CTG and mucosal volume loss.

Mid-buccal mucosa levels displayed a significant difference between both groups between T_{pre} - $T_{12'}$ with a small mean gain in the test group and a loss in the control group. Furthermore, only 2 out of 25 patients (8%) displayed advanced cases of recession (≥ 1 mm) in the test group against 8 out of 25 patients (32%) in the control group. This confirms the findings of two RCT's which found significantly more stable mid-buccal mucosa levels when a CTG was applied, although a small recession of the mid-buccal mucosa was still reported in these studies when a CTG was applied.^{8,9}

The aesthetic assessment with PES showed significantly higher scores in the test group regarding the marginal gingiva level, as a result of the applied CTG. In contrast, the texture of the peri-implant soft tissues was scored significantly lower in the test group. A possible explanation is that the surgical envelope technique used to place the CTG resulted in more mucosal deformation and scarring of the peri-implant soft tissues. Regarding the total PES score, no significant differences were found in between both groups. This contradicts the findings of Migliorati et al.⁸, who found significantly better

PES scores when a CTG was applied.

In addition to the aesthetic outcome, patient satisfaction showed high overall scores, regardless of study group and topic. These findings are comparable to other studies describing immediately placed and provisionalized implants in the aesthetic region.^{26,27}

In summary, a higher mucosal volume loss, a similar PES and significantly more coronally placed mid-buccal mucosa level was found in the test group. These findings lead to the statement that a CTG should only be considered concomitant with immediate implant placement in order to prevent asymmetry in mid-buccal mucosa levels between the peri-implant mucosa and the gingiva contour of the neighbouring teeth.

Conclusion

The use of a CTG in immediately placed and provisionalized implants in the aesthetic region does not result in less mucosal volume loss after 12 months. A significantly more coronally located mid-buccal mucosa level is detected when a CTG was performed. Further research with CBCT data is needed to explore the role of buccal bone loss in relation to mucosal volume loss.

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Conflict of interest

The authors have stated explicitly that there is no conflict of interest in connection to this article.

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Figure 1. The stereolithographic (STL) files from baseline (yellow) and 1-year follow-up (green) were superimposed and the region of interest was determined (black box).

Figure 2. CONSORT flow diagram

Table 1. Patient characteristics at baseline (T_{pre})

	Test group	Control group
Male/female ratio	13/17	15/15
Age in years – mean $\pm$ SD (range)	45.5 $\pm$ 15.5 (19.5 – 67.8)	47.8 $\pm$ 16.5 (20.9 – 82.2)
Gingival biotype thin/thick	20/10	15/15
Implant site location I ₁ / I ₂ / C / P ₁	16 / 9 / 3 / 2	12 / 10 / 7 / 1

Table 2. Change in mucosal thickness in mm between baseline (T_{pre}) and 1 year after placement of the final implant restoration (T_{12}).

	Test group n=25	Control group n=25	p-value
Mean $\pm$ SD / Median	-0.68 $\pm$ 0.59 / -0.56	-0.49 $\pm$ 0.54 / -0.27	0.24

Table 3. Change in mid-buccal mucosa levels in mm between baseline (T_{pre}) and 1 year after placement of the final implant restoration (T_{12}).

	Test group n=25	Control group n=25	p-value
Mean $\pm$ SD / Median	+0.20 $\pm$ 0.70 / +0.24	-0.48 $\pm$ 1.13 / -0.55	0.014

Table 4. Implant probing depths in mm, 1 year after placement of the final implant restoration (T_{12}).

	Test group n=25	Control group n=25	p-value
Mid-buccal Implant probing depth			
Mean $\pm$ SD	2.28 $\pm$ 0.79	2.44 $\pm$ 1.19	0.813

Table 5. Pink Esthetic Scores at T_{12}

Topics PES	Test group <i>Mean$\pm$SD (95% CI)</i>	Control group <i>Mean$\pm$SD (95% CI)</i>	p-value
Mesial papilla	1.48 $\pm$ 0.51 (1.27-1.69)	1.44 $\pm$ 0.51 (1.23-1.65)	0.779
Distal papilla	1.48 $\pm$ 0.65 (1.21-1.75)	1.68 $\pm$ 0.48 (1.48-1.88)	0.299
Level gingiva margin	1.80 $\pm$ 0.50 (1.59-2.01)	1.44 $\pm$ 0.71 (1.15-1.73)	0.034
Contour	1.40 $\pm$ 0.71 (1.11-1.69)	1.60 $\pm$ 0.58 (1.36-1.84)	0.318
Alveolar process	1.48 $\pm$ 0.65 (1.21-1.75)	1.24 $\pm$ 0.72 (0.94-1.54)	0.223
Colour	1.84 $\pm$ 0.37 (1.69-1.99)	1.96 $\pm$ 0.20 (1.88-2.04)	0.162
Texture	1.80 $\pm$ 0.50 (1.59-2.01)	2.00 $\pm$ 0.00	0.039
Total score	11.28 $\pm$ 1.67 (10.59-11.97)	11.36 $\pm$ 1.65 (10.68-12.04)	0.866

T_{12} : 1 year after placement of the final implant restoration

Table 6. Patient satisfaction regarding overall score and soft tissue aesthetics at T₁₂

Topics	Test group	Control group	p-value
	<i>Mean±SD (95% CI)</i>	<i>Mean±SD (95% CI)</i>	
Soft tissue aesthetics			
Colour of the peri-implant mucosa	8.37±2.20 (7.46-9.27)	8.70±1.76 (7.98-9.43)	0.711
Shape of the peri-implant mucosa	8.27±2.25 (7.34-9.20)	8.18±2.38 (7.20-9.17)	0.892
Overall satisfaction			
Total score	8.38±2.28 (7.44-9.32)	8.84±1.23 (8.33-9.34)	0.861

T₁₂: 1 year after placement of the final implant restoration

CHAPTER 04

Immediate implant placement and provisionalization of single teeth in the aesthetic region, with or without a connective tissue graft: A 1-year CBCT study and volumetric sub-analysis

This chapter is an edited version of the manuscripts:

van Nimwegen WG, Raghoobar GM, Zuiderveld EG, Jung RE, Meijer HJA, Mühlemann S.
Immediate placement and provisionalization of implants in the aesthetic zone with or without a
connective tissue graft: A 1-year randomized controlled trial and volumetric study.
Clin Oral Implants Res 2018; 29:671-678. doi: 10.1111/clr.13258

and

Zuiderveld EG, van Nimwegen WG, Meijer HJA, Jung RE, Mühlemann S, Vissink A, Raghoobar GM.
Effect of connective tissue grafting on the change of buccal bone thickness in single immediate
implants in the aesthetic zone. (submitted)

Abstract

Background: Connective tissue grafts (CTG's) are placed in combination with implants in an attempt to preserve peri-implant soft tissue levels.

Purpose: To assess the effect of a CTG on change in mid-buccal mucosal volume (MBMV) and buccal bone thickness (BBT) of single immediate implants in the aesthetic region.

Materials and methods: The study design consisted of a sub-analysis of a randomized controlled trial with 60 patients, who received an immediately placed implant and non-occluding provisional restoration, either combined with a CTG (test group, n=30) or without a CTG (control group, n=30). Conventional alginate impressions were obtained before removal of the tooth (T_{pre}) and at 12 months following placement of the final implant restoration (T_{12}). The casts were digitized by a laboratory scanner and a volumetric analysis was performed between T_{pre} and T_{12} . Additionally, cone beam computer tomographic (CBCT) images were taken before removal of the tooth (T_{pre}) and twelve months (T_{12}) after placement of the final implant restoration and change in BBT was analysed

Results: Twenty-five patients in the test group (n=25) and twenty-four patients in the control group (n=24) were available for analysis at T_{12} . Between T_{pre} - T_{12} , mean ($\pm$ SD) change in MBMV was -0.68 ± 0.59 mm in the test group and -0.49 ± 0.55 mm in the control group ($p=0.25$). The mean change in BBT between T_{pre} - T_{12} was -0.81 ± 0.66 mm in the test group and -0.47 ± 0.55 mm in the control group ($p=0.05$).

Conclusion: These findings suggest that a CTG cannot fully compensate for the volume loss caused by underlying resorption of the buccal bone wall.

Introduction

Single-tooth replacement by immediate implant placement and provisionalization (IIPP) in the aesthetic region has evolved into a viable treatment option with aesthetically acceptable results.¹⁻³ Recession of the mid-buccal mucosa still commonly occurs, however.^{4,5} This recession is most likely a result of the bone remodeling following tooth extraction, which cannot be prevented by immediate implant placement.⁶⁻⁸ It is presumed that recession of the mid-buccal mucosa may lead to a less favourable aesthetic outcome.

To reduce the effects of bone resorption after tooth extraction, it is recommended that an implant should be positioned at least two millimeters palatal from the internal buccal socket wall and that the implant-socket gap should be grafted. The grafting procedure helps to create additional amounts of peri-implant hard tissue⁹ and is presumed to have a beneficial effect on the peri-implant soft tissues.^{6,10,11} In addition to grafting of the implant-socket gap, it has been proposed to thicken the peri-implant soft tissues with a connective tissue graft combined with implant placement in order to reduce recession and volume loss of the mid-buccal mucosa.^{12,13} Two randomized clinical trials observed less recession of the mid-buccal mucosa in immediate implant cases when combined with connective tissue grafting.^{14,15} Additionally, Migliorati et al.¹⁴ observed an increase in mucosal thickness when a connective tissue graft was applied.

Changes in mucosal volume of large areas of peri-implant soft tissues can be objectively measured using the volumetric analysis of Windisch et al.¹⁶ This analysis allows us to objectively measure the change in mid-buccal mucosal volume (MBMV) after implant placement either combined or not with a connective tissue graft. It has to be mentioned, however that this analysis does not provide accurate information on the changes of the underlying buccal bone thickness (BBT). BBT is proposed as a key factor that determines the overlying soft-tissue contour.⁶ Therefore, changes in BBT can be considered an important outcome measure to aesthetic success. Slagter et al.¹⁷ concluded that changes in BBT can be measured in a reliable and reproducible way on cone beam computer tomographic (CBCT) images. Therefore, for the purpose of this study, we used both the volumetric analysis according to Windisch et al.¹⁶ and the CBCT analysis according to Slagter et al.¹⁷

As far as we know, no literature is available on assessing the effect of connective tissue grafting on MBMV and BBT in the aesthetic region when combined with immediate placed and provisionalized implants. Therefore, the aim of this sub-analysis of our randomized controlled trial evaluating the effect of connective tissue grafting on peri-implant soft tissues¹⁸ was to assess the effect of connective tissue grafting on the change in MBMV and change in BBT of single immediate implants in the aesthetic region.

Materials and methods

Study design

Sixty patients were included in a RCT assessing the effect of connective tissue grafting on peri-implant soft and hard tissues.¹⁸ In a separate analysis by van Nimwegen et al.¹⁹, mucosal volume changes were assessed. The RCT was approved by a Medical Ethical Committee (NL43085.042.13) and registered in a trial register (www.trialregister.nl: TC3815). Written informed consent was obtained before enrollment of patients. All patients (aged ≥ 18 years) with a single failing tooth in the maxillofacial aesthetic zone (14-24) received an immediately installed implant-supported restoration. After immediate implant placement, patients were randomly allocated to one of the two study groups by sealed envelopes, carried out by an independent research-assistant, either receiving a connective tissue graft harvested from the tuberosity region or no graft at implant placement. The present study consists of a sub-analysis of the data presented by van Nimwegen et al.¹⁹, combined with data of CBCT scans taken before implant placement (T_{pre}), one month (T_1) and one year after placement of the final implant restoration (T_{12}).

Patients

The following inclusion criteria were used:

- ≥ 18 years of age;
- the failing tooth is an incisor, canine or first bicuspid in the maxilla;
- the failing tooth has adjacent and opposing natural teeth;
- adequate oral hygiene and absence of active and uncontrolled periodontal disease;
- sufficient mesial-distal and interocclusal space for placement of the implant and final implant restoration;
- sufficient interocclusal space to design a non-occluding provisional restoration;
- an intact buccal bone wall is present on the preoperative CBCT.

Exclusion criteria were:

- medical and general contraindications for the surgical procedure, expressed by ASA score $\geq III$;²⁰
- presence of periodontal disease, expressed by pocket probing depths of ≥ 4 mm and bleeding on probing (modified sulcus bleeding index score ≥ 2);
- smoking;
- earlier treatment with radiotherapy to the head and neck region;
- pregnancy;
- A post-extraction bony defect and a distance, measured in a vertical direction from the bony defect of the buccal bone wall to the mucosa at the cement-enamel junction of the adjacent teeth, that exceeded 5 mm (example given: 3 mm bony defect and 2 mm mucosa). This distance was assessed with a periodontal probe (Williams Color-Coded Probe, Hu-Friedy, Chicago, Illinois, USA) to the nearest millimeter.

Surgical and prosthetic protocol

One day prior to surgery, patients started taking antibiotics (amoxicillin 500 mg, 3 times daily for 7 days or clindamycin 300 mg, 4 times daily for 7 days in case of amoxicillin allergy) and using a 0.2% chlorhexidine mouthwash (2 times daily for 7 days). After administration of local anaesthesia, the failing tooth was removed without raising a flap. Next, the implant site was prepared on the palatal side of the extraction socket according to the manufacturer's manual with the aid of a surgical template representing the ideal position of the prospective implant crown. Augmentation of the buccal implant-socket gap was carried out with a 1:1 mixture of autogenous bone, harvested from the maxillary tuberosity region or bone chips collected from the implant drills, and anorganic bovine bone (Geistlich Bio-Oss®, Geistlich Pharma AG, Wolhusen, Switzerland). Following, the implant (NobelActive, Nobel Biocare AB, Gothenburg, Sweden) was inserted 3mm apical of the most apical part of the prospective implant crown margin and primary stability was achieved with an insertion torque of ≥ 45 Ncm. The horizontal distance between buccal socket wall and the outer implant contour was at least 2 mm. Afterwards, an implant-level impression was taken for the fabrication of a non-occluding screw-retained provisional restoration and a healing abutment was placed. In the test group, a connective tissue graft was harvested from the maxillary tuberosity region. The graft was placed in a suprapariosteal envelope flap prepared at the buccal aspect and secured with vertical and horizontal mattresses (4-0 vicryl, Johnson&Johnson Gateway, Piscataway, USA). The wounds in both groups were closed with Ethilon 5-0 nylon sutures (Johnson&Johnson). The same day as implant placement, the screw-retained provisional restoration was placed with a torque of 20Ncm.

After three months, a final implant-level open tray impression was taken for fabrication of the final implant restoration with an individualized zirconia abutment (NobelProcera, Nobel Biocare AB). The abutment screw was torqued with 35Ncm. Depending on the location of the screw access hole, the final implant restoration was either screw-retained or cement-retained. All prosthetic procedures were accomplished by two experienced prosthodontists (H.J.A.M. and C.S.), and all implant restorations were fabricated by one dental technician (M.v.d.V.).

Outcome measures

Change in MBMV (transformed to a mean linear change in thickness in mm) and change in BBT (mm) were assessed between preoperative assessment before extraction of the failing tooth (T_{pre}) and 12 months after placement of the final implant restoration (T_{12}).

Volumetric measurements

Full-arch alginate impressions (Cavex, Cavex Holland BV, Haarlem, The Netherlands) were taken at T_{pre} and T_{12} . Afterwards, the impressions were poured in dental stone type IV (Sherahard-rock, Shera Werkstoff-Technologie, Lemförde, Germany) and the gypsum casts were optically scanned with a laboratory optical scanner (IScan D301i, Imetric, Courgenay, Switzerland) resulting in digital STL files (Standard Tessellation Language). For each patient the digital surface models representing T_{pre} and T_{12} were imported into the volume analysis software (Swissmeda/SMOP, Zürich, Switzerland). A

best-fit algorithm was then used to superimpose the digital surface models based on unchanged neighbouring tooth surfaces as reference. The study-relevant area of interest for the volumetric measurements was defined as described in previous volumetric studies.^{21,22} The mesial and distal papilla, the mucogingival line, and the margin of the implant restoration served as anatomical reference structures to define the area of interest. If necessary, the coronal area of interest was shifted 1-2mm more apical to avoid non-readable measurements because of an invalid superimposition. As a result, the area of interest was of variable size between patients. In order to allow for a direct comparison in volumetric changes between patients, the mean dimensional change per area was calculated and transformed to a mean linear buccal distance in mm.²²

Measurement of buccal bone thickness

Change in BBT from T_{pre} to T_{12} was measured on CBCT scans (iCAT 3D exam scanner, KaVo Dental GmbH, Biberach, Germany) taken at T_{pre} , T_1 and T_{12} using NobelClinician (version 2.1, Nobel Biocare-Guided Surgery Center, Mechelen, Belgium). The CBCT scanner was validated for measuring bone thickness²³ with a method error of 0.05mm (95CI 0.03-0.07). A standard voxel size of 0.30 and a FoV of 100x100mm were used for all CBCTs. A new measuring method was used to measure changes in BBT.¹⁷

First, the CBCT Digital Imaging and Communications in Medicine (DICOM) files of T_1 and T_{12} were imported into a medical image computing program (Maxilim, version 2.3, Medicim, Sint-Niklaas, Belgium). The exact position of the implant was then determined with Multimodality Image Registration using Information Theory (MIRIT; Fig. 2a-d)²⁴ and a Maxilim file with the exact coordinates of the implant in this particular patient was created. Then, these coordinates were used to align a planning implant on the exact same position with planning software (NobelClinician, NobelBiocare AB). Next, measurements of the buccal bone (in mm) could be done. The area of interest was the upper 5mm section of the implant starting at the implant neck towards apical (location M_0 - M_5 , Fig. 3). For each location, the distance of the buccal bone outline to the center of the implant was measured. The radius of the interior contour of the implant, as provided by the manufacturer for each location, was then subtracted from this measurement to determine the distance of the outline of the implant to the buccal bone outline. This measuring method prevented measurements at the interface between implant and bone, which are disturbed by scattering.

For buccal bone measurements in CBCT images taken at T_{pre} , DICOM files of T_1 and T_{pre} were both imported into Maxilim and aligned (Fig. 4a). Next, the Maxilim file with the exact coordinates of the implant in the CBCT image taken at T_1 was inserted in a new DICOM file consisting of the combined DICOM files of T_{pre} and T_1 to place a planning implant according to the coordinates (Fig. 4b). Now, buccal bone measurements could be done on the prospective implant position in the T_{pre} CBCT image.

All measurements were done (with time interval to prevent recollection) by three independent operators (H.J.A.M., G.C.B. and E.G.Z.) in a random order.

Assessment of gingival biotype

The gingival biotype (thin/thick) was assessed at T_{pre} by means of transparency of a periodontal probe (Williams Color-Coded probe; Hu-Friedy) through the gingival margin.²⁵

Statistical analysis

Normal distribution of continuous data was assessed with Shapiro-Wilk tests together with normal Q-Q-plots. Normal distributed data are shown with means and standard deviation ($\pm$ SD) and were analyzed using independent t-test to detect differences between groups. Non normal distributed data are depicted with median and interquartile range (IQR) and were evaluated with Mann-Whitney tests.

The influence of gingival biotype on MBMV and BBT was assessed by a multiple variance analysis (MANOVA). Furthermore, a Pearson's test was carried out to test for correlation between MBMV and BBT (locations M_0 - M_5 combined).

Results

Patient characteristics of the study groups at T_{pre} are depicted in Table 1. The distribution of gingival biotype was not significantly different between both groups ($p=0.49$). Of the original 60 patients, data of 49 patients was available for the current sub-analysis (Fig. 1): Two implants, one in both group, were lost due to early failure of osseointegration. Nine patients (five in the control group and four in the test group) were excluded from final analysis due to irregularities in eight cast models and difficulties measuring one CBCT because of scattering.

Change in mid-buccal mucosal volume

At T_{12} , MBMV showed a loss of volume in the test group and control group, transformed to a mean ($\pm$ SD) loss of mucosal thickness of -0.68 ± 0.59 mm (95%CI: $-0.92 - -0.44$) in the test group and -0.49 ± 0.55 mm (95%CI: $-0.72 - -0.26$) in the control group ($p=0.25$).

Change in buccal bone thickness

The change in BBT at locations M_0 - M_5 between T_{pre} and T_{12} is displayed in Table 2. No statistical differences in buccal bone loss were found between both groups, except for the measurement 2 mm apical of the implant neck (M_2 , $p=0.04$). In general, the test group showed a slight tendency for higher buccal bone loss in all locations (M_0 - M_5).

Influence of gingival biotype on MBMV and BBT

At T_{12} , a significantly higher mean ($\pm$ SD) loss of MBMV was found in the control group in the presence of a thick pre-operative gingival biotype than in the presence of a thin gingival biotype (-0.74 ± 0.66 mm versus -0.28 ± 0.46 mm, $p=0.04$). In contrast, no significant differences in loss of MBMV were found in the test group between a thin or thick gingival biotype. Furthermore, no significant differences in change of BBT was found between a thin or thick pre-operative gingival biotype, regardless of study group.

Correlation testing between MBMV and BBT

At T_{12} , a significant correlation was found between the average change in BBT (M_0 - M_5) and change in MBMV in the control group (0.517, $p=0.01$). This implicated that the loss of BBT correlated with the loss of MBMV in the control group. This significant correlation was not found in the test group, where the (higher) loss in BBT did not correlate with the loss in MBMV. A possible explanation to this phenomenon is provided in the discussion section.

Discussion

The results of the present study revealed that placement of a connective tissue graft compared to no soft tissue grafting in single immediate implants leads to a comparable changes in mid-buccal mucosal volume and buccal bone thickness after one year.

This study could not confirm that applying a connective tissue graft resulted in a thickened mid-buccal mucosa, since on average a loss of MBMV was found in both groups. A slight tendency of more buccal bone loss was noted in the test group compared to the control group. A possible explanation for the higher bone loss in the test group could be the surgical intervention used for application of the connective tissue graft. A small envelope flap had to be prepared, which is accompanied by disruption of the vascularization between mucosa and periosteum. In addition to the bone remodeling process after tooth extraction^{7,8}, this disruption of the blood supply could have induced further loss of buccal bone.^{26,27}

As most teeth in the anterior maxilla display a thin (≤ 1 mm) buccal bone wall²⁸⁻³⁰, the BBT measured at T_{12} and the amount of loss of BBT observed between T_{pre} - T_{12} could suggest that the entire buccal bone wall was lost as a consequence of the bone remodeling process following tooth extraction.^{30,31} In addition, since it was stressed to place the implant at least two mm from the internal buccal socket wall and to graft the remaining gap^{6,10}, which was done in the present study, it can be suggested that despite the more pronounced bone resorption in the test group a sufficient width of buccal bone and bone grafting material for the support of the MBML was left.

In the present study a significant correlation between change in BBT and change in MBMV in the control group was observed. This indicates that together with buccal bone loss also a loss of MBMV occurred. When a connective tissue graft was used, no correlations were found. This observation might be explained by the possibility that the additional thickness of a connective tissue graft can (partially) mask changes in BBT. This is in line with what has been observed by Schwarz et al.³², viz. an inverse correlation between mucosal thickness and buccal bone thickness. However, because of their very short follow-up of 8 weeks, the true nature of this correlation is questionable.

The higher loss of MBMV in the control group in the presence of a thick pre-operative gingival biotype cannot be fully explained by existing literature, as no comparable studies are available. An earlier study of Cook et al.³³ concluded that a thin gingival biotype is significantly correlated to a thinner BBT, which might be more prone to bone remodeling and bone loss. In contrast, this correlation was not found by La Rocca et al.³⁴ As it is unknown whether the gingival biotype correlates with the thickness of the labial bone plate in current study, no conclusions can be drawn on this finding.

Conclusion

Connective tissue grafting combined with immediate placement and provisionalization of single implants in the aesthetic region results in comparable changes in mid-buccal mucosal volume and BBT. The additional mucosal volume that is added by a CTG seems to be lost as a result of slightly higher loss of BBT when a CTG is applied.

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Conflict of interest

The authors have stated explicitly that there is no conflict of interest in connection to this article.

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Figure 1. CONSORT Flow Diagram

Immediate implant placement and provisionalization of single teeth in the aesthetic region, with or without a connective tissue graft:
A 1-year CBCT study and volumetric sub-analysis

Figure 2a. CBCT image of the implant and the planning implant aside.

Figure 2b. Manual alignment of the planning implant with the implant in the CBCT image.

Figure 2c. Last part of alignment done with MIRIT to obtain the exact coordinates of the implant in the CBCT image.

Figure 3. Planning implant superimposed over the implant in the CBCT image according to the exact coordinates obtained. Measurements at each millimeter (M_0 - M_5) along the axis of the implant for 5mm, starting at the neck of the implant.

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Figure 4a. Alignment of DICOM files of CBCT images taken at T_{pre} and T_1 .

Figure 4b. Alignment of planning implant according to the coordinates of the prospective position of the implant in the CBCT image taken at T_{pre} with the failing tooth still in place.

Table 1. Patient characteristics per study group at T_{pre} .

Variable	Test group (n=25)	Control group (n=24)
Male / Female	12 / 13	11 / 13
Age (years) mean $\pm$ SD (range)	44.9 $\pm$ 15.1 (19-67)	47.8 $\pm$ 16.5 (20-82)
Gingival biotype		
Thin / Thick	16 / 9	13 / 11
Implant site location		
I ₁ / I ₂ / C / P ₁	13 / 9 / 1 / 2	8 / 8 / 7 / 1

T_{pre} = preoperative state

Table 2. Change in buccal bone thickness between T_{pre} – T_{12} .

Location	Test group (n=25) mean $\pm$ SD (mm)	Control group (n=24) mean $\pm$ SD (mm)	p-value
M ₀	-1.19 $\pm$ 1.12	-0.81 $\pm$ 0.67	0.15
M ₁	-0.80 $\pm$ 0.90	-0.48 $\pm$ 0.54	0.13
M ₂	-0.84 $\pm$ 0.81	-0.40 $\pm$ 0.63	0.04*
M ₃	-0.72 $\pm$ 0.65	-0.35 $\pm$ 0.65	0.05
M ₄	-0.69 $\pm$ 0.59	-0.40 $\pm$ 0.71	0.13
M ₅	-0.63 $\pm$ 0.64	-0.39 $\pm$ 0.66	0.21
Total	-0.81 $\pm$ 0.66	-0.47 $\pm$ 0.55	0.05

*significant difference between study and control group

T_{pre} = preoperative state; T_{12} = twelve months following placement of the final implant restoration

Immediate implant placement and provisionalization of single teeth in the aesthetic region, with or without a connective tissue graft:
A 1-year CBCT study and volumetric sub-analysis

CHAPTER

05

Delayed implant placement of two adjacent implants in the aesthetic region: A 5-year randomized controlled trial on two implant platform designs

This chapter is an edited version of the manuscript:
van Nimwegen WG, Raghoobar GM, Stellingsma K, Tymstra N, Vissink A, Meijer HJA.
Treatment Outcome of Two Adjacent Implant-Supported Restorations with Different Implant
Platform Designs in the Esthetic Region: A Five-Year Randomized Clinical Trial.
Int J Prosthodont 2015; 28(5):490-498. doi: 10.11607/jip.4199

Abstract

Purpose: To evaluate the condition of peri-implant soft and hard tissues and satisfaction in patients with two adjacent implant-supported restorations in the aesthetic region, treated with two adjacent implants with a scalloped or with a flat implant platform.

Material and methods: The randomized clinical trial consisted of 40 patients allocated to a scalloped implant group consisting of 20 patients or a flat implant group with 20 patients. Clinical and radiographic examinations were performed during a 5-years' follow-up period, together with patients' satisfaction.

Results: The scalloped implant group showed significantly higher mean ($\pm$ SD) marginal bone loss (scalloped: 3.2 ± 1.1 mm, flat: 1.5 ± 0.8 mm) and significantly higher bone loss at the inter-implant bone crest (scalloped: 2.4 ± 1.0 mm, flat: 1.3 ± 1.0 mm) after 5-year follow-up. Furthermore, peri-implant soft tissues showed significantly more bleeding when provided with scalloped implants than with flat implants. Papilla index scores were low in both groups. Patients' satisfaction was high in both groups.

Conclusions: After the first year of more bone loss and compromised inter-implant papilla regeneration around scalloped compared to flat implant platforms, the following four years of follow-up presented stable results with both systems. Scalloped implant platforms seem to have no beneficial use compared to conventional flat implant platforms in the aesthetic region.

Introduction

Long-term research shows promising results on the life span of dental implants in the aesthetic region.^{1,2} As failure rates of dental implants have shown to be low, criteria determining implant success rather than implant survival have become an area of interest within international research.³ These criteria include the establishment of a soft tissue contour with intact papillae and a gingival outline that is harmonious with the gingival silhouette of the adjacent healthy dentition.^{4,5} The preservation of interproximal papillae next to single-tooth implants is presumed to depend predominantly on the level of marginal bone and the attachment level of the neighbouring teeth in particular, but also a range of other factors, including the gingival biotype, are mentioned which contribute to presence of papillae.⁶⁻⁸ This explains why papilla formation between two adjacent implants is rather unpredictable and difficult to achieve as there is no support from marginal bone of neighbouring teeth. In addition, preoperative bone conditions for adjacent implants are often poor as many patients have a history of dental trauma. In these cases, ongoing bone resorption and vertical and horizontal bone deficiencies require augmentation procedures to allow for predictable and reliable implant placement and prosthodontics. When taking these factors into account, placement of two adjacent implant-supported restorations in the aesthetic region is considered a treatment with many uncertainties, in particular with regard to achieving satisfactory results in peri-implant hard and soft tissue stability.^{9,10}

Conventional implant therapy in the aesthetic region includes the use of implants with a flat implant platform. A major issue with the flat implant platform design is that this design is not able to fully maintain the alveolar bone crest, i.e., the interproximal bone peak in particular that exists after extraction of teeth in the aesthetic zone. The vertical difference between the buccal bone wall at the zenith of the tooth and the interproximal bone peak has been shown to contribute to the formation of an interproximal papilla. The scalloped implant was launched in 2003 and had a new implant platform design to create or maintain the anatomy of the alveolar bone crest and thereby maintaining satisfactory peri-implant soft tissue levels and interproximal papillae.¹¹

Until recent years, little research was available on the clinical results of the scalloped implant design. The few articles that were available showed contradicting results. For example, some studies reported that the interproximal bone crest could be preserved using a scalloped implant design,^{12,13} whereas other studies reported that marginal bone levels were not maintained properly around the scalloped implant design.^{14,15} Furthermore, another study conducted by Nowzari et al.¹⁶ reported a significant greater amount of bone loss around scalloped implants when compared to flat implants. Because of these contradicting results, the need arose to conduct further research on the treatment outcome of the scalloped implant design. Den Hartog et al.¹⁷ and Tymstra et al.¹⁰ conducted research on scalloped implants in the aesthetic region. Both studies showed that scalloped implants had less stable marginal bone levels than flat implants. Furthermore, it seemed that marginal bone levels did not follow the scalloped three-dimensional platform of the scalloped implant design. Moreover, the study of Tymstra et al.¹⁰ showed deeper implant probing depths and more marginal recession of the gingiva around scalloped implants compared to flat implants. Although both studies

showed less favourable bone levels around scalloped implants, no significant differences between scalloped and conventional flat implant designs were found regarding peri-implant soft-tissues and patient's satisfaction. Both studies implicated that scalloped implants offer no clinical advantage compared to flat implants on short term, but longer evaluation periods are needed to confirm this claim. The present study is the follow-up of the 1-year results of Tymstra et al.¹⁰ The study aims for assessing the 5-years clinical (implant probing depth, plaque, bleeding, gingival health), radiographic (peri-implant bone changes) and patients' satisfaction parameters of two adjacent implant restorations in the aesthetic region, treated with either a scalloped implant platform or a conventional implant platform.

Material and methods

The patients selected for this study had been referred to the Department of Oral and Maxillofacial Surgery (University Medical Center Groningen, University of Groningen, the Netherlands) for implant-based prosthodontic rehabilitation of two adjacent teeth in the maxillary aesthetic region. Patients were selected according to the following inclusion criteria:

- missing or lost teeth were an incisor (central or lateral), a canine or a first premolar in the maxilla;
- teeth missing are neighbouring teeth;
- healed site (at least 3 months after tooth removal);
- sufficient bone was available for the placement of two adjacent dental implants (if required, a bone augmentation procedure was performed at least 4 months before implant placement);
- sufficient space in the mesial-distal dimensions was available for the placement of two adjacent dental implants (with the minimum dimensions of 10 x 3.5 mm) with an inter-implant distance of 3 mm and a tooth-implant distance of at least 1.5 mm;
- sufficient space in the mesial-distal, buccal-lingual, and interocclusal dimensions was available for the placement of two functional implant crowns with an anatomical design;
- implant site was free from infection.

The exclusion criteria for this study were as follows:

- presence of medical and general contraindications for the surgical procedures; presence of an active and uncontrolled periodontal disease;
- bruxism;
- smoking;
- a history of local radiotherapy to the head and neck region.

All radiographic assessments were performed by a single performer (N.T.) and also ratings with the aesthetic index were done by the same examiner throughout the evaluation period (K.S.). Clinical measurements and line measurements on photographs were done by one and the same examiner

at a certain follow-up time but by different examiners throughout the period (N.T. and W.G.v.N.). Training and calibration was done to keep differences in measurements to a minimum.

Surgical and prosthetic procedures

To rehabilitate two adjacent missing teeth in the aesthetic region, two treatment modalities were applied:

1. the “scalloped implant group” (Fig. 1a and 1b, scalloped neck of the implant, with extended approximal sides and with internal abutment connection, test group), consisting of 20 patients treated with two adjacent implants with a scalloped implant platform (NobelPerfectGroovy; Nobel Biocare AB, Göteborg, Sweden);
2. the “flat implant group” (Fig. 1c, flat neck of the implant with internal abutment connection, control group), consisting of 20 patients treated with two adjacent implants with a flat implant platform (NobelPerfectGroovy; Nobel Biocare AB).

Preoperatively, diagnostic casts were made with a diagnostic arrangement representing the future implant restorations in the ideal prosthetic position. Next, this ideal position was translated into a surgical template by fabricating a transparent acrylic resin template. One day before implant surgery, patients started taking antibiotics (amoxicillin 500 mg, three times daily for 7 days or clindamycin 300 mg, four times daily for 7 days in case of amoxicillin allergy) and using a 0.2% chlorhexidine mouthwash (two times daily for 7 days) for oral disinfection. Under local anaesthesia, two implants were placed, according to the manufacturer’s instructions, guided by the surgical template. The implants were placed with a maximum of 45Ncm torque. Furthermore, when the bone apposition area of the implants remained uncovered after proper positioning in the coronal-apical direction, a local augmentation was performed. For this small simultaneous augmentation procedure, an autogenous bone graft, collected during drilling (bone collected from the flutes of the implant drill) or harvested intraorally, was combined with anorganic bovine bone (spongiosa granules, 0.25–1.0 mm, Geistlich Bio-Oss; Geistlich Pharma AG, Wolhusen, Switzerland) and covered with a Geistlich Bio-Gides resorbable bilayer membrane (Geistlich Bio-Gides; Geistlich Pharma AG). Three months after implant placement, the implants were uncovered and a healing abutment was placed. Next, two single final implant restorations were fabricated. These restorations consisted of individual zirconia abutments covered with porcelain or individual zirconia abutments with separate zirconia cores with porcelain (either screw-retained or cemented with glass ionomer cement (Fuji Plus cement; GC, Alsip, IL, USA). The patient was instructed in hygiene procedures associated with single implant-supported restorations (gentle tooth brushing and use of dental floss) and scheduled for routine maintenance recalls every six months with their general dentists.

Survival rate

Survival rate was defined as the percentage functional implants at follow-up. Patients not examined at during follow-up appointments were counted as having functional implants, unless their dental record revealed otherwise.

Clinical examinations

One month (T_0), 1 year (T_{12}) and 5 years (T_{60}) after placement of the final implant restorations, the peri-implant soft tissues were clinically examined. The following parameters were assessed:

- papilla index according to Jemt;¹⁸
- implant probing depths, assessed with a periodontal probe (Williams Color-Coded Probe, Hu-Friedy, Chicago, Illinois, USA) to the nearest millimeter at the mid-buccal, inter-implant and implant-teeth aspect;
- modified plaque-index according to Mombelli;¹⁹
- modified Bleeding-index according to Mombelli;¹⁹
- Gingiva-index according to Loë & Sillness.²⁰

Photographic examinations

Standardized digital photographs were taken from the implant restorations and surrounding soft tissues²¹ and analyzed using computer software to perform linear measurements. The level of the marginal gingiva was assessed to the nearest 0.1 mm by measuring the vertical distance of the incisal edge of the crown to the tip of the papilla and to the border of the gingiva mid-buccally. Examiners were blinded for the photographs.

Radiographic examinations

Two weeks after implant placement (T_{post}) and 1 month (T_0), 1 year (T_{12}) and 5 years (T_{60}) after placement of the definitive restorations, digital periapical radiographs (Planmeca Intra X-ray unit; Planmeca, Helsinki, Finland) were taken using a paralleling technique (Fig. 2a and 2b). The following linear measurements were assessed to the nearest 0.1 mm: for the scalloped implant group, the apical corners of the implant collar were used as a reference line, and for the flat implant group the interface of the implant and the abutment was used as a reference line, from which all distances were measured (Fig. 3):

- the first bone to implant level: the distance between the reference line and the first bone to implant level, measured at the implant side facing the adjacent implant and at the implant side facing the neighbouring tooth
- the bone crest level: the distance between the reference line and the most coronal peak of the inter-implant bone crest.

The radiographic examination could not be blinded, as the study group could be deduced from these radiographs.

Implant crown aesthetic index

Aesthetic outcome by the professional was rated using the Implant Crown Aesthetic Index as described by Meijer et al.²² by one and the same examiner at all evaluations periods (K.S.). The index was applied to both implant restorations separately and scored at T_{12} and T_{60} .

Patients' satisfaction

A subjective appreciation of the results of the treatment was carried out at T_{12} and T_{60} using the questionnaire used by Meijndert et al.²³ Questions relating to overall score (numeric scale 0-10), colour of the implant restoration and mucosa and the shape of the crown and mucosa (numeric scale 0-4) were used in present study.

Statistical analysis

All analyses were performed at implant level, except for patients' satisfaction. Normality of data was tested with Q-Q plots and the Kolmogorov-Smirnov test. If possible, differences between groups were analysed using the independent t-test. If the data violated the assumptions of a normal distribution, differences between the groups were analysed using the Mann-Whitney test. In all statistical tests, a significance level of $p=0.05$ was chosen.

Results

Patient characteristics per group at baseline are presented in Table 1. Despite the dropout of some patients at T_{60} , both groups show more or less an equal distribution of balancing criteria. At T_{12} , in both groups one patient was missing for the evaluation. At T_{60} , four patients in the scalloped implant group could not be analysed and one patient in the flat implant group (Fig. 4). The most cited reason of withdrawal was the distance to the Department of Oral and Maxillofacial Surgery after a change of address. The assumption was made that not attending the 5-years' follow-up visit, was independent of clinical outcome or satisfaction.

Clinical and radiographic assessments

Two implants in the same patient were lost in the scalloped implant group at T_{60} , resulting in a 95% survival rate. Both implants were lost 4 years after placement due to extensive peri-implant bone loss. No implants were lost in the flat implant group, resulting in a 100% survival rate. Plaque scores in both groups were low and showed no significant differences. The frequency distribution of the bleeding-index and gingiva index at the implants is given in Table 2. Bleeding scores were significantly higher in the scalloped implant group at T_0 ($p = 0.016$) and T_{60} ($p = 0.001$) than in the flat implant group. Gingiva scores were significantly higher in the scalloped implant group at T_{60} ($p = 0.001$) than in the flat implant group. Implant probing depths at the implants are given in Table 3. The scalloped implant group showed significantly deeper implant probing depths than the flat implant group at T_0 and T_{60} . Marginal gingival levels showed recession in both groups, with no significant differences. Both groups showed compromised papillae height with no significant

differences between groups (Table 4).

Table 5 shows the results of the marginal bone changes from $T_{\text{post}}-T_{60}$ and $T_{12}-T_{60}$. Between $T_{\text{post}}-T_{60}$, the marginal bone loss was significantly higher around the scalloped implants. The proximal side facing the adjacent implant showed a mean ($\pm$ SD) marginal bone loss of 3.4 ± 1.0 mm in the scalloped implant group (whereas 1.5 ± 0.7 mm in the flat implant group). Furthermore the inter-implant bone crest also showed a significant higher mean marginal bone loss of 2.4 ± 1.0 mm (whereas 1.3 ± 1.0 mm in the flat implant group). The marginal bone loss around the scalloped implants between $T_{12}-T_{60}$ was not significantly different than the bone loss around the flat implants.

The implant crown aesthetic index rated the majority of patients as having poor aesthetics, with no significant differences between groups. The results of the patient questionnaire are shown in Table 6. Patient satisfaction was very high. Mean ($\pm$ SD) overall scores were 8.4 ± 1.7 and 9.1 ± 0.8 for the scalloped implant group and the flat implant group, respectively.

Discussion

There was more bone loss, more inflammation and bleeding of the peri-implant soft tissues and deeper implant probing depths around scalloped implants than around flat implants. Marginal recession of the peri-implant soft tissues occurred in both groups, with no significant differences. The inter-implant papilla showed compromised regeneration and was unable to maintain its shape in both groups. Although treatment results were often judged as poor by professional observers, patients' satisfaction regarding the aesthetic outcome was very high.

The implant survival rate after 5 years of function was 95% for the scalloped implant group and 100% for the flat implant group. Two implants were lost in the scalloped group after ongoing bone loss as a result of peri-implantitis (after four years of functioning). The implant survival of the flat implant group is comparable to another study reporting on implants with the same titanium oxide surface (TiUnite)²⁴ as the one used in this study. The implant survival rate of the scalloped group is comparable to the one reported in the article of Noelken, et al.²⁵ No articles reported on the survival rate after 5 years of two adjacent implants. Therefore, no true comparison could be made with the present study.

The mean marginal bone loss around the implants during the period $T_{\text{post}}-T_{60}$ was significantly higher in the scalloped implant group than the flat implant group. A factor contributing to the higher marginal bone loss in the scalloped group could be that proximal sides of the scalloped implants were (partially) augmented with bone. This augmented bone could have been subject to higher resorption. The mean marginal bone loss of the flat implant group is comparable with the results of articles reporting on the same implant system (TiUnite surface) used in single-tooth replacement.^{24,26} Comparing results with other studies is difficult, because no comparable 5-years' studies on two adjacent implants are available. In the period of $T_{12}-T_{60}$ both groups showed less marginal bone loss compared with the period $T_{\text{post}}-T_{12}$. Therefore, it seems that on short term the scalloped

three-dimensional platform of the scalloped implant design is unable to maintain marginal bone levels¹⁰ but on long term no significant differences between groups are found regarding the stability of the marginal bone levels. In contrast, the inter-implant bone crest did show a significant higher bone loss in the scalloped group during both periods of $T_{\text{post}}-T_{60}$ and $T_{12}-T_{60}$. This ongoing bone loss is presumably caused by two factors. First, the marginal bone loss around scalloped implants is higher than around flat implants. Probably, with adjacent implants these regions of peri-implant bone resorption meet in between, resulting in resorption of the inter-implant bone crest.²⁷ Secondly, the mean horizontal distance of 3.2 mm between adjacent scalloped implants was significantly smaller than the mean horizontal distance of 3.8 mm between the adjacent flat implants.⁹ Furthermore, there were more patients in the scalloped implant group with a horizontal distance of less than 3 mm than in the flat implant group. This could partly be due to the design of the narrow scalloped implants placed at the position of the lateral incisor. The scalloped implant placed at this site has a neck with a diameter of 4.31 mm instead of the 3.54 mm of the narrow platform of the flat implant. A horizontal inter-implant distance smaller than 3 mm will result in more horizontal and vertical inter-implant bone crest loss.²⁷ This is predominantly caused by the overlap of the bone resorption areas between adjacent implants.²⁸ Criteria for implant success as stated by Albrektsson et al.²⁹ propose an average bone loss of a maximum of 1.5 mm in the first year after implant placement and a further annual bone loss of less than 0.2 mm. The flat implant group does meet these criteria of success; however, the scalloped implant group does not.

Plaque scores were at a low level in both groups. The bleeding-index and gingiva-index around the implants gave significantly higher scores in the scalloped group than the flat implant group. Mean implant probing depths were deeper around scalloped implants than around flat implants. At T_{60} , the mean implant probing depths next to the scalloped implants ranged from 4.7 mm at the proximal side facing the adjacent tooth to 4.9 mm at the proximal side facing the adjacent implant. This was significantly higher than in the flat implant group. The implant probing depths in the flat implant group are comparable with the ones reported in studies on single-tooth replacement.^{30,31} The deeper implant probing depths around the implants in the scalloped implant group most likely reflect the significantly greater marginal bone loss around the scalloped implants.

During the 5 years following implant placement, changes occurring in the marginal gingiva level around both implant designs were small. This indicates that the marginal gingiva level remains fairly stable after implant therapy. Multiple studies reporting on single-tooth replacement showed comparable results.^{32,33} Papilla index scores in both groups pointed out the partial absence of papillae in both groups, with no significant differences between the groups. Therefore, no one-to-one relation between bone height and presence of papillae seems to exist and more factors are probably involved.⁸ The inter-implant papilla showed less favourable scores in both groups when compared to the papillae between the implant and the tooth. The inter-implant bone crest is a dominant factor in maintaining the inter-implant papilla. The reduced height of this bone crest causes the inter-implant papilla to collapse, as the soft tissues tend to follow the contour of the hard tissues. Moreover, the soft tissue height of the inter-implant papilla is lower than the papillae between the implant and tooth. The maximum soft tissue height of the inter-implant papilla is 3-4 mm as opposed

to the 5 mm of the papillae between an implant and a tooth.²⁷ Therefore, these factors contribute to the compromised presence of the papilla between two adjacent implants in both groups. If papillae are not to be expected because of a compromised bone height between two implants, black triangles due to absence of filling with soft tissue, are prevented by manipulating the contact area between the crowns and the contact area is extended cervically. Both groups experienced loss of the inter-implant bone crest, so in both groups a substantial part of the inter-implant papilla was missing and contact areas of adjacent implant restorations were adjusted in both groups.

A self-administered non-validated questionnaire was used, but applied in this study because comparison with previous and ongoing research would be possible. Patients' satisfaction in both groups was very high. At $T_{60'}$, mean overall scores were 8.4 (range: 0-10) for the scalloped implant group and 9.1 for the flat implant group. There is hardly any difference at T_{60} compared to $T_{12'}$, meaning that patient satisfaction was stable after the first year. In contrast, the implant crown aesthetic index by professionals rated the majority of patients as having poor aesthetics. This difference in rating by patients and professionals has been seen before in earlier studies. In the study of Meijndert et al.²³, also on implant based restorations in the aesthetic region and with use of the same index and questionnaires, was found that patients were much more satisfied than was expected after rating aesthetics by professionals. A reason for this paradox could be the fact that preoperative bone conditions for adjacent implants could be poor among patients with a history of trauma. As a result, more than half of the patients in both groups had undergone augmentation procedures to compensate for the large defect. Therefore, the final result was probably very satisfying for these patients. Moreover, patients were informed about the risks and consequences of implant placement and the limitations of two adjacent implants regarding soft tissue regeneration. Factors considered to be of importance by professionals therefore may not be of paramount importance to patients.^{23,34}

Conclusion

From the present study can be concluded that regardless of the implant design used, it remained difficult to establish a predictable and harmonious result with adjacent implants restorations in the aesthetic region. After the first year of more bone loss and compromised inter-implant papilla regeneration around scalloped compared to flat implants, the following four years of follow-up presented stable results with both systems. Scalloped implant platforms seem to have no beneficial use compared to conventional flat implant platforms in the aesthetic region.

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Conflict of interest

The authors have stated explicitly that there is no conflict of interest in connection to this article.

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Figure 1a. Illustration of the buccal aspect of the scalloped implant platform

Figure 1b. Illustration of the proximal aspect of the scalloped implant platform

Figure 1c. Illustration of the flat implant platform

Figure 2a. Radiograph of two adjacent scalloped implants at T₆₀.

Figure 2b. Radiograph of two adjacent flat implants at T₆₀.

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Figure 3. Illustration of the radiographic measurements in the vertical and horizontal plane

Figure 4. Consort flow diagram.

Table 1. Characteristics of the study groups at baseline

	Scalloped-platform group	Flat-platform group
Number of participants	20	20
Age (years; mean/ range)	38.8 / 18-70	35.8 / 15-59
Gender (male/female)	9 / 11	11 / 9
Tooth gap position (I ₁ -I ₁ / I ₁ -I ₂ / I ₂ -C, C-P ₁)	10 / 7 / 2 / 1	9 / 7 / 2 / 2
Augmentation prior to implant insertion (y/n)	10 / 10	9 / 11
Local augmentation during implant insertion (yes/no)	13 / 7	12 / 8

Table 2. Frequency distribution of bleeding-index and gingival index.

	Bleeding-index				Gingival index			
	Scalloped-platform group		Flat-platform group		Scalloped-platform group		Flat-platform group	
	T ₀	T ₆₀	T ₀	T ₆₀	T ₀	T ₆₀	T ₀	T ₆₀
Patients	n=20	n=16	n=20	n=19	n=20	n=16	n=20	n=19
Implants	n=40	n=32	n=40	n=38	n=40	n=32	n=40	n=38
Score								
0	9	7	12	19	30	20	34	36
1	11	10	21	14	9	10	6	2
2	19	13	7	5	1	2	0	0
3	1	2	0	0	0	0	0	0
Total	40	32	40	38	40	32	40	38

Bleeding-index			Gingiva index		
Difference between groups	T ₀	T ₆₀	Difference between groups	T ₀	T ₆₀
Implants	p=0.016*	p=0.001*	Implants	NS***	p=0.001**

T₀ = 1 month after placement of the of the final implant restoration

T₆₀ = 5 years after placement of the of the final implant restoration

* Peri-implant soft tissues around scalloped implants showed

significantly more bleeding than around flat implants at T₀ and T₆₀

** Peri-implant soft tissues showed significantly more inflammation

around scalloped implants than around flat implants at T₆₀

*** No significant difference found.

Bleeding-index:

score 0 = no bleeding after probing

score 1 = isolated bleeding spots

score 2 = confluent line of blood

score 3 = heavy or profuse bleeding

Gingiva-index:

score 0 = normal gingival/mucosa around tooth/implant

score 1 = mild inflammation

score 2 = moderate inflammation

score 3 = severe inflammation

Table 3. Mean±SD of implant probing depths (mm) measured around implants at the proximal sides facing the adjacent implant, midbuccally and the proximal sides facing the adjacent tooth.

		Scalloped-platform group		Flat-platform group		
		T_0	T_{60}	T_0	T_{60}	
Patients		n=20	n=16	n=20	n=19	
Implants		n=40	n=32	n=40	n=38	
Location		Mean±SD	Mean±SD	Mean±SD	Mean±SD	Significance
Implant	Proximal side facing adjacent implant	4.8±1.5	4.9±2.0	3.6±1.3	3.8±1.2	T_0 : p=0.001 * T_{60} : p=0.012
	Midbuccally	4.1±1.4	4.8±2.2	3.1±0.9	3.0±0.8	T_0 : p<0.001 ** T_{60} : p<0.001
	Proximal side facing adjacent tooth	4.4±1.8	4.7±2.4	3.4±1.4	3.2±1.1	T_0 : p=0.003 *** T_{60} : p=0.003

*Implant probing depths at the proximal side of the implants facing the adjacent implant were significantly higher in the scalloped-platform group than in the flat-platform group at T_0 and T_{60}

**Implant probing depths midbuccally of the implants were significantly higher in the scalloped-platform group than in the flat-platform group at T_0 and T_{60}

***Pocket probing depths at the proximal side of the implants facing the adjacent tooth were significantly higher in the scalloped-platform group than in the flat-platform group at T_0 and T_{60}

T_0 = 1 month after placement of the of the final implant restoration

T_{60} = 5 years after placement of the of the final implant restoration

Table 4. Frequency distribution of papilla-index.

		Scalloped-platform group*				Flat-platform group*			
		T_0	T_{60}	T_0	T_{60}	T_0	T_{60}	T_0	T_{60}
Location of papillae		Implant-Implant	Implant-Tooth	Implant-Implant	Implant-Tooth	Implant-Implant	Implant-Tooth	Implant-Implant	Implant-Tooth
Number of papillae		n=20	n=40	n=16	n=32	n=20	n=40	n=19	n=38
Score									
0		5	0	6	1	5	0	3	1
1		8	8	7	11	10	8	12	13
2		6	25	3	15	4	23	3	19
3		1	7	0	5	1	9	1	5
4		0	0	0	0	0	0	0	0
Total		20	40	16	32	20	40	19	38

*No significant differences were found between groups at T_0 and T_{60}

Papilla-index: score 0 = no papilla formation, score 1 = less than half of papilla is present, score 2= at least half of the papilla is present, score 3 = papilla fills whole approximate space and score 4 = abundance of papilla / hyperplastic papilla.

T_0 = 1 month after placement of the of the final implant restoration

T_{60} = 5 years after placement of the of the final implant restoration

Table 5. Mean±SD change in marginal bone level and bone crest level (mm).

		Scalloped-platform group (n=16)		Flat-platform group (n=19)		Difference
Location		$T_{post} - T_{60}$	$T_{12} - T_{60}$	$T_{post} - T_{60}$	$T_{12} - T_{60}$	
		Mean±SD	Mean±SD	Mean±SD	Mean±SD	
Implant	Inter-implant bone crest level	-2.4±1.0	-0.8±0.7	-1.3±1.0	-0.1±0.5	$T_p - T_{12}$: p<0.001* $T_{12} - T_{60}$: p<0.001*
	Marginal bone level facing the adjacent implant	-3.0±1.1	-0.6±1.1	-1.4±0.9	-0.4±0.4	$T_p - T_{12}$: p<0.001** $T_{12} - T_{60}$: NS ^a
Implant	Marginal bone level facing the adjacent tooth	-3.4±1.0	-1.0±1.3	-1.5±0.7	-0.6±0.7	$T_p - T_{12}$: P<0.001*** $T_{12} - T_{60}$: NS ^a

* The inter-implant bone crest loss was significantly higher in the scalloped-platform group during the periods of $T_p - T_{12}$ and $T_{12} - T_{60}$ than in the flat-platform group.

** The marginal bone loss at the side facing the adjacent implants was significantly higher in the scalloped-platform group during the period of $T_p - T_{12}$ than in the flat-platform group.

*** The marginal bone loss at the side facing the adjacent tooth was significantly higher in the scalloped-platform group during the period of $T_p - T_{12}$ than in the flat-platform group.

^a Not significant.

T_p (post) = directly after implant placement

T_{12} = 1 year after placement of the final implant restoration

T_{60} = 5 years after placement of the final implant restoration

Table 6. Results of the patients' questionnaire.

Satisfaction	T_{12} [*]		T_{60}		Difference
	Scalloped (n=19)	Flat (n=19)	Scalloped (n=16)	Flat (n=19)	
	Mean±SD	Mean±SD	Mean±SD	Mean±SD	
Overall score	8.3±1.2	8.6±0.8	8.4±1.7	9.1±0.8	T_{60} : p=NS**
Colour mucosa	2.8±1.2	3.0±1.2	2.8±1.2	3.5±0.6	T_{60} : p=NS**
Shape mucosa	2.4±1.2	2.8±1.2	2.5±1.2	3.4±0.6	T_{60} : p=0.014***
Colour crown	3.5±0.8	3.7±0.6	3.6±0.8	3.7±0.6	T_{60} : p=NS**
Shape crown	3.2±0.9	3.3±1.2	3.5±0.5	3.7±0.6	T_{60} : p=NS**

* No significant differences between groups were found at T_{12}

** No significant differences at T_{60}

*** The shape of the mucosa was rated significantly lower in the scalloped group than in the conventional group at T_{60}

Overall satisfaction (range 0-10); 0 = very dissatisfied, 10 = very satisfied

Satisfaction mucosa and crown (range 0-4); 0 = very dissatisfied, 4 = very satisfied

T_{12} = 1 year after placement of the final implant restoration

T_{60} = 5 years after placement of the final implant restoration

CHAPTER 06

Implant treatment of two neighbouring missing teeth in the aesthetic region: A systematic review on single implant-supported two-unit cantilever restorations and results of a 5-year prospective comparative study

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How to treat two adjacent missing teeth with dental implants. A systematic review on single implant-supported two unit cantilever FDP's and results of a 5-year prospective comparative study in the aesthetic zone. J Oral Rehabil 2017; 44(6):461-471. doi: 10.1111/joor.12507

Abstract

Purpose 1: To conduct a systematic review on the clinical outcome of single implant-supported two-unit cantilever restorations in the anterior and posterior maxilla and mandibula

Purpose 2: To conduct a 5-year prospective comparative pilot study of patients with a missing central and lateral upper incisor treated with either a single implant-supported two-unit cantilever restoration or two implants with solitary implant restorations in the maxillary aesthetic region.

Material and methods: Medline, Embase and the Cochrane Central Register of Controlled Trials were searched (last search August 1, 2016) for eligible studies. In the comparative pilot study, an implant-cantilever group of five patients with a single implant-supported two-unit cantilever restoration (NobelReplace Groovy Regular Platform) was compared with an implant-implant group of five patients with two adjacent single implant-supported restorations (NobelReplace Groovy Regular Platform) in the aesthetic region. Implant survival, marginal bone level changes, implant probing depth, papilla index and patient satisfaction were assessed during a 5-year follow-up period.

Results: 5 out of 276 articles were considered eligible for data extraction. Implant survival ranged from 96.6-100%. Marginal bone level changes were higher in the anterior region than in the posterior region. Technical complications occurred more often in the posterior than anterior region. In the 5-year comparative pilot study, no clinically significant differences in hard and soft peri-implant tissue levels occurred between both groups.

Conclusions: Single implant-supported two-unit cantilever restorations can be a viable alternative to the placement of two adjacent single implant restorations in the aesthetic region. Due to technical complications, placement of two-unit cantilever restorations in the posterior region of the maxilla and mandibula can be considered unwise.

Introduction

Replacement of two missing adjacent teeth is considered a difficult treatment in implant dentistry. This treatment becomes even more challenging when the missing teeth are located in the aesthetic region due to the aesthetic demands. It is difficult to establish the desired presence and stability of papillae adjacent to the implant restorations. In case of single-tooth replacements in the aesthetic region, the presence of the papillae is determined predominantly by the attachment levels of the neighbouring teeth.¹ In periodontally healthy patients, neighbouring teeth enhance the aesthetic outcome by maintaining stability of peri-implant papillae. When two adjacent teeth are missing in the aesthetic region, the presence of the papilla between two implant restorations is determined predominantly by the level of the inter-implant bone crest.² Therefore, only a maximum of 3 mm of inter-implant papilla height should be expected as a result of the lower inter-implant bone crest between two adjacent implant restorations.³ A reduced inter-implant papilla height can result in a black triangle between adjacent implant restorations, thus reducing the aesthetic outcome. To avoid black triangles, contact points of adjacent implant crowns are often positioned more apically to camouflage these defects. This compensation is frequently used when papilla presence is compromised but it also impedes the creation of aesthetic and anatomically shaped implant restorations. Therefore, the purpose of replacing two missing teeth in the aesthetic region should be to place implants at an ideal position to maintain peri-implant bone and soft tissue levels.

In case of a missing adjacent upper central incisor and lateral incisor, there is often limited horizontal space available to place two implants with a sufficient inter-implant space, even when smaller diameter implants are used in the region of the lateral incisor. As a result, implants are often placed too close to each other which often results in lateral resorption of the inter-implant bone crest and leads to recession of the inter-implant papilla. An alternative treatment is to place one implant in the region of the central incisor and an implant restoration connected with a cantilever restoration at the position of the lateral incisor. With this treatment, bone crest height is not affected by proximal resorption between adjacent implants. Tymstra et al.⁴ conducted a 1-year prospective comparative pilot study of patients with a missing central and lateral upper incisor treated with either one implant and an implant restoration with a cantilever or two implants with solitary implant restorations. The results of that study showed no clinically significant differences in hard and soft peri-implant tissue levels between both approaches.

In case of two missing teeth in the posterior region, two implants are usually placed to replace these missing teeth. Again, proximal resorption between these implants can lower clinical outcomes. Placement of a single implant-supported two-unit cantilever restoration in this region prevents the proximal resorption between implants and could also offer a less expensive treatment. Due to the lack of available literature on single implant-supported two-unit cantilever restorations, no evidence-based decisions can be made on the choice of treatment for two missing adjacent teeth in general.

The aim of current study is to conduct a systematic review on the outcome of single implant-supported two-unit cantilever restorations in general (anterior and posterior maxilla and mandibula) and to

conduct a 5-year prospective comparative pilot study of patients with a missing central and lateral upper incisor treated with either one single implant-supported two-unit cantilever restoration or two implants with solitary implant-supported restorations in the aesthetic region.

Materials and methods

Systematic review

Search strategy

An extensive search of the literature in Medline (PubMed), Embase and the Cochrane Central Register of Controlled Trials was conducted and was completed on August 1, 2016. The search was completed by a hand-search of the references found in eligible studies. The search strategy was defined in Mesh terms and free text words: ("Dental Implants"[Mesh]) OR "Dental Implantation"[Mesh] OR dental implant*[tiab] AND cantilever*[tiab].

Eligibility criteria

The studies had to meet the following requirements:

1. *Type of participants*: patients treated with an single implant-supported two-unit cantilever restoration (maxilla and mandible);
2. *Type of intervention*: placement of a single implant-supported two-unit cantilever restoration in the maxilla or mandibula. No restrictions regarding implant type, abutment type, loading protocol or region (anterior/posterior) were made;
3. *Follow-up*: studies with a follow-up of at least 1 year after placement of the single implant-supported two-unit cantilever restoration;
4. *Principle outcomes*: Studies must at least report on implant survival and/or changes in peri-implant marginal bone level (MBL)
5. *Outcomes*: implant survival, changes in marginal bone level (MBL), aesthetic evaluation by dental professionals, level of marginal gingiva, papilla index or level of papilla, presence of plaque, bleeding on probing, implant probing depth, patient satisfaction, biological and technical complications;
6. *Study designs*: randomized controlled trials, clinical trials, retrospective studies and case-series (at least 5 patients) were considered for selection.
7. *Study language*: studies must be reported in English, German or Dutch

Quality assessment

Screening of the abstracts was performed by one reviewer (W.G.V.N.) based on the eligibility criteria and inclusion criteria. Full-text analysis was performed independently by two reviewers (W.G.V.N. and H.J.A.M.). Agreement was reached by a discussion between the two reviewers and if necessary, a third reviewer (G.M.R.) was consulted.

The methodological quality of each full-text paper was assessed using specific study-design related

checklists designed by the Dutch Cochrane Collaboration as described by Offringa et al.⁵ Since there were no specific checklists available for the included study designs, a checklist was used that was adapted by den Hartog et al.⁶ from the quality checklist used for clinical trials. Both reviewers (W.G.V.N. and H.J.A.M.) independently generated a score for the included studies, which resulted in a number of plusses given. Studies scoring 5 or more plusses were deemed methodologically acceptable.

Statistical analysis

Descriptive statistics were used to describe the means, standard deviation and median of data found in the selected articles.

Pilot study

Patient selection

A comparative pilot study with two parallel groups was designed as described in detail by Tymstra et al.⁴ In short, the patients selected for this study were referred to the Department of Oral and Maxillofacial Surgery (University Medical Center Groningen, University of Groningen, Groningen, the Netherlands) for implant therapy. To be included in this study, patients had to present two missing adjacent teeth, a central and a lateral maxillary incisor. Randomly, 5 patients were treated with one dental implant in the region of the central incisor (Implant-cantilever group: NobelReplace Groovy Regular Platform; Nobel Biocare AB, Göteborg, Sweden); the prosthetic restoration consisted of a two-unit cantilever restoration with a cantilever at the position of the lateral incisor. The other 5 patients were treated with two adjacent dental implants (implant-implant group: Regular Platform at the position of the central incisor and Narrow Platform at the position of the lateral incisor); the prosthetic restoration consisted of two single implant-supported restorations.

Data collection

Data were collected preoperatively (T_{pre}), directly after implant surgery (T_{post}), directly (within a month) after placement of the final implant restoration (T_0), and one (T_{12}) and five (T_{60}) years after placement of the final implant restoration. The following parameters were assessed:

- implant loss;
- implant probing depth at T_0 , T_{12} and T_{60} , assessed with a periodontal probe (Williams Color-Coded Probe, Hu-Friedy, Chicago, Illinois, USA) to the nearest millimeter at the mid-buccal aspect of the implant and both proximal sides;
- papilla index at T_{12} and T_{60} , according to Jemt et al.;⁷
- marginal bone level and bone crest level at T_{post} , T_{12} and T_{60} , measured on intraoral periapical radiographs taken with a paralleling technique. For details see Tymstra et al.;⁴
- patients' satisfaction was scored with a validated questionnaire.⁸

Statistical analysis

The statistical analysis has been restricted to means and standard deviation due the pilot study design with small groups.

Results

Systematic review

The results of the primary search were 284 records for the Medline search, 263 records for the Embase search and 12 records for the Cochrane Library search. After exclusion of double titles and systematic reviews a total of 276 records was identified for further screening. After scanning of titles and abstracts, 21 articles remained for full-text evaluation. After full-text evaluation, another 16 articles were excluded with reasons (Table 1).⁹⁻²⁴ The remaining 5 articles were deemed methodologically acceptable and were qualitatively assessed for data extraction (Fig. 1). Characteristics and outcomes of the included studies are described in Table 2 and 3. The number of single implant-supported two-unit cantilever FDP in the selected studies ranged from 5 to 108 and the follow-up from 1 year to a mean ($\pm$ SD) follow-up of 4.2 ± 2.8 years. Because of the heterogeneity in study designs and data presented, the outcomes of the studies are mainly presented as a descriptive review.

Implant survival

Implant survival ranged from 96.6% to 100% (Table 2). A variety of implant systems was applied. In two studies, implant survival was not mentioned.^{25,28}

Marginal bone level changes

Assessing changes in MBL was not uniform scored (Table 2). Halg et al.²⁵ only reported a mean MBL change for both mesial and distal sides of the implants, Palmer et al.²⁶ reported a **median** MBL change for the cantilever and non-cantilever sides of the implants, and Tymstra et al.⁴, Wu et al.²⁷ and Kim et al.²⁸ reported **mean** MBL changes of the cantilever and non-cantilever sides of the implants.

Aesthetics

None of the included studies reported on aesthetics.

Marginal gingiva level

None of the included studies reported on change of marginal gingiva level.

Papilla, plaque and bleeding indices.

One study reported a mean ($\pm$ SD) change in papilla height of -0.22 ± 0.41 mm at 3 years follow-up.²⁷ Another study only reported compromised papillae height at 1 year follow-up with a papilla index.⁴ Plaque and bleeding scores reported by one study were moderate to high (Table 3).

Probing depth

Implant probing depths ranged from 2.4-3.8 mm and were slightly larger on the cantilever side than the non-cantilever side of the implants (Table 3).

Patients satisfaction

Patient satisfaction reported was very high (Table 3) and ranged from 8.8-8.9 (on a 0-10 scale) and **median** 5 (on a 1-6 scale).

Biological and technical complications

No biological complications, except one case of early implant loss, were reported (Table 3). Porcelain fracture was reported solely in the posterior region of the maxilla and mandible. Screw loosening occurred more often in the posterior region than the anterior region of the maxilla and mandible. No studies reported loosening of cemented implant crowns.

Comparative pilot study

All 10 patients could be re-evaluated during the 5-year evaluation period. No implants were lost, resulting in a 100% survival rate. The implant probing depths at proximal sides of the central implant in the implant-cantilever group continued to be slightly larger than the pocket probing depths in the implant-implant group, but overall probing depths appeared to be low and rather stable during the 5-years follow-up (Table 4). The same applies to the papilla index (Table 5). MBL was higher in the implant-implant group than the implant-cantilever group as is loss of marginal bone crest level (Table 6). With regard to patients' satisfaction, the implant-cantilever group rates the color and shape of their peri-implant mucosa lower than the implant-implant group, but overall satisfaction was high in both groups (Table 7).

Discussion

Systematic review

The implant survival rate reported in the included studies was high (100%, 96.6% and 100%) with only one case of early implant loss occurring in the posterior maxilla or mandible. No late implant loss occurred, although the follow-up (1 to 3 years) and number of studies might be insufficient to show any form of late implant loss. Marginal bone level changes varied widely between studies (-0.0 to -1.85 at cantilever side and -0.2 to -1.23 at non-cantilever side), with greater MBL changes in the anterior maxilla and mandibula than the posterior maxilla and mandibula. Because of the small number of implants placed in the anterior maxilla and mandibula, no conclusions can be drawn from these studies.

Tymstra et al.⁴ reported compromised papilla index scores at 1 year follow-up and Wu et al.²⁷ reported a change in papilla height of -0.22 mm (SD 0.41) between baseline and 3 years follow-up. Both scores cannot be compared with other literature or treatment modalities, due to the absence of baseline scores.

The low probing depths (range 2.4 – 3.8 mm) reported by Tymstra et al.⁴, Palmer et al.²⁶ and Wu et al.²⁷ suggest that the presence of a two-unit cantilever restoration might not affect peri-implant

probing depths, in both anterior and posterior region of the mandibula and maxilla. Also, patient satisfaction described by Tymstra et al.⁴, Palmer et al.²⁶ and Wu et al.²⁷ was very high. Therefore, single implant-supported two-unit cantilever restorations might prove a useful alternative to two adjacent single implant-supported restorations. Finally, the biological and technical complications reported by Palmer et al.²⁶ and Wu et al.²⁷ suggest that there might be a minor risk of screw loosening in the anterior mandibula and a large, impermissible risk of porcelain fracture and screw loosening in the posterior maxilla and mandible.

Comparative pilot study

No implants were lost during 5-years follow-up in both groups, resulting in a survival rate of 100%. This survival rate was also achieved in a 5-years prospective study of two adjacent implants in the aesthetic region, using the same implant design.²⁹ The only comparable study regarding single implant-supported two-unit cantilever restorations in the aesthetic region reported an implant survival rate of 100% after a mean 2.5 years of follow-up.²⁷ Mean implant probing depths in both groups were comparable; the presence of a cantilever restoration attached to an single implant appears to have no or negligible negative effect on implant probing depths. This finding corresponds with other studies regarding single implant-supported two-unit cantilever restorations.^{26,27} Furthermore, implant probing depths remained stable over time between placement of the final implant restorations and 5 years of functional loading in both groups. The papilla scores were relatively low in both groups, pointing towards compromised papillae. The papilla scores in the implant-implant group remained stable during the 5-years follow-up. In contrast, papilla scores decreased between 1 year and 5 year follow-up in the implant-cantilever group, in particular between the cantilever extension and the implant supported restoration of the central implant. No literature regarding the papilla index and single implant-supported two-unit cantilever restorations in the aesthetic region is available for comparison, except one article describing a decrease in papilla height of 0.22 mm (SD 0.48) after 3 years.²⁷

In the implant-cantilever group, mean marginal bone loss at the distal side of the central implant (cantilever side) was higher in comparison with the mesial side (non-cantilever side) of the implant-cantilever group and both proximal implant sides in the implant-implant group after 5-years follow-up. This corresponds with the findings of Wu et al.²⁷ in the aesthetic region, although two studies reporting on the posterior mandible and maxilla reported no or only slight differences in marginal bone loss between the cantilever and non-cantilever side of the implant.^{26,28}

In the implant-implant group, mean marginal bone loss on both proximal sides of the implants is comparable with the findings of another 5-year prospective study on two adjacent implants in the aesthetic region.²⁹ Furthermore, mean bone crest resorption distally of the central implant in the implant-cantilever group was higher than the mean inter-implant bone crest resorption in the inter-implant group after 5 years follow-up (-2.77 mm vs -1.39 mm). Considerable large standard deviations were observed for mean changes in the marginal bone level and the crestal bone level of the implant-cantilever group, which might suggest variability in changes in marginal bone level between patients, making a reliable prediction of the expected changes in hard and soft peri-implant tissues very difficult. These large standard deviations in marginal bone level changes were also

found in other studies reporting on single implant-supported two-unit cantilever restorations.^{26,29} The patient satisfaction was very high during the 5-year follow-up, with no differences between both groups. Although papilla-index scores pointed out towards compromised papillae in both groups, this did not seem to have a negative effect on patient satisfaction. This is comparable to the findings of other studies.^{8,29,30} Based on the patients' satisfaction, patients have a financial incentive to choose for the prosthodontic solution of one single implant-supported two-unit cantilever FDP as this is less expensive than two single implant-supported restorations.

Conclusions

Both the systematic review and the pilot study showed that single implant-supported two-unit cantilever restorations are accompanied by high short and mid-term implant survival rates and excellent patient satisfaction. Therefore, a single implant-supported two-unit cantilever restoration in the aesthetic region seems a viable alternative to the placement of two adjacent single implant-supported restorations in the aesthetic region. In contrast, single implant-supported two-unit cantilever restorations placed in the posterior region might be more prone to technical complications, and are therefore less suited as an alternative treatment method to placement of adjacent implants in the posterior region.

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The initial study was approved by the hospital medical ethical committee and written consent was obtained from all patients. No additional ethical approval was necessary for the 5-year follow-up of current study.

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Conflict of interest

The authors have stated explicitly that there are no conflict of interest in connection with this article.

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Figure 1. Study selection procedure.

Table 1. Studies excluded after full-text evaluation with main reason for exclusion.

	Design	Main reason for exclusion
Shackleton et al. (1994)	Retrospective	Interventions not specified
Preiskel et al. (1995)	Retrospective	Interventions not specified
Johansson et al. (2003)	Retrospective	Interventions not according to inclusion criteria
Romeo et al. (2003)	Retrospective	Marginal bone level change not specified
Romeo et al. (2004)	Prospective	Interventions not specified
Becker et al. (2004)	Retrospective	Interventions not according to inclusion criteria
Wennstrom et al. (2004)	Retrospective	Interventions not according to inclusion criteria
Nedir et al. (2006)	Retrospective	Interventions not according to inclusion criteria
Tawil et al. (2006)	Retrospective	Interventions not according to inclusion criteria
Kreissl et al. (2007)	Prospective	Interventions not according to inclusion criteria
Bragger et al. (2011)	Retrospective	Interventions not specified
Mumcu et al. (2011)	Prospective	Interventions not according to inclusion criteria
Rammelsberg (2013)	Retrospective	Interventions not according to inclusion criteria
Malo et al. (2013)	Retrospective	Marginal bone level change not specified
Witneben et al. (2014)	Retrospective	Interventions not specified
Ozgur et al. (2016)	Retrospective	Interventions not specified

Table 2. Characteristics of the included studies with regard to design, implants placed, implant location, implant survival, marginal bone peri-implant bone change and follow-up.

Study	Study design	Implant brand / type	No. of implants	Maxilla / mandibula	Follow-up (years)	Implant survival (%)	Marginal bone level change Mean±SD (mm)
Halg et al. 2008	Retrospective case-control study	Straumann / NS	8	Posterior maxilla and mandible	Mean 3.5 (range 2.9-5.4)	NS	Mesial and distal side -0.12±0.58
Tymstra et al. 2011	Prospective case-control study	Nobel Biocare / NobelReplace	5	Anterior maxilla	1	100	Distal cantilever side -1.85±1.16 Mesial non-cantilever side -0.90±0.74
Palmer et al. 2012	Prospective case series	Astra Tech / MT Osseospeed	29	Posterior maxilla and mandible	3	96.6	Median / range Cantilever side -0.0 (+0.1 to -0.3) Non-cantilever side -0.2 (-0.0 to -0.8)
Wu et al. 2013	Retrospective case series	19 Straumann / NS and 14 NobelBiocare / NobelReplace	33	Anterior mandible	Mean 2.5 (range 1.3-3.7)	100	Cantilever side 3 years -1.46±0.53 Non-cantilever side 3 years -1.23±0.43
Kim et al. 2014	Retrospective cohort study	NS	108	Anterior and posterior maxilla and mandible	Mean 4.2 ±SD 2.8	NS	Cantilever side -0.57±0.96 Non-cantilever side -0.55±1.02

NS: not specified

Table 3. Characteristics of the included studies with regard to aesthetics, satisfaction and complications.

Study	Aesthetic Index	Level marginal gingiva change	Papilla index*	Plaque index	Bleeding index	Probing Depth Mean±SD (mm)	Questionnaire Patient satisfaction	Biological and technical complications
Halg et al. 2008	NR	NR	NR	NR	NR	NR	NR	NS
Tymstra et al. 2011	NR	NR	Score 0: 20% Score 1: 60% Score 2: 20% Score 3: 0%	NR	NR	Cantilever side 3.8±1.1 Non-cantilever side 3.4±1.5	Mean 8.8 (possible score 0-10)	NR
Palmer et al. 2012	NR	NR	NR	NR	NR	Median Cantilever 3 Median Non-cantilever side 2.5	Median 5 (scale 1-6)	- Porcelain fracture (n=11) - Screw loosening (n≥16) - Early loss of implant (n=1)
Wu et al. 2013	NS	NR	-0.22 ± 0.41 mm	Score 0: 18.2% Score 1: 15.9% Score 2: 13.6% Score 3: 52.3%	Score 0: 13.6% Score 1: 43.2% Score 2: 36.4% Score 3: 6.8%	2.4±1.6	Mean 8.9 (possible score 0-10)	- Screw loosening (n=1)
Kim et al. 2014	NR	NR	NR	NR	NS	NS	NS	NS

NR: not reported

NS: not specified

*Papilla between the implant and the cantilever side of the implant-supported two-unit cantilever restoration.

Table 4. Implant probing depths (mm) at the proximal side facing the adjacent implant, midbuccally and at the proximal sides facing the adjacent tooth.

Location		Implant-Cantilever group			Implant-Implant group		
		T ₀	T ₁₂	T ₆₀	T ₀	T ₁₂	T ₆₀
		Mean±SD			Mean±SD		
Central implant	Proximal side facing adjacent tooth	3.4±0.89	3.4±1.52	3.2±0.45	2.2±0.84	2.2±0.84	2.4±1.14
	Midbuccaly	3.0±0.71	3.2±1.10	3.0±1.30	2.2±0.84	2.8±0.45	2.8±1.10
	Proximal side facing no implant / lateral implant	4.4±0.89	3.8±1.10	3.8±0.71	2.4±0.55	4.0±1.00	2.8±1.30
No implant/ lateral implant	Proximal side facing adjacent implant	NA	NA	NA	3.2±1.64	3.6±0.89	3.8±1.30
	Midbuccaly	NA	NA	NA	3.0±1.00	3.6±0.89	3.0±0.71
	Proximal side facing adjacent tooth	NA	NA	NA	2.8±0.45	3.81.30	3.2±0.84

NA, not applicable; T₀, evaluation visit directly after placement of the final implant restoration; T₁₂, evaluation visit 1 year after placement of the final implant restoration; T₆₀, evaluation visit 5 years after placement of the final implant restoration

Table 5. Frequency distribution of the papilla index scores up to 5 years after placement of the final implant restoration.

Location papillae	Implant-Cantilever group						Implant-Implant group					
	Central incisor-Implant		Implant-Cantilever		Cantilever-Cuspid		Central incisor-Implant		Implant-Implant		Implant-Cuspid	
Score	T ₁₂	T ₆₀	T ₁₂	T ₆₀	T ₁₂	T ₆₀	T ₁₂	T ₆₀	T ₁₂	T ₆₀	T ₁₂	T ₆₀
0	0	0	1	4	0	0	1	1	1	1	0	0
1	0	3	3	1	1	2	0	1	3	3	1	0
2	3	2	1	0	1	3	4	3	1	1	2	2
3	2	0	0	0	3	0	0	0	0	0	2	3
4	0	0	0	0	0	0	0	0	0	0	0	0

Score 0, no papilla formation; score 1, less than half of the papilla present; score 2, at least half of the papilla is present; score 3, papilla fills whole approximate space; score 4, abundance of papilla.
T₁₂, evaluation visit 1 year after placement of final implant restoration; T₆₀, evaluation visit 5 years after placement of the final implant restoration.

Table 6. Marginal bone levels and bone crest level and change (in mm) up to 5 years after placement of the implant.

		Implant-Cantilever group			
	Location	T_{post}	T_{12}	T_{60}	$T_{\text{post}} - T_{60}$
Mean $\pm$ SD					
Central implant	Marginal bone level facing the adjacent central incisor	-0.02 $\pm$ 0.04	0.88 $\pm$ 0.72	0.99 $\pm$ 0.73	-1.01 $\pm$ 0.74
	Marginal bone level facing no implant	0.06 $\pm$ 0.14	1.92 $\pm$ 1.23	2.12 $\pm$ 1.50	-2.06 $\pm$ 1.51
Bone crest	Bone crest level between central implant and no implant	-1.19 $\pm$ 0.09	-0.06 $\pm$ 1.92	1.58 $\pm$ 1.51	-2.77 $\pm$ 1.26
		Implant-Implant group			
	Location	T_{post}	T_{12}	T_{60}	$T_{\text{post}} - T_{60}$
Mean $\pm$ SD					
Central implant	Marginal bone level facing the adjacent central incisor	0.03 $\pm$ 0.08	0.95 $\pm$ 0.23	1.67 $\pm$ 0.53	-1.64 $\pm$ 0.54
	Marginal bone level facing lateral implant	0.37 $\pm$ 0.64	1.34 $\pm$ 0.32	1.84 $\pm$ 0.4	-1.47 $\pm$ 0.52
Bone crest	Bone crest level between central implant and lateral implant	-0.38 $\pm$ 0.60	0.96 $\pm$ 0.54	1.01 $\pm$ 0.59	-1.39 $\pm$ 0.52
Lateral implant	Marginal bone level facing the adjacent central implant	0.34 $\pm$ 0.46	1.37 $\pm$ 0.84	1.59 $\pm$ 0.89	-1.25 $\pm$ 1.00
	Marginal bone level facing the adjacent cuspid	0.43 $\pm$ 0.48	1.33 $\pm$ 0.26	1.67 $\pm$ 0.98	-1.24 $\pm$ 0.97

T_{post} , evaluation directly after implant placement; T_{12} , evaluation visit 1 year after placement of the final implant restoration; T_{60} , evaluation visit 5 years after placement of the final implant restoration.

Table 7. Scores of the patient satisfaction questionnaires.

Topics	Implant-Cantilever		Implant-Implant	
	T ₁₂	T ₆₀	T ₁₂	T ₆₀
	Mean±SD	Mean±SD	Mean±SD	Mean±SD
Shape of the restoration	3.8±0.4	3.6±0.9	3.4±1.3	3.4±0.9
Color of the restoration	4.0±0.0	3.8±0.4	3.8±0.4	4.0±0.0
Shape of the mucosa	2.8±1.1	3.0±0.7	3.2±1.3	3.6±0.5
Color of the mucosa	3.2±1.3	2.8±0.4	3.6±0.5	3.8±0.4
Overall score (range 0-10)	8.8±0.8	9.2±0.4	9.2±0.8	9.0±1.0

Implant restoration and mucosa score: scale 0, completely dissatisfied; 1, dissatisfied; 2, neutral; 3, satisfied; 4, completely satisfied.

Overall score: scale 0, completely dissatisfied to score 10, completely satisfied.

T_{12'} evaluation visit 1 year after placement of the final implant restoration;

T_{60'} evaluation visit 5 years after placement of the final implant restoration.

CHAPTER

07

Implant treatment of two failing or missing central incisors in the aesthetic region: A treatment proposal and 1-year prospective case series study

This chapter is an edited version of the manuscript:

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Abstract

Purpose: Implant treatment of two central incisors in the maxillary aesthetic region is complex due to concerns regarding inter-implant hard and soft tissue stability. A treatment protocol was therefore developed and implemented in a 1-year prospective case series study with 16 patients with two failing or missing central incisors in the maxillary aesthetic region.

Material and methods: The protocol consisted of five options depending on whether teeth were still present (options 1-3) or not (options 4 and 5) and on the amount of bone available at start of treatment: 1. Extraction, immediate implant placement and provisionalization, 2. Extraction, immediate implant placement, delayed provisionalization, 3. Extraction, ridge preservation, delayed implant placement and immediate provisionalization, 4. Delayed implant placement and guided bone regeneration, delayed provisionalization, 5. Guided bone regeneration (extensive bone augmentation of the alveolar ridge), delayed implant placement, delayed provisionalization. The case series was assessed regarding peri-implant hard and soft tissue parameters, aesthetic-index score and patient satisfaction.

Results: All treatment options showed good clinical and radiographical results and high patient satisfaction. The proposed implant treatment is assumed to be a useful tool.

Introduction

Failure of two adjacent central incisors in the maxillary aesthetic region creates a difficult challenge for dental professionals.^{1,2} Extraction of these teeth is often preceded by a history of trauma and endodontic treatment or retreatment. When these teeth must be removed, peri-apical inflammation and root resorption often result. Prior to the introduction of dental implants, such cases were usually treated with conventional fixed dental prostheses or removable partial dentures. Nowadays, implant treatment provides enables replacement of these failing teeth with implant-supported solutions.

Despite the high reported implant survival rates^{1,3}, placement of two adjacent implants in the aesthetic region is considered a complex treatment due to the risk of loss of peri-implant hard and soft tissue and aesthetic concerns, especially in the inter-implant region.⁴ The implant protocol that is used can influence the final outcome, especially peri-implant soft tissue aesthetics.⁵

In case of a single failing tooth in the maxillary aesthetic region, promising results have been reported regarding immediate implant placement and immediate provisionalization.^{6,7} In case of buccal bony defects, immediate implant placement with delayed provisionalization and delayed implant placement have shown their merit.⁸ However, no studies have been published on using such single-tooth implant protocols for two adjacent implants, so it is questionable whether these protocols can be extrapolated to adjacent implant treatment.

In the study presented here, we developed an implant treatment protocol consisting of five treatment options on replacing two adjacent failing or missing central incisors in the maxillary aesthetic region. To assess the outcome of these treatment options, they were tested in a 1-year case series study.

Material and methods – Treatment protocol for two central incisors

Based on an established treatment protocol for single tooth replacement in the maxillary aesthetic region^{7,8}, the following division into 5 treatment options was made for two failing or missing central incisors (Fig. 1):

Extraction of failing teeth and consecutive treatment:

- Option 1: *Immediate implant placement and provisionalization*
- Option 2: *Immediate implant placement, delayed provisionalization*
- Option 3: *Ridge preservation, delayed implant placement, immediate provisionalization*

Healed site and consecutive treatment:

- Option 4: *Implant placement and guided bone regeneration, delayed provisionalization*
- Option 5: *Guided bone regeneration (extensive bone augmentation on the buccal and palatal aspect of the alveolar ridge), delayed implant placement, delayed provisionalization*

Preoperative screening

Medical history and periodontal condition are assessed. The keratinized mucosa (KM) is measured to ensure a KM thickness of $\geq 2\text{mm}^9$. A Cone Beam Computed Tomogram (CBCT) is taken to determine if there is sufficient palatal bone volume for primary implant stability. Based on the bone conditions of the CBCT and presence or absence of failing teeth, a preliminary treatment choice is made (Fig. 1).

Options 1-3: *Failing teeth, post-extraction assessment, consecutive treatment*

In case of failing teeth, mid-buccal mucosa levels of the failing teeth are assessed preoperatively for asymmetries with their neighbouring teeth. Symmetrical mucosa levels allow immediate implant placement and provisionalization (**option 1**). Asymmetries of $\geq 2\text{ mm}$ exclude the possibility of immediate provisionalization (**option 2**).

Next, extraction is performed without raising a flap. The alveolar bone geometry is assessed by a bone sounding technique with a periodontal probe (Williams Color-Coded probe, Hu-Friedy, Chicaco, IL, USA) at the buccal, mesial and distal aspect of the failing teeth and the proximal sides of the adjacent teeth facing the alveoli. In case of a post-extraction defect of the buccal bone wall, this defect is measured to determine the treatment option. A bony defect and a distance, measured in a vertical direction from the bony defect of the buccal bone wall to the mucosa at the cement-enamel junction of the adjacent tooth, of $\leq 5\text{ mm}$ (for example: 3 mm bony defect and 2 mm mucosa) allows immediate implant placement and provisionalization (**option 1**). A distance of $>5\text{ mm}$ excludes the possibility of immediate provisionalization (**option 2**). When no primary implant stability could be reached, **option 3** is applied.

Option 1: *Immediate implant placement and provisionalization*

Symmetrical mucosa levels, sufficient palatal bone (CBCT) for primary implant stability and a buccal

defect of ≤ 5 mm allows immediate implant placement and provisionalization (Fig. 2a). After removal of the teeth, two implant sites are prepared on the palatal side of the alveoli using a surgical template representing the ideal position of the prospective implant restorations. The last used implant drill, depending on the diameter of the implants used, is placed in the prepared alveoli. The space remaining between the implant drill and the peri-implant bone is locally augmented. As grafting material, a 1:1 mixture of autogenous bone, harvested from the tuberosity region, and inorganic bone (Geistlich Bio-Oss®, Geistlich, Pharma AG, Wolhusen, Switzerland) is used. Two implants with an expanding taper (NobelActive, Nobel Biocare AG, Kloten, Switzerland) are then inserted 3 mm apical of the most apical aspect of the prospective implant restoration. Primary stability is achieved with insertion torque of ≥ 45 Ncm. Within 24 hours after implantation, two non-occluding screw-retained provisional restorations are placed. Three months later, two final screw-retained implant restorations are fabricated and fixated on the implants (Fig 2b).

Option 2: *Immediate implant placement, delayed provisionalization*

Sufficient palatal bone (CBCT) for primary stability of the implants, asymmetrical mucosa levels of >2 mm and/or a buccal defect of >5 mm allows immediate implant placement and delayed provisionalization. The implant sites are prepared in the same manner as in option 1 and the space remaining between the last implant drill and the peri-implant bone and buccal bony defects are augmented with a 1:1 mixture of autogenous bone and inorganic bone (Bio-Oss®). Next, two implants with an expanding taper (NobelActive) are inserted with the aid of a surgical template with insertion torque of ≥ 45 Ncm. Both implant sites are closed with a mucosagraft, harvested from the tuberosity region. After 2 weeks of soft tissue healing, the sutures are removed. Following a 3-month submerged healing phase, two occluding screw-retained provisional restorations are placed. Six months after implant placement, two final screw-retained implant restorations are fabricated and fixated on the implants.

Option 3: *Ridge preservation, delayed implant placement and immediate provisionalization*

A lack of palatal bone (CBCT), compromising primary stability of the implants, and a buccal defect of >5 mm, precludes options 1 and 2. The alveoli are augmented with a 1:1 mixture of autogenous bone from the tuberosity region and inorganic bovine bone (Bio-Oss®). Next, both alveoli are closed with a mucosagraft, harvested from the tuberosity region. After 2 weeks of soft tissue healing, the sutures were removed. Following a 3 month healing phase, two implants with an expanding taper (NobelActive) are inserted with the aid of a surgical template representing the ideal position of the prospective implant restorations. Primary stability is achieved with insertion torque of ≥ 45 Ncm. Within 24 hours after implant placement, two non-occluding screw-retained provisional restorations are placed. Three months after implant placement, two final screw-retained implant restorations are fabricated and fixated on the implants.

Options 4 and 5: *Healed site and consecutive treatment*

If a healed site is present, buccal and palatal full thickness flaps are raised to assess the bone

geometry and the subsequent treatment is chosen.

Option 4: *Implant placement and guided bone regeneration, delayed provisionalisation*

Sufficient palatal bone (CBCT) for primary implant stability allows delayed implant placement. First, two implants with an expanding taper (NobelActive) are inserted with the aid of a surgical template representing the ideal position of the prospective implant restorations. Primary stability is achieved with insertion torque of ≥ 45 Ncm. If parts of the implant remained uncovered or the buccal bone wall thickness is < 2 mm¹⁰, a local augmentation procedure is performed with a mixture of autogenous bone chips collected during implant bed preparation and inorganic bovine bone (Bio-Oss®), which is covered with a resorbable collagen membrane (Geistlich Bio-Gide®, Geistlich). The wounds are primarily closed with non-resorbable sutures. After 2 weeks of soft tissue healing, the sutures are removed. Following a 3-month submerged healing phase, two occluding screw-retained provisional restorations are placed. Six months after implant placement, two final screw-retained implant restorations are fabricated and fixated on the implants.

Option 5: *Guided bone regeneration (extensive bone augmentation of the alveolar ridge), delayed implant placement, delayed provisionalization*

Insufficient bone (CBCT) for primary stability of the implants necessitates an extensive guided bone regeneration procedure. The bony defects are reconstructed with autogenous bone blocks harvested from the retromolar region. The wounds are primarily closed with non-resorbable sutures. After 2 weeks of soft tissue healing, the sutures are removed. Following a 3-month healing phase, a full thickness flap is raised and two implants with an expanding taper (NobelActive) are placed with the aid of a surgical template representing the ideal position of the prospective implant restorations. Next, the wounds are closed primarily with non-resorbable sutures. After 2 weeks of soft tissue healing, the sutures are removed. Following a 3-month submerged healing phase, two occluding screw-retained provisional restorations are placed. Six months after implant placement, two final screw-retained implant restorations are fabricated and fixated on the implants.

Materials and methods – Case Series

Study design

Consecutive patients referred to the department of Oral and Maxillofacial Surgery of the University Medical Center Groningen (University of Groningen, Groningen, the Netherlands) between April 2011 and July 2015 with two failing or missing maxillary central incisors were enrolled in the study. All eligible patients were informed about the features of the study and gave their informed consent before enrolment.

Inclusion criteria

Fulfilment of the inclusion criteria was verified by clinicians at the screening session, including:

- ≥ 18 years of age;
- failing or missing teeth are central upper incisors;
- natural teeth are located distally (region 12 and 22) and opposing the failing or missing teeth;
- adequate oral hygiene;
- sufficient mesial-distal, buccal-palatal and interocclusal space for placement of implants and final restorations;
- sufficient interocclusal space to design non-occluding provisional restorations.

Exclusion criteria

- medical and general contraindications for the surgical procedure (ASA score $\geq III^{11}$);
- presence of active periodontal disease (pocket probing depths ≥ 4 mm and bleeding on probing);
- excessive smoking (≥ 10 cigarettes per day);
- history of head and neck radiotherapy;
- pregnancy.

Depending on the presence or absence of teeth and the available bone and soft tissue, patients were allocated to one of five treatment options (Fig. 1). The surgical and prosthetic procedures have been described in detail by Slagter et al.⁷ All surgical procedures were performed by one oral and maxillofacial surgeon (G.M.R.). All prosthetic procedures were done by one prosthodontist (H.J.A.M.).

Outcome measures

Study parameters were collected at three time points: two weeks after implant surgery (T_{post}), within one month after placement of the final implant restoration (T_1), and one year after placement of the final implant restoration (T_{12}). All clinical parameters at T_1 and T_{12} were assessed by one examiner (W.G.V.N.). The following parameters were assessed:

- implant survival (T_{12});¹²
- biological and technical complications (T_{12});
- change in marginal bone levels (T_{post} - T_{12});
- change in inter-implant bone crest level (T_{post} - T_{12});
- implant probing depths (T_1 and T_{12});
- papilla Index (T_1 and T_{12});¹³
- plaque index (T_1 and T_{12});¹⁴
- gingiva index (T_1 and T_{12});¹⁵
- bleeding index (T_1 and T_{12});¹⁴
- Pink Esthetic Score and White Esthetic Score (PES-WES) (T_{12});¹⁶
- patient satisfaction (T_{12}).¹⁷

Implant survival

Implant survival was defined as the percentage of functional implants at follow-up (T_{12}).

Radiographic assessment

Digital periapical radiographs (Planmeca Intra X-ray unit; Planmeca, Helsinki, Finland) were taken at T_{post} , T_1 and T_{12} using a paralleling technique. The known length and width of the implants were used to calibrate the radiographs. The implant collar was used as a reference line to determine the following measurements to the nearest 0.1 mm:³

- marginal bone level facing the adjacent teeth (MBL-t);
- marginal bone level facing the adjacent implant (MBL-ii);
- inter-implant bone crest level (BC-ii).

All radiographic measurements were performed twice by one examiner (W.G.V.N.), after which the average of both measurements was used.

Aesthetic assessment

Aesthetic outcome was assessed on standardized digital photographs¹⁷ (Canon EOS 650 with ring flash, Canon Inc., Ota, Tokyo, Japan) taken at T_{12} . Peri-implant soft tissue and implant crown aesthetics were determined with the PES-WES. All measurements were performed blinded by two examiners (H.J.A.M., W.G.V.N.) in random order.

Patient satisfaction

Patients received a validated questionnaire¹⁷ prior to the assessment at T_{12} and were asked to complete questions relating to overall satisfaction score (numeric rating scale 0-10, 10 highest possible score), satisfaction regarding colour of the implant restoration and mucosa and the shape of the implant restoration and mucosa (numeric rating scale 0-4, 4 highest possible score).

Statistical analysis

Due to the small number of patients, descriptive statistics were used.

Results

Patient characteristics

During the inclusion period, 16 eligible consecutive patients were treated according to the implant treatment protocol presented above (option 1: n=4, option 2: n=3, option 3: n=3, option 4: n=3, option 5: n=3). This group consisted of 9 males (mean age: 29 years, range: 18-63) and 7 females (mean age: 36 years, range: 18-55). All patients were treated according to the treatment protocol after pre-operative assessment. All patients received the clinical assessments at T_1 and T_{12} .

Implant survival

No implants were lost during the 1-year follow-up (implant survival rate 100%). Morbidity of donor sites was low and wound healing of the grafting sites and implant sites was uneventful. No sensory disturbances occurred.

Biological and technical complications

No biological and technical complications were seen during follow-up.

Radiographic assessment

The changes in BC-ii, MBL-ii and MBL-t between T_{post} - T_1 and T_1 - T_{12} are shown in Table 1. The total mean ($\pm$ SD) change in BC-ii between T_p - T_{12} ranged from -0.21 ± 0.56 mm (option 4) to -1.94 ± 2.48 mm (option 2). The total mean change in MBL-ii between T_p - T_{12} ranged from -0.21 ± 0.05 mm (option 4) to -1.16 ± 1.60 mm (option 2). The total mean change in MBL-t between T_p - T_{12} ranged from -0.20 ± 0.37 mm (option 1) to -0.64 ± 0.48 mm (option 5).

Clinical assessment

Health of the keratinized gingiva remained stable. Papilla index scores of the inter-implant papilla and the papillae facing the adjacent teeth at T_1 and T_{12} are listed in Table 2. All treatment options showed incomplete fill of peri-implant papillae at T_1 and T_{12} . The implant probing depths of both proximal sides (facing the implant and adjacent teeth) and midbuccally at T_1 and T_{12} are listed in Table 3. All implant probing depths were low and did not exceed 3.2 mm. The gingiva index scores were low at T_1 and T_{12} , with no mucosal inflammation (score 0) or mild inflammation (score 1) seen for all options. In addition, bleeding index scores were low at T_1 and T_{12} for all options, with no bleeding (score 0) or isolated bleeding spots found after probing (score 1). Plaque scores were very low (score 0= no plaque) during follow-up, with the exception of one patient (option 4) at T_{12} (score 2: plaque visible to the eye).

Aesthetic assessment

The PES-WES scores at T_{12} are listed in Table 5. The mean ($\pm$ SD) PES score ranged from 5.33 ± 2.08 (option 3) to 7.75 ± 0.96 (option 1).

Patient satisfaction

Patient satisfaction scores at T₁₂ are listed in Table 6. Overall satisfaction scores were very high for all options (range 8.67-10.00).

Discussion

In the study presented here we propose a protocol with five implant treatment options for specific conditions accompanying two failing or missing central incisors in the maxillary aesthetic zone. This protocol was tested in a case series study consisting of patients with two failing or missing maxillary central incisors and differences in the degree of bone resorption. The study resulted in a 1-year survival rate of 100%, good clinical and radiographical results and high patients satisfaction for all treatment options.

Ours is the first study to report on the treatment outcome of two adjacent implants in the maxillary central incisor region. Regarding the maxillary aesthetic zone in general, a randomized controlled trial by Tymstra et al.¹ described a 1-year survival rate of 100% for two adjacent implants when using a delayed implant placement and provisionalization protocol.

In our study, inter-implant marginal bone loss was acceptable for all options and ranged from 0.21 to 1.19 mm. In comparison, Tymstra et al.¹ reported a mean 1-year inter-implant marginal bone loss of 0.9mm (delayed implant placement, NobelReplace implants, Nobel Biocare AG). Loss of inter-implant bone crest was evident after extraction of the failing teeth (options 1-3) and continued after placement of the final implant restoration (options 1-3). This suggests that continuing inter-implant bone loss should be expected after extraction of failing teeth, regardless of the treatment protocol used.

The inter-implant papilla was best preserved when implants were placed using an immediate placement protocol (options 1 and 2), although a decrease in papilla fill was still observed after placement of the final implant restoration. Additionally, all options were associated with compromised inter-implant papilla fill after placement of the final implant restoration, which is in line with previous studies using adjacent implants in the maxillary aesthetic zone.¹⁻³

The PES was scored the highest when implants were placed immediately (options 1 and 2), suggesting that additional surgical interventions and lower papilla index scores might negatively influence pink aesthetics. Overall satisfaction was very high for all options, however. These findings might reflect patient satisfaction with a fixed dental solution instead of a removable partial denture. Similar patient satisfaction scores have been reported in earlier studies assessing the treatment outcome of adjacent implants in the maxillary aesthetic zone.¹⁻³

A limitation of the present case series is the small number of patients. However, the clinical and radiographic results and the high patient satisfaction indicate that the treatment protocol proposed here for two failing or missing central incisors in the maxillary aesthetic zone is an effective guideline for clinicians on how to treat these patients.

Conclusion

Based on the favourable clinical and radiographic results and the high patient satisfaction scores, the proposed implant treatment protocol for two failing or missing central incisors in the maxillary aesthetic zone can be assumed to be a useful tool.

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Conflict of interest

No conflict of interest declared.

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Figure 1. Flow chart for implant treatment of two failing or missing teeth.

Figure 2a. Preoperative photo of two failing maxillary central incisors.

Figure 2b. Photo of the final implant restorations, taken within one month after placement of the final implant restoration (T_1)

Table 1. Change in marginal bone levels and inter-implant bone crest level.

Location	Option 1 n=4		Option 2 n=3		Option 3 n=3		Option 4 n=3		Option 5 n=3	
	T_p-T_1	T_1-T_{12}	T_p-T_1	T_1-T_{12}	T_p-T_1	T_1-T_{12}	T_p-T_1	T_1-T_{12}	T_p-T_1	T_1-T_{12}
	Mean $\pm$ SD		Mean $\pm$ SD		Mean $\pm$ SD		Mean $\pm$ SD		Mean $\pm$ SD	
BC-ii	-0.92	-0.53	-1.41	-0.53	-1.20	-0.62	-0.09	-0.12	-0.20	-0.37
	± 0.72	± 0.90	± 1.40	± 1.22	± 1.61	± 0.40	± 0.52	± 0.13	± 0.60	± 0.30
MBL-ii	-0.10	-0.19	-0.86	-0.30	-0.57	-0.26	-0.38	+0.17	-0.53	+0.06
	± 0.29	± 0.41	± 0.61	± 1.00	± 0.67	± 0.43	± 0.40	± 0.39	± 0.32	± 0.24
MBL-t	-0.13	-0.07	-0.24	-0.03	-0.61	+0.02	-0.38	+0.20	-0.58	-0.06
	± 0.16	± 0.31	± 0.52	± 0.40	± 0.76	± 0.14	± 0.36	± 0.44	± 0.28	± 0.20

BC-ii = change in inter-implant bone crest level

MBL-ii = change in inter-implant marginal bone level

MBL-t. = change in implant marginal bone level, facing the adjacent teeth

T_p (post) = directly after implant placement

T_1 = 1 month after placement of the final implant restoration

T_{12} = 1 year after placement of the final implant restoration

Table 2. Papilla index scores

Location	Option 1 n=4		Option 2 n=3		Option 3 n=3		Option 4 n=3		Option 5 n=3	
	T ₁	T ₁₂	T ₁	T ₁₂	T ₁	T ₁₂	T ₁	T ₁₂	T ₁	T ₁₂
	Mean±SD		Mean±SD		Mean±SD		Mean±SD		Mean±SD	
Between implants	1.25 ±0.96	0.75 ±0.50	1.33 ±0.58	1.00 ±1.00	0.33 ±0.58	0.33 ±0.58	0.33 ±0.58	0.00 ±0.00	0.33 ±0.58	0.33 ±0.58
Towards adjacent teeth	1.87 ±0.75	1.62 ±0.75	2.00 ±0.50	2.17 ±0.76	1.50 ±0.50	1.67 ±0.29	1.50 ±0.00	1.33 ±0.29	1.33 ±0.76	1.00 ±0.87

Papilla index:

score 0 = no papilla formation

score 1 = less than half of papilla is present

score 2 = at least half of the papilla is present

score 3 = papilla fills whole approximate space

score 4 = abundance of papilla/hyperplastic papilla.

T₁ = 1 month after placement of the final implant restoration

T₁₂ = 1 year after placement of the final implant restoration

Table 3. Implant probing depths (mm) measured around implants at the proximal sides facing the adjacent implant, midbuccally and the proximal sides facing the adjacent tooth.

Location	Option 1 n=4		Option 2 n=3		Option 3 n=3		Option 4 n=3		Option 5 n=3	
	T ₁	T ₁₂	T ₁	T ₁₂	T ₁	T ₁₂	T ₁	T ₁₂	T ₁	T ₁₂
	Mean±SD		Mean±SD		Mean±SD		Mean±SD		Mean±SD	
Proximal sides facing adjacent implant	3.00 ±0.87	2.87 ±0.85	2.33 ±0.58	2.67 ±1.15	2.83 ±0.76	3.00 ±0.00	2.50 ±0.50	3.17 ±1.15	2.67 ±0.29	3.00 ±0.50
Midbuccally	2.50 ±0.58	2.25 ±0.50	2.00 ±0.00	2.33 ±0.58	2.67 ±0.76	2.67 ±0.58	2.33 ±0.58	2.83 ±1.04	2.00 ±0.00	2.67 ±0.58
Proximal sides facing adjacent tooth	3.12 ±0.63	3.00 ±0.82	2.33 ±0.58	2.33 ±0.58	2.17 ±0.29	2.67 ±0.58	2.50 ±0.00	2.50 ±0.50	2.17 ±0.58	2.50 ±0.50

T₁ = 1 month after placement of the final implant restoration

T₁₂ = 1 year after placement of the final implant restoration

Table 4. PES-WES scores.

	Option 1 n=4	Option 2 n=3	Option 3 n=3	Option 4 n=3	Option 5 n=3
	T_{12}	T_{12}	T_{12}	T_{12}	T_{12}
	Mean±SD	Mean±SD	Mean±SD	Mean±SD	Mean±SD
PES	7.75±0.96	7.00±1.00	5.33±2.08	5.67±1.15	5.67±0.58
WES	7.50±3.00	5.33±1.53	6.33±1.15	7.67±0.58	6.67±1.53
PES-WES	15.25±3.59	12.33±2.52	11.67±1.53	13.33±0.58	12.33±2.08

T_{12} = 1 year after placement of the final implant restoration

Table 5. Results of the patients' questionnaire.

	Option 1 n=4	Option 2 n=3	Option 3 n=3	Option 4 n=3	Option 5 n=3
	T_{12}	T_{12}	T_{12}	T_{12}	T_{12}
	Mean±SD	Mean±SD	Mean±SD	Mean±SD	Mean±SD
Overall score	9.00±1.15	8.67±0.58	9.33±1.15	10.00±0.00	9.33±0.58
Colour of mucosa	3.75±0.50	3.33±0.58	3.67±0.58	3.67±0.58	3.67±0.58
Shape of mucosa	3.5±0.58	3.00±1.00	3.67±0.58	3.00±1.00	3.33±1.15
Colour of restoration	3.75±0.50	3.67±0.58	4.00±0.00	4.00±0.00	4.00±0.00
Shape of restoration	4.00±0.00	3.67±0.58	3.67±0.58	4.00±0.00	4.00±0.00

T_{12} = 1 year after placement of the final implant restoration

Overall satisfaction score (range 0-10); 0 = very dissatisfied, 10 = very satisfied

Satisfaction score mucosa and crown (range 0-4); 0 = very dissatisfied, 4 = very satisfied

CHAPTER

08

General discussion

General discussion

Failing or missing teeth in the maxillary aesthetic region create a difficult challenge for patients and dental professionals, because of aesthetic concerns and patient's expectations. In case of single failing teeth, immediate implant placement is considered a fast and well-established treatment protocol with excellent short-term results¹ and high patient satisfaction,² but long-term results are scarce. Furthermore, concerns exist about peri-implant soft tissue stability when immediate implant placement is applied.³

If two adjacent teeth in the maxillary aesthetic region are failing or missing, implant treatment is often a reasonable option. Placement of two single implant-supported restorations, using a delayed implant placement protocol, has shown good short-term results with regard to implant survival, peri-implant marginal bone loss and patient satisfaction.⁴ However, when two implants are placed adjacent to each other, inter-implant bone crest height is difficult to maintain⁵ and inter-implant papilla height is often compromised.⁶ These issues are particularly factors to consider when implants are placed at the location of the lateral and central incisor as there is often insufficient horizontal space for placement of two adjacent implants. An alternative treatment at this location is placement of one single implant-supported cantilever restoration, using a delayed implant placement protocol. This approach has shown good short term results with regard to peri-implant marginal bone loss and patient satisfaction⁷. It was unknown, however, whether these satisfactory results can be achieved on long-term, as long-term research on both treatment types in the maxillary aesthetic region is non-existent. As a result, it was unclear whether inter-implant bone crest height and peri-implant papilla height remain stable on long-term. Both issues have been studied in the studies reported in this thesis.

Additionally, a variety of implant protocols has been described for single implant placement in the maxillary aesthetic region⁸. Again, it was unknown whether these existing protocols are equally successful when used for placement of two adjacent implants in the maxillary aesthetic region, since no comparative studies were available. Therefore, the general aim of the research described in this thesis was to assess a variety of treatment strategies for one or two failing or missing teeth in the aesthetic region.

Immediate implant placement and provisionalization

The studies in this thesis demonstrate an excellent medium-term survival rate of immediately placed and provisionalized implants in the aesthetic region (**chapter 2**). This medium-term survival rate reported is comparable to the short-term survival rate described in a systematic review by Slagter et al.¹ Studies with a follow-up >1 year on immediate implant placement and provisionalization in the aesthetic region are still few in number, but also commonly show excellent results, often reaching implant survival rates of 100%.^{2,3,9-13} However, these high survival rates commonly reported in studies on immediate placement and provisionalization that have been published between 2008 and 2018 might be biased by the very strict inclusion criteria used in these studies¹⁴, excluding patients with risk factors that might affect the outcome of implant therapy (for example: uncontrolled diabetes

mellitus or active periodontal disease). Notwithstanding this limitation, survival rate of immediately placed and provisionalized implants in the aesthetic region nowadays seems to be a less debatable issue than when immediate implant placement was introduced in 1989.¹⁵

In the various studies described in this thesis, also favourable results were reported with regard to peri-implant marginal bone loss. Bone levels were stable after 4 years following immediate implant placement and provisionization (**chapter 2**), at least when using a platform-switched stock abutment for the screw-retained provisional restoration and a platform-switched individual abutment on which the final implant restoration was cemented. Studies are available for comparison^{3,9-11,13}, but the heterogeneity of inclusion criteria and surgical and prosthetic protocols used in these studies impede the possibility of comparison with identical studies. Kan et al.⁹ and Paul et al.¹¹ reported a higher marginal bone loss after a mean follow-up period of 4 and 3.4 years, respectively. Both studies did not include platform switched abutments as well as that Paul et al.¹¹ used implants with a scalloped collar design, which are thought to induce higher marginal bone loss than conventional implant platform designs in the aesthetic region.¹⁶ Two more recent studies, with a follow-up period of 2 years (Mangano et al.¹⁰) and 5 years (Cosyn et al.³), using platform-switched abutments and similar treatment protocols, reported results comparable to the marginal bone loss reported in this thesis. The recent study by Kolerman et al.¹³, using platform-switched abutments and similar treatment protocols, reported a higher marginal bone loss after a mean follow-up period of 3.7 years, however. Kolerman et al.¹³ also reported 51% of their patients as having gingivitis and/or mild adult chronic periodontitis and 49% as having chronic moderate/advanced adult periodontitis or aggressive periodontitis¹³, which can be seen as a risk for peri-implantitis¹⁷ and possibly higher marginal bone loss. Therefore, the results of the studies reported in this thesis endorse the use of strict inclusion criteria and careful case selection with regard to immediate implant placement and provisionalization in the aesthetic region (**chapter 2 and 3**).

With regard to peri-implant soft tissues, stability of the mid-buccal mucosa level was found to improve when a connective tissue graft (CTG) was applied in concurrence with immediate implant placement and provisionalization (**chapter 3**). Earlier studies also found less vertical loss of the mid-buccal mucosa when a CTG was applied.^{12,18} The mid-buccal mucosa volume after implant placement, transformed to a change in mucosal thickness, was found to decrease during 1-year when a CTG was applied and even tended to result in more volume loss when compared to immediate implant placement and provisionalization without the application of a CTG (**chapter 3**). This observation leads to the assumption that the use of a CTG cannot fully compensate for the mid-buccal volume loss caused by underlying bone loss of the buccal bone wall following immediate implant placement.

Change in buccal bone thickness after immediate implant placement and provisionalization was also investigated in this PhD research (**chapter 4**). In patients with a CTG, a tendency for a higher buccal bone loss was found compared to patients without a CTG. A possible explanation to this phenomenon is that the surgical intervention needed to position the CTG submucosally might induce additional bone loss by compromising the vascularization of the mucosa and bone in that area. However, post-extraction buccal bone thickness also has to be recognized as an important

risk factor for buccal bone loss and soft tissue alterations. Chappuis et al.¹⁹ showed that in case of a post-extraction thin buccal bone wall phenotype (<1 mm), significantly higher bone and soft tissue alterations were found. Due to the fact that this thesis did not include post-extraction buccal bone wall phenotype as a risk-factor, the exact influence of a CTG on changes in buccal bone thickness, mid-buccal mucosa volume and mid-buccal mucosa level remains unclear.

The studies in this thesis showed that immediate implant placement and provisionalization resulted in good soft tissue aesthetics (**chapters 2 and 3**), when measured by dental professionals with the Pink Esthetic Score (PES)^{20,21}, with similar findings reported by literature.^{2,13} Our findings, however, also indicate that the overall PES was negatively influenced by peri-implant papillae fill, often showing compromised peri-implant papillae height at short-term (**chapter 3**) and medium-term follow-up (**chapter 2**). The use of a CTG also was found to have a negative effect on the overall PES by changes in the texture of the mid-buccal mucosa, possibly caused by scar tissue as a result of the surgical intervention used to place the CTG (**chapter 3**). In contrast, the overall PES was positively influenced by a CTG as a result of the more stable mid-buccal mucosa levels. As a result, no significant differences were found in the overall PES of immediately placed implants with or without a CTG. The results of the PES suggest that compromised peri-implant papillae should be discussed with patients as a possible downside of immediate implant placement and provisionalization in the aesthetic region, regardless whether a CTG is used or not. This also applies to possible scar tissue after the application of a CTG.

Patient satisfaction, measured with a question regarding overall satisfaction and questions regarding the colour and shape of the implant crown (**chapter 2**) and the colour and shape the peri-implant mucosa (**chapters 2 and 3**), was also found to be very high in the studies reported in this thesis. This result is in agreement with literature, where immediate implant placement and provisionalization is associated with high subjective patient satisfaction.² In this thesis, the use of a CTG did not lead to a significantly higher patient satisfaction rate (**chapter 3**).

Soft tissue aesthetics, measured by patients and dental professionals in our studies, were given the highest scores by patients through subjective patient questionnaires. This phenomenon was also reported by Hartlev et al.² who suggested that dental professionals were more critical with regard to the pink aesthetics in the aesthetic region than the average patient.

With regard to the placement of a CTG, the results of this thesis suggest that a CTG should not be used as a standard treatment in concurrence with immediate implant placement in the aesthetic region. However, in case of a preoperative asymmetry in mid-buccal mucosa level of the failing tooth, or when mid-buccal mucosa recession occurs after implant placement, placement of a CTG should be considered to restore symmetry in the mid-buccal mucosa levels of the implant restoration and its neighbouring teeth.

Treatment of two missing teeth with two adjacent implants in the aesthetic region

When two adjacent implants with a scalloped or flat implant platform were placed in the aesthetic region, using a delayed placement and loading protocol, excellent results with regard to the 5-year implant survival for both implant designs and patient satisfaction were observed (**chapter 5**). There

are, however, concerns with regard to the clinical and radiographical outcome of the scalloped implant platform design. The scalloped implant platform was originally designed for better maintaining the peri-implant bone crest and soft tissue levels in the aesthetic region by its scalloped implant collar that resembles the emergence profile of natural teeth.²² The studies reported in this thesis show that the scalloped implant platform design results in significantly more loss of peri-implant marginal bone and height of the inter-implant bone crest compared to the conventional implant platform design after 5 years (**chapter 5**). Similar findings with regard to marginal bone loss were reported in studies with single scalloped implants in the aesthetic region.^{23,24} The higher marginal bone loss and bone crest loss around scalloped implants is presumed to be caused by two factors. First, the scalloped implant platform is of a larger diameter than the conventional implant platform, resulting in less horizontal distance between the adjacent implants (3.2 mm vs 3.8 mm). Second, when implants are placed in (too close) proximity of each other, the lateral resorption areas of these implants overlap which could have resulted in higher marginal bone loss and more pronounced loss of the inter-implant bone crest.²⁵ Despite the higher bone loss, being evident around scalloped implant platforms, no differences in inter-implant papilla fill were found in our studies, with both implant platform designs showing a compromised papilla height. This corresponds with the findings of Kourkouta et al.⁶ who also found a compromised inter-implant papilla height using a delayed implant placement protocol and a flat implant platform design.

Nowadays, the inter-implant distance is presumed to have less effect on inter-implant bone loss, since most implant systems use platform switched abutments and this type of abutment connection seems to reduce peri-implant bone loss.²⁶ It is still unclear, however, what kind of influence platform switching has on inter-implant bone loss in the aesthetic region, since only one study has thus far been undertaken using platform switched abutments (**chapter 7**).

The aesthetic outcome of two adjacent implants, rated with the Implant Crown Aesthetic Index (ICAI)²⁷, was judged to be poor in most patients due to the (partial) absence of inter-implant papillae without showing differences between both implant platform designs (**chapter 5**). These results are of importance when discussing the clinical and aesthetic outcome with patients, but do not seem to affect patients satisfaction on long-term. Patients were very satisfied with two adjacent implants in the aesthetic region, regardless of the implant platform design used and the presence or absence of inter-implant papillae (**chapter 5**). This difference in rating aesthetics by patients and professionals was also found by Meijndert et al.²⁸, using the ICAI. A possible explanation to this phenomenon could be that a large group of patients in our studies with two adjacent implants had experienced dental trauma in the past and had undergone augmentation procedures to compensate for the large bony defects that were present preoperatively. In addition, most patients wore removable partial dentures before and during several months of implant treatment. Therefore, the final treatment result after placement of the final implant restorations was probably very satisfying to these patients. As a result, factors that are considered important to the aesthetic outcome by professionals may not be of paramount importance to patients.²⁹

Treatment of two missing teeth with one single implant-supported cantilever restoration

In search for an alternative to implant treatment with two adjacent implants, a systematic review on single implant-supported cantilever restorations in the anterior and posterior maxilla and mandible was performed (**chapter 6**). Only 5 studies could be included with a follow-up period ranging from 1 to 4.2 years³⁰⁻³⁴, highlighting the necessity for additional and long-term research. Despite limitations in study design (no RCT's and CCT's were included) and heterogeneity of studies included, the implant survival rate was found to be high and low implant probing depths were reported.³¹⁻³³ No conclusions with regard to peri-implant bone loss and papilla fill or height could be made due to large differences between the included studies or underreporting. One study, reporting on single implant-supported cantilever restorations in the posterior maxilla and mandible, experienced several cases of porcelain fracture and screw loosening during the 3-year follow-up period.³² These technical complications are thought to be the result of high masticatory forces that are applied in the posterior maxilla and mandible.

Patient satisfaction was found to be very high for single-implant supported cantilever restorations³¹⁻³³ and similar to studies with two adjacent implants in the maxillary aesthetic region.^{6,35} This finding should be taken into consideration when discussing implant treatment with patients who have two missing teeth in the maxillary aesthetic region. In addition, a single implant-supported cantilever restoration is a less expensive treatment option compared to two single implant-supported restorations for patients with two missing teeth in the aesthetic region, which could act as a financial incentive for patients to choose for the single implant based solution. More research is needed on single-implant supported cantilever restorations, especially in the posterior maxilla and mandible before any recommendations can be made for this treatment option.

In case of a missing central and lateral incisor in the maxillary aesthetic region, the available mesial-distal space is sometimes too limited for placement of two adjacent implants as well as that implant treatment shifts automatically to placement of a single implant-supported cantilever restoration. To gain further insight into this issue, the 5-years results of the comparative case-control study of Tymstra et al.³¹ were obtained in which single implant-supported cantilever restorations were compared to two adjacent implant-supported restorations in the maxillary aesthetic region (**chapter 6**). After 5 years, both treatment groups displayed low scores in peri-implant papilla fill, measured with the papilla index by Jemt et al.³⁶, pointing towards compromised papillae. The single implant-supported cantilever restorations were also accompanied by a further decrease of papilla fill between 1 and 5 years, located between the implant and the cantilever side of the restoration, whereas the papilla fill between two implants remained stable. This decrease in papilla fill was also reflected by ongoing loss of the bone crest on the cantilever side of the implant which was found to be higher than the inter-implant bone crest loss after 5 years. Despite these changes, peri-implant probing depths and patient satisfaction remained stable throughout the 5-year follow-up period, with no relevant differences between both treatment options. Single implant-supported cantilever restorations therefore seem a sensible treatment alternative when there is limited space available for placement of two adjacent implants restorations in the aesthetic region, but further research is needed to monitor the long-term stability of peri-implant hard and soft tissues.

Implant treatment strategies for two failing or missing teeth in the aesthetic region

In response to the absence of implant treatment protocols for two failing and missing teeth, a clinical guideline and implant treatment protocol on was developed on how to treat two failing or missing teeth in the maxillary aesthetic region (**chapter 7**) and implemented in a 1-year prospective case series study on two failing or missing maxillary central incisors (**chapter 7**). The intent of this treatment protocol was to provide reasonable treatment options (3 options for failing teeth, 2 for missing teeth) which include frequently used combinations of immediate and delayed implant placement and loading protocols as commonly used at the Department of Oral and Maxillofacial Surgery in the University Medical Center Groningen. The treatment protocol did not intend to exclude the numerous other combinations of implant placement and loading protocols that have been reported in the literature,³⁷ but rather serve as a starting point for this difficult and complex type of implant treatment.

The proposed treatment protocol was implemented in the prospective case series and resulted in excellent implant survival, good clinical and radiographic results and high patient satisfaction for all treatment options. Loss of the inter-implant bone crest was evident after extraction of the failing teeth and implant placement (option 1-3) and continued after placement of the final implant restoration up to 1-year follow-up. This findings suggest that continuing inter-implant bone loss should be expected after extraction of failing teeth up to 1-year, regardless of the implant placement and loading protocol used.

The case series also showed that the inter-implant papilla was best preserved if implants were placed using an immediate implant placement protocol (options 1 and 2), although a decrease in inter-implant papilla fill was reported after placement of the final implant restorations. This corresponds with the early findings of Kourkouta et al.⁶, who found more stable inter-implant papillae when an immediate implant placement and provisionalization protocol was used. Despite differences in papilla fill, all treatment options were associated with compromised inter-implant papilla fill after placement of the final implant restorations. This finding should be taken into consideration when discussing clinical outcome with patients.

An obvious limitation of the case series is the small number of patients that was included in the study. Notwithstanding this limitation, the results of the case series suggest that the treatment protocol can be used as a useful tool to treat two failing or missing central upper incisors in the aesthetic region.

Future perspectives

In this thesis, the thickness of the buccal bone after extraction was not included in the various analyses as a risk factor to changes in buccal bone thickness and mid-buccal mucosa volume. In future volume and CBCT studies on the outcome of immediate implant placement in the aesthetic region, with or without a CTG, post-extraction buccal bone thickness should be added as a variable to determine the contribution of this risk factor on the change in buccal bone thickness and mid-buccal mucosa volume.

With regard to two adjacent implants in the aesthetic region, more research is needed in general

due to the absolute scarceness of studies on this topic. In this respect, the implant treatment protocol for two adjacent implants that was introduced in this thesis should be tested in a clinical trial, preferably in a multi-center study setting.

Conclusions

Based on the results of the various studies described in this PhD thesis, the following specific conclusions can be drawn:

- Immediate implant placement and provisionalization in the aesthetic region, at least when applying the strict inclusion criteria as described in this thesis, results in excellent implant survival, minimal peri-implant bone loss, good aesthetics and very satisfied patients after a mean follow-up period of 4 years (**chapter 2**).
- The use of a connective tissue graft, in combination with immediately placed and provisionalized implants in the aesthetic region, does not result in less mid-buccal mucosal volume loss after 1 year. It does lead to more stable mid-buccal mucosa levels, however (**chapter 3**).
- In patients with a connective tissue graft in combination with immediately placed and provisionalized implants in the aesthetic region, a tendency for a higher loss of buccal bone thickness was found compared to patients without a connective tissue graft (**chapter 4**).
- A scalloped implant platform design has no additional beneficial effect on the treatment outcome when compared to treatment with a conventional flat implant platform in case of two adjacent implants in the aesthetic region (**chapter 5**).
- Delayed placement and provisionalization of two adjacent implants in the aesthetic region results in excellent implant survival, stable peri-implant bone levels and satisfied patients after 5 years (**chapter 5**).
- Single implant-supported cantilever restorations are accompanied high implant survival rates and excellent patient satisfaction scores after 5 years (**chapter 6**).
- Single implant-supported cantilever restorations are a viable alternative to placement of two adjacent implant-supported restorations in the aesthetic region, in particular when there is limited space for placement of two adjacent implants (**chapter 6**).
- Based on the clinical and radiographic results and high patient's satisfaction, the proposed implant treatment protocol for two failing or missing central incisors in the maxillary aesthetic

zone is presumed to be a useful clinical guideline (**chapter 7**).

- It is very difficult to establish a predictable and harmonious treatment result with two adjacent implant-supported restorations in the aesthetic region, despite high patient satisfaction scores (**chapters 5 and 7**).

Thus, implant treatment for one failing or missing tooth as well as for two adjacent failing or missing teeth in the maxillary aesthetic region results in healthy peri-implant tissues, limited peri-implant bone loss and high patient satisfaction scores, with the exception of the compromised inter-implant papilla that is often seen in case of two adjacent implants.

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CHAPTER

09

Summary

Summary

Failing or missing teeth in the aesthetic region of the maxilla (1st premolar to 1st premolar) create a difficult challenge for patients and dental professionals, because of the aesthetic demands and patient's expectations. In case of single failing teeth, immediate implant placement has proven itself as a fast and well-established treatment protocol with excellent short-term results and high patient satisfaction, but concerns exist about peri-implant soft tissue stability when immediate implant placement is applied. If two adjacent teeth in the maxillary aesthetic region are failing or missing, implant treatment becomes even more complex as a result of the reduced peri-implant stability of hard and soft tissues between two implants, the inter-implant bone crest height is difficult to maintain and the inter-implant papilla height is often compromised. These issues are particularly factors to consider when implants are placed at the location of the lateral and central incisor as there is often insufficient horizontal space for placement of two adjacent implants. This PhD thesis discusses the complexity of implant treatment in the maxillary aesthetic region (**chapter 1**). The overall aim of the studies described in this thesis was to assess the outcome of several implant treatment strategies for one or two failing or missing teeth in the maxillary aesthetic region. The following treatments were studied:

- Treatment of one failing tooth with immediate implant placement and provisionalization (**chapter 2**);
- Treatment of one failing tooth with immediate implant placement and provisionalization, with or without a connective tissue graft (**chapters 3 and 4**);
- Treatment of two missing teeth with delayed placement of two adjacent implants and single implant-supported restorations (**chapter 5**);
- Treatment of two missing teeth with delayed placement of a single implant and one implant-supported cantilever restoration (**chapter 6**);
- Treatment of two central upper incisors with two adjacent implants and single implant-supported restorations, following a new implant treatment proposal that includes immediate and delayed implant placement and loading protocols (**chapter 7**).

The treatment outcome of immediately placed and provisionalized single implants after extraction of a failing tooth, with implant-supported restorations in place for more than one year, was assessed by means of a retrospective study design (**chapter 2**). All consecutive patients (n=64) who were treated in a dental referral practice (Amsterdam, the Netherlands), between January 1st, 2006 and April 1st, 2013 were included in the study. Between October 2014 and August 2015, fifty-one (n=51) patients attended the recall visit. Before visiting the dental practice, patients were asked to complete a questionnaire at home addressing patients' satisfaction. During the recall visit, peri-implant hard and soft tissues were evaluated by clinical examination and intra-oral radiographs. In addition, digital photographs were taken to assess the professionals aesthetic score (Pink Esthetic Score and White Esthetic Score).

Implant survival rate was 96.9% after a mean follow-up period of 4 years following implant placement. Mean marginal bone loss between implant placement and mean follow-up was 0.31 mm (SD 0.20) indicating that peri-implant bone loss was minor and marginal bone levels stable. In addition, peri-implant soft tissues were healthy. The overall patient's satisfaction was high (9.0, SD 0.7) and the overall aesthetic score was good: 16.49 (SD 1.86) on a possible scale of 0-20.

It was concluded that immediate placement of implants followed by immediate provisionalization resulted in a high implant survival rate, minimal peri-implant bone loss, good overall aesthetics and satisfied patients after a mean follow-up of 4 years following implant placement.

Despite the promising results of immediate implant placement and provisionalization in the aesthetic region, literature has reported that recession of the mid-buccal mucosa level and buccal volume loss often occurs after this type of treatment as a result of physiological bone loss of the labial bone plate at the buccal side of the implant. Placement of a connective tissue graft has been proposed to counter this problem. Therefore, a one-year randomized controlled trial was carried out in the University Medical Center Groningen at the Department of Oral and Maxillofacial Surgery, the Netherlands, to volumetrically compare mid-buccal mucosal changes in immediately placed and provisionalized implants in the aesthetic region, with or without a connective tissue graft (**chapter 3**).

Sixty patients were included. After randomization, one group received a connective tissue graft (test group, $n=30$) that was placed in a suprapariosteal envelope flap prepared at the buccal aspect of the implant without using vertical incisions. The other group (control group, $n=30$) received no connective tissue graft. Clinical parameters, digital photographs and conventional dental impressions were obtained before extraction (T_{pre}) and at 12 months following placement of the final implant restoration (T_{12}). Gypsum casts, made at both time points, were digitized by a laboratory scanner and the change in volume was calculated between T_{pre} and T_{12} .

Twenty-five patients in each group were available for analysis at T_{12} . Volumetric change, transformed to a mean change in thickness, was -0.68 mm (SD 0.59, test group) and -0.49 mm (SD 0.54, control group, $p=0.189$). The mid-buccal mucosa level was significantly different between both groups ($p=0.014$), with a mean change of +0.20 mm (SD 0.70, test group) and -0.48 mm (SD 1.13, control group). The Pink Esthetic Scores were similar between both groups.

It was concluded that the use of a connective tissue graft in immediately placed and provisionalized implants in the aesthetic region did not result in less mucosal volume loss after one year, leading to the assumption that a connective tissue graft cannot compensate for the volume loss caused by the physiological bone loss of the labial bone plate, although a significantly more coronally located mid-buccal mucosa level was found when a connective tissue graft was performed.

To assess the buccal bone loss of the labial bone plate, at the neck of the implant, a cone beam computed tomographic (CBCT) study and volumetric sub-analysis of the randomized controlled trial described in **chapter 3** was carried out to evaluate the influence of a connective tissue graft on the change in buccal bone thickness after immediate implant placement and provisionalization

(chapter 4). During the randomized controlled trial, CBCT images were taken before removal of the tooth (T_{pre}) and twelve months (T_{12}) after placement of the final implant restoration and change in buccal bone thickness (BBT) was analysed. Twenty-five patients in the test group ($n=25$) and twenty-four patients in the control group ($n=24$) were available for the sub-analysis at T_{12} . Between T_{pre} - T_{12} , the change in mid-buccal mucosal volume, transformed to a mean change in mucosal thickness, was -0.68 mm (SD 0.59, test group) and -0.49 mm (SD 0.55, control group, $p=0.25$). The mean change in BBT between T_{pre} - T_{12} was -0.81 mm (SD 0.66, test group) and -0.47 mm (SD 0.55, control group, $p=0.05$). It was concluded that these findings suggest that a connective tissue graft cannot compensate for the mucosal volume loss caused by the underlying resorption of the buccal bone wall after immediate implant placement and provisionalization.

If two neighbouring teeth in the maxillary aesthetic region are replaced with two single-implant supported restorations, implant treatment becomes even more complex and issues arise with regard to peri-implant stability of hard and soft tissues, especially in the inter-implant region.

To assess the condition of peri-implant soft and hard tissues, and satisfaction in patients with two adjacent implant-supported restorations in the aesthetic region, treated with two adjacent implants with a scalloped or with a flat implant platform, 5-years data of a previous randomized controlled trial were collected at the University Medical Center Groningen, the Netherlands (**chapter 5**). A total of 40 patients was included. In that trial, after randomization, patients were allocated to a scalloped platform group (test group, $n=20$) or a flat platform group (control group, $n=20$). All implants were placed using a delayed implant placement and delayed provisionalization protocol. The data was collected preoperatively (T_{pre}), directly after implant surgery (T_{post}), directly (within a month) after placement of the final implant restoration (T_0), and one (T_{12}) and five (T_{60}) years after placement of the final implant restoration.

Between T_{post} - T_{60} , the scalloped implant group showed significantly more marginal bone loss: 3.2 mm (SD 1.1) compared to the 1.5 mm (SD 0.8) of bone loss in the flat implant group. The scalloped implant group also showed significantly more bone loss at the inter-implant bone crest (scalloped: 2.4 mm (SD 1.0), flat: 1.3 mm (SD 1.0)). As a result, the peri-implant soft tissues showed significantly more bleeding ($p=0.001$) and signs of inflammation when ($p=0.001$) at T_{60} when provided with scalloped implants than with flat implants. Regardless of the implant design used, papilla index scores were low and pointed towards compromised inter-implant papilla height. Nonetheless, patient's satisfaction was high in both groups, with a mean score of 8.3 (SD 1.2) in the scalloped implant group and 8.6 (SD 0.8) in the flat implant group.

It was concluded that, after the first year of more bone loss and compromised inter-implant papilla regeneration around scalloped compared to flat implant platforms, the following four years of follow-up presented stable results with both systems. Scalloped implant platforms have no beneficial use compared to conventional flat implant platforms in the aesthetic region.

When little space is available for two adjacent implants, in particular when a central and lateral incisor are missing, the alternative treatment of a single implant-supported cantilever restoration can be chosen. To gain insight into the literature on the clinical outcome of this treatment option, a

systematic review was conducted on single implant-supported two-unit cantilever restorations in the anterior and posterior maxilla and mandible (**chapter 6**). An extensive search in Medline (PubMed), Embase and the Cochrane Central Register of Controlled Trials was carried out (last search August 1, 2016). The search was completed by a hand-search of the references found in eligible studies. Studies with a follow-up of at least 1 year following placement of the implant-supported cantilever restorations were selected which reported on at least implant survival and/or changes in marginal bone level. The methodological quality was assessed using specific study design-related checklists. Five studies were considered eligible for data extraction. The number of implant-supported two-unit cantilever restorations in these studies ranged from 5 to 108 and the follow-up from 1 year to a mean follow-up of 4.2 ± 2.8 years. Because of the heterogeneity in study designs and data presented, the outcomes of the studies were presented as a descriptive review. The implant survival ranged from 96.6% to 100% in three studies and patient satisfaction was found to be high in two studies reporting on the anterior maxilla or mandible. One study reporting on 29 implant-supported two-unit cantilever restorations in the posterior maxilla and mandible found 11 cases of porcelain fracture and 16 cases of screw loosening.

Within the limitations of the systematic review, it was concluded that single implant-supported two-unit cantilever restorations are accompanied by high short and mid-term implant survival rates and excellent patient satisfaction. Therefore, a single implant-supported two-unit cantilever restorations seems to be a reasonable alternative to the placement of two adjacent single implant-supported restorations in the aesthetic region. In contrast, single implant-supported cantilever restorations in the posterior region might be more prone to technical complications and are therefore less suited as an alternative treatment method to placement of two adjacent implants.

In addition to the systematic review, an existing prospective comparative pilot study on missing central and lateral upper incisors treated with either a single implant-supported two-unit cantilever restoration or two implants with solitary implant restorations in the maxillary aesthetic region was continued up to 5 years follow-up (**chapter 6**).

In this comparative pilot study, an implant-cantilever group of five patients with a single implant-supported two-unit cantilever restoration was compared with an implant-implant group of five patients with two adjacent single implant-supported restorations in the aesthetic region. Implant survival, marginal bone level changes, implant probing depth, papilla index and patient satisfaction were assessed during a 5-year follow-up period.

The study resulted in no clinically significant differences in hard and soft peri-implant tissue levels between both groups. For example, both groups displayed compromised peri-implant papilla height after 1 and 5 years follow-up, especially in the inter-implant region and the cantilever side of the implant. In addition, patient satisfaction was found to be high in both treatment groups. Therefore, it was concluded that single implant-supported two-unit cantilever restorations can be a viable alternative to the placement of two adjacent single implant restorations in the maxillary aesthetic region.

Implant treatment with two adjacent implants in the maxillary aesthetic region, as is shown in **chapters 5 and 6**, is complex due to concerns regarding inter-implant hard and soft tissue stability. It was unknown whether existing protocols for single implant placement could be utilized in case of two missing or failing teeth in the maxillary aesthetic region. Therefore, an implant treatment protocol was developed and implemented in a 1-year prospective case series study with 16 patients with two failing or missing central incisors in the maxillary aesthetic region (**chapter 7**).

The protocol consisted of five options depending on whether teeth were still present (options 1-3) or not (options 4 and 5) and on the amount of bone available at start of treatment: 1. Extraction, immediate implant placement and provisionalization, 2. Extraction, immediate implant placement, delayed provisionalization, 3. Extraction, ridge preservation, delayed implant placement and immediate provisionalization, 4. Delayed implant placement and guided bone regeneration, delayed provisionalization, 5. Guided bone regeneration (extensive bone augmentation of the alveolar ridge), delayed implant placement, delayed provisionalization. The case series was assessed regarding peri-implant hard and soft tissue parameters, professionals aesthetic score (Pink Esthetic Score) and patient satisfaction.

All treatment options resulted in good clinical and radiographical findings and high patient satisfaction. The proposed implant treatment protocol was assumed to be a useful tool, although more research is needed, preferably in an multicentre setting.

The results of the various studies described in this thesis are discussed in **chapter 8**. Suggestions for future research were added. In general, it was concluded that implant treatment for one failing or missing tooth as well as for two adjacent failing or missing teeth in the maxillary aesthetic region results in healthy peri-implant tissues, limited peri-implant bone loss and high patient satisfaction scores, with the exception of the compromised inter-implant papilla that is often seen in case of two adjacent implants.

CHAPTER

10

Nederlandse samenvatting

Dankwoord

Curriculum Vitae

Samenvatting

Wanneer niet te behouden of reeds geëxtraheerde gebitselementen in de esthetische zone van de maxilla (1^e premolaar tot en met 1^e premolaar) worden vervangen door implantaatgedragen kronen, dan heeft de implantaatbehandeling vaak een complex karakter vanwege de hoge esthetische eisen die gesteld worden in dit gebied. In het geval van één gebitselement leidt het direct na extractie vervangen van het gebitselement met een implantaat en tijdelijke implantaatkroon vaak tot goede behandelresultaten maar zijn er tegelijkertijd ook problemen met betrekking tot de stabiliteit van peri-implantaire zachte weefsels. In het geval van twee naast elkaar gelegen gebitselementen, die niet te behouden zijn of reeds geëxtraheerd, kunnen twee implantaten en implantaatgedragen kronen worden geplaatst. Hiermee neemt echter wel de complexiteit van de implantaatbehandeling verder toe, doordat de stabiliteit van peri-implantair bot en zacht weefsels tussen twee implantaten moeilijk te waarborgen is. Verlies van bot en zachte weefsels treedt vaak op wanneer er weinig ruimte is voor beide implantaten, zoals in het geval van een centrale en laterale incisief. In dit proefschrift worden een aantal studies beschreven waarin de complexiteit wordt besproken van het vervangen van gebitselementen in de esthetische zone van de maxilla met tandheelkundige implantaten en implantaat gedragen kronen (**hoofdstuk 1**). Het overkoepelende doel van dit promotieonderzoek was het belichten van het resultaat van een aantal implantaatbehandelingen voor het vervangen van één niet te behouden gebitselement in de esthetische zone, of het vervangen van twee naast elkaar gelegen, niet te behouden of reeds geëxtraheerde gebitselementen in de esthetische zone.

In **hoofdstuk 2** worden de uitkomsten beschreven van een studie waarin een niet meer te behouden gebitselement in de esthetische zone direct na extractie werd vervangen door een implantaat en een tijdelijke implantaatkroon. In een retrospectieve studieopzet werden 64 opeenvolgende patiënten geïnccludeerd die tussen 1 januari 2006 en 1 april 2013 waren behandeld in een implantologische verwijsp praktijk in Amsterdam. Twee patiënten (n=2) verloren hun implantaat tijdens de fase van osseointegratie. De overige 62 patiënten waarbij tenminste 1 jaar lang een definitieve implantaatgedragen kroon aanwezig was werden uitgenodigd om naar de praktijk te komen voor klinisch en röntgenologisch intra-oraal onderzoek, waarbij vooraf werd gevraagd om thuis een patiënttevredenheidsformulier in te vullen. Tijdens het klinische onderzoek werden er ook intra-orale digitale lichtfoto's gemaakt om achteraf de esthetiek van de implantaatkroon en omringende weefsels te beoordelen.

51 patiënten gaven gehoor aan deze uitnodiging. Het implantaatoverlevingspercentage was 96,9% na een gemiddelde periode van 4 jaar na plaatsing van het implantaat. Het peri-implantair botverlies tijdens deze periode was gering en bedroeg gemiddeld 0.31 mm (SD 0.20). De peri-implantaire zachte weefsels waren gezond en de patiënttevredenheid was hoog: 9,0 (SD 0,7) op een schaal van 0-10. De Pink en White Esthetic Score (PES-WES) werd door twee tandheelkundige professionals beoordeeld. De PES-WES score was 16,49 (SD 1,86) op een schaal van 0-20, hetgeen duidt op een goed esthetisch resultaat.

Op grond van de uitkomsten van deze studie werd geconcludeerd dat het direct plaatsen van

een implantaat en tijdelijke implantaatkroon na extractie van solitaire gebitselementen resulteert in een hoog implantaat overlevingspercentage, gering peri-implantair botverlies, een goede esthetische uitkomst en een hoge patiënttevredenheid na een periode van 4 jaar na plaatsing van het implantaat.

Ondanks de veelbelovende resultaten, zoals beschreven in **hoofdstuk 2**, worden er rondom implantaten die direct na extractie van een gebitselement zijn geplaatst ook ongunstige waarnemingen gedaan in de literatuur. Zo is er vaak sprake van verticale recessie van de mid-buccale gingiva. Deze recessie kan leiden tot een asymmetrische gingiva ten opzichte van de natuurlijke gebitselementen naast het implantaat. Ook wordt volumeverlies gezien ter plekke van de buccale gingiva en mucosa, door resorptie van de labiaal van het implantaat gelegen botplaat. Deze fysiologische resorptie treedt op na het extraheren van een gebitselement. De toepassing van een bindweefseltransplantaat in dit gebied, die gelijktijdig wordt geplaatst met het implantaat, is afgelopen jaren meerdere malen voorgesteld als oplossing voor dit probleem.

Om de toepassing van een bindweefseltransplantaat nader te onderzoeken werd een gerandomiseerd gecontroleerd onderzoek (RCT) uitgevoerd in het Universitair Medisch Centrum Groningen, afdeling Mondziekten, Kaak- en Aangezichtschirurgie, met als doel om volumeveranderingen van de buccale mucosa en verticale veranderingen in de buccale gingiva te meten bij implantaten die direct geplaatst en voorzien waren van een tijdelijke kroon in de esthetische zone, mét of zonder de toepassing van een bindweefseltransplantaat (**hoofdstuk 3**). Er werden 60 patiënten geïncludeerd, na randomisatie ontving de helft van de patiënten een bindweefseltransplantaat die suprapariostaal aan de buccale zijde van het implantaat werd geplaatst (testgroep), de andere helft ontving geen bindweefselimplantaat (controlegroep). Voorafgaande aan het implanteren en 12 maanden na het plaatsen van de definitieve implantaat kroon werd klinisch onderzoek verricht, intra-orale foto's gemaakt en een alginaat afdruk genomen van de maxilla. De afdrukken werden uitgegoten in gips en gedigitaliseerd door middel van een 3D scanner in een tandtechnisch laboratorium. De digitale bestanden werden gebruikt om de verandering in volume te meten van de buccale mucosa. Van de 60 patiënten waren 25 patiënten in beide groepen beschikbaar voor analyse na 12 maanden. De volumeverandering, conform de toegepaste methodiek getransformeerd naar een gemiddelde verandering in dikte, bedroeg -0,68 mm (SD 0,59) in de testgroep en -0,49 mm (SD 0,54) in de controlegroep ($p=0,189$). Het verticale niveau van de mid-buccale gingiva liet een significant verschil zien tussen beide groepen, met een gemiddelde verandering van 0,20 mm (SD 0,70) in de test groep en -0,48 mm (SD 1,13) in de controlegroep ($p=0,014$). De Pink Esthetic Score, de esthetische score waarmee de peri-implantaire gingiva en mucosa wordt beoordeeld, was vergelijkbaar in beide groepen.

Op grond van de uitkomsten van deze studie werd geconcludeerd dat de toepassing van een bindweefseltransplantaat in combinatie met het direct plaatsen van een implantaat én tijdelijke implantaatkroon niet leidt tot minder volume verlies aan de buccale zijde van het implantaat. Met andere woorden, het plaatsen van een bindweefselgraft compenseert onvoldoende compenseert voor het onderliggende fysiologische botverlies dat optreedt ter plekke van de labiaal van het

implantaat gelegen botplaat na extractie van een gebitselement. Een bindweefseltransplantaat bleek wel te leiden tot een significant meer coronaal gelegen niveau van de mid-buccale gingiva.

Om ook het onderliggende botverlies van de labiale botplaat te kunnen evalueren in combinatie met het gebruik van een bindweefseltransplantaat werd er in de in **hoofdstuk 3** beschreven RCT tevens een Cone Beam Computed Tomographic (CBCT) studie uitgevoerd (**hoofdstuk 4**). Tijdens de RCT werden er CBCT's vervaardigd voorafgaande aan het extraheren van het gebitselement en 12 maanden na het plaatsen van de definitieve implantaatkroon. Van de 60 patiënten waren 25 patiënten in de testgroep en 24 patiënten in de controlegroep beschikbaar voor de analyse wanneer de gegevens van de CBCT's en de volumemetingen werden gecombineerd. Na 12 maanden was de volumeverandering, getransformeerd naar een gemiddelde verandering in dikte, -0,68 mm (SD 0,59) in de testgroep en -0,49 mm (SD 0,55) in de controlegroep ($p=0,25$). De gemiddelde verandering in de onderliggende botdikte van de labiale botplaat was -0,68 mm (SD 0,59) in de testgroep tegenover -0,47 mm (SD 0,55) in de controlegroep ($p=0,05$).

Op basis van de resultaten van deze studie werd geconcludeerd dat het aanbrengen van een bindweefselgraft niet volledig kan compenseren voor het volume verlies van de mucosa dat wordt veroorzaakt door het fysiologische botverlies van de onderliggende labiale botplaat.

Wanneer twee aangrenzende gebitselementen in de esthetische zone verloren gaan en in tweede instantie worden vervangen door implantatengedragen kronen, dan wordt de implantaat behandeling nog complexer omdat er meer problemen optreden die betrekking hebben op de stabiliteit van peri-implantair bot en zachte weefsels. Dit geldt vooral voor het gebied tussen beide implantaten. Derhalve werd de 5 jaar resultaten van een eerdere opgezette RCT naar de uitkomsten van twee naast elkaar gelegen implantaatgedragen kronen en twee type implantaatplatformen in de esthetische zone verricht in het Universitair Medisch Centrum Groningen, afdeling Mondziekten, Kaak- en Aangezichtschirurgie en verzameld (**hoofdstuk 5**). Er werden 40 patiënten geïncludeerd, na randomisatie ontving de helft van de patiënten twee implantaten met een omgekeerd konisch implantaatplatform (testgroep) en de andere helft twee implantaten met een plat implantaatplatform (controlegroep). Alle implantaten werden minimaal 3 maanden na extractie van beide gebitselementen geplaatst. De tijdelijke implantaatkronen werden 3 maanden na het plaatsen van de implantaten geplaatst, de definitieve implantaatkronen na 6 maanden. Na 5 jaar follow-up liet de testgroep significant meer peri-implantair botverlies zien, met een gemiddeld verlies van 3,2 mm (SD 1,1) tegenover een verlies van 1,5 mm (SD 0,8) in de controle groep. Daarnaast liet de testgroep ook significant meer botverlies zien van de botpiek tussen beide implantaten, met een gemiddeld verlies van 2,4 mm (SD 1,0) tegenover een verlies van 1,3 mm (SD 1,0) in de controle groep.

Als gevolg van het verhoogde botverlies vertoonden de peri-implantaire weefsels na 5 jaar significant meer bloeding ($p=0,001$) en tekenen van ontsteking ($p=0,001$) bij patiënten in de testgroep. Na 5 jaar lieten beide onderzoeksgroepen een gecompromitteerde hoogte zien van de gingivapapil tussen beide implantaten. De patiënttevredenheid was hoog in beide groepen, met

een score van 8,3 (SD 1,2) in de testgroep en 8,6 (SD 0,8) in de controle groep.

Uit deze studie werd geconcludeerd dat, na het eerste jaar waarin de testgroep meer peri-implantair botverlies liet zien, beide typen implantaten stabiele resultaten lieten zien gedurende de volgende 4 jaar. Hieruit valt op te maken dat een het gebruik van omgekeerd konische implantaatplatform niet tot een beter behandelresultaat leidt dan een conventioneel, plat, implantaatplatform in de esthetische zone.

Wanneer er weinig ruimte is voor het plaatsen van twee naast elkaar gelegen implantaten, bijvoorbeeld in het geval van een centrale en laterale incisief in de maxilla, dan kan er ook voor gekozen worden om één implantaat te plaatsen en een tweedelige implantaatgedragen brug. Om meer inzicht te krijgen in de bestaande literatuur en de behandelresultaten van dit type behandeling werd de bestaande literatuur systematisch doorzocht in de databases van Medline (Pubmed), Embase en de Cochrane Central Register of Controlled Trials (**hoofdstuk 6**). De zoektocht betrof zowel de anterieure (esthetische) en posterieure zone van de maxilla én mandibula. Om geïnccludeerd te worden moest er sprake zijn in artikelen van een tweedelige brug die door één implantaat werd ondersteund en moest ten minste de uitkomstmaat implantaatoverleving en/of peri-implantair botverlies worden beschreven. Er werden geen restricties toegepast met betrekking tot het studieontwerp, met uitzondering van case reports, deze werden geëxcludeerd. De methodologische kwaliteit van geïnccludeerde studies werd beoordeeld met studie-specifieke checklists. In totaal 5 studies werden van voldoende kwaliteit bevonden voor extractie van de data. In deze studies varieerde het aantal tweedelige bruggen, ondersteund door één implantaat, tussen 5 en 108. De duur van de studies varieerde van 1 jaar tot gemiddeld 4,2 (SD 2.8) jaar. Het overlevingspercentage van de implantaten varieerde van 96,6% tot 100% in 3 van de 5 studies, de overige 2 studies maakten hier geen melding van. De patiënttevredenheid die in 2 studies werd gerapporteerd was hoog wanneer dit type behandeling werd uitgevoerd in de esthetische zone van de maxilla en mandibula. Eén studie met 29 tweedelige bruggen in de posterieure maxilla en mandibula beschreef het optreden van 11 gevallen van porseleinfacturen en het 16 keer loskomen van implantaatschroeven.

De beperkingen van de geïnccludeerde studies beschouwend, kan voorzichtig worden geconcludeerd dat een tweedelige brug, ondersteund door één implantaat, een goede implantaatoverleving heeft op korte en middellange termijn en de patiënttevredenheid hoog is. Om die reden lijkt deze behandeling een prima alternatief voor het plaatsen van twee solitaire implantaatgedragen kronen in de esthetische zone. Daarentegen lijken er bij dit type behandeling in de posterieure zone van de maxilla en mandibula vaker technische complicaties op te treden en is daarom minder geschikt dan het plaatsen van twee solitaire implantaatgedragen kronen.

In aanvulling op het literatuuronderzoek werd een bestaande pilot studie voortgezet tot 5 jaar waarin bij 5 patiënten, op de locatie van de centrale en laterale incisief, een tweedelige brug geplaatst werd die ondersteund werd door één implantaat in de regio van het centrale incisief (testgroep) en 5 patiënten die op dezelfde locatie twee naast elkaar gelegen implantaten en twee

solitaire implantaatgedragen kronen ontvingen (**hoofdstuk 6**). De studie resulteerde in klinisch vergelijkbare uitkomsten tussen beide onderzoeksgroepen. In beide groepen was sprake van verlies in hoogte van de gingiva papil naast het implantaat of tussen de implantaten. Dit was vooral duidelijk waarneembaar bij de gingiva papil tussen beide implantaten (controle groep) en tussen het implantaat en de dummy (cantilever) van de tweedelige brug (testgroep). Zowel na 1 als na 5 jaar was de patiënttevredenheid hoog in beide groepen.

Ook uit deze studie kon worden geconcludeerd dat tweedelige bruggen die door één implantaat worden ondersteund in de esthetische zone van de maxilla een goed alternatief zijn voor het plaatsen van twee solitaire implantaatgedragen kronen.

Vanwege de complexiteit van het plaatsen van twee naast elkaar gelegen implantaten en solitaire implantaatgedragen kronen (**hoofdstukken 5 en 6**) is er behoefte aan een behandelprotocol voor het vervangen van twee falende of geëxtraheerde gebitselementen met implantaatgedragen kronen in de esthetische zone. Het is onbekend of de bestaande behandelprotocollen voor het vervangen van één gebitselement door een implantaat en implantaatkroon ook succesvol voor het vervangen van twee gebitselementen kunnen worden gebruikt. Om deze reden werd een nieuw implantologisch behandelprotocol opgesteld en toegepast bij 16 patiënten die twee falende of reeds geëxtraheerde centrale incisieven in de esthetische regio hadden en tot 1 jaar na het plaatsen van de definitieve implantaatkronen gevolgd (**hoofdstuk 7**). Het behandelprotocol bestond uit 5 behandelopties, waarvan 3 voor niet meer te behouden gebitselementen (opties 1-3) en 2 opties voor reeds geëxtraheerde gebitselementen (opties 4 en 5). De keuze tussen opties 1-3 en 4-5 is afhankelijk van de kwaliteit en kwantiteit van het alveolair bot dat beschikbaar is bij de start van de behandeling en de primaire stabiliteit die behaald kan worden tijdens het plaatsen van het implantaat:

Optie 1: Extractie van beide gebitselementen, direct plaatsen van twee implantaten én het plaatsen van tijdelijke implantaatkronen;

Optie 2: Extractie van beide gebitselementen, direct plaatsen van twee implantaten en na 3 maanden plaatsen van tijdelijke implantaatkronen;

Optie 3: Extractie van beide gebitselementen, augmentatie van de alveole door ridge preservation en na 3 maanden het plaatsen van twee implantaten en tijdelijke implantaatkronen;

Optie 4: Plaatsen van twee implantaten en het toepassen van guided bone regeneration, na 3 maanden plaatsen van twee tijdelijke implantaatkronen;

Optie 5: Het reconstrueren van de alveolaire botwand door guided bone regeneration, het na 3 maanden plaatsen van twee implantaten en na 6 maanden plaatsen van twee tijdelijke implantaatkronen.

Alle behandelopties resulteerden in goede klinische en röntgenologische bevindingen en in een hoge patiënttevredenheid. Binnen de beperkingen van de studie wordt aangenomen dat het behandelprotocol een nuttige aanvulling voor de implantologie behandeling van twee niet meer te behouden of reeds geëxtraheerde gebitselementen in esthetische zone. Vanwege het geringe aantal patiënten die met dit behandelprotocol zijn behandeld, is het aan te raden om verder

onderzoek te verrichten, bij voorkeur in een multi-center studiesetting.

De resultaten van alle in dit proefschrift beschreven studies zijn bediscussieerd in **hoofdstuk 8**, waarbij ook suggesties worden gegeven voor toekomstig onderzoek. In het algemeen kan worden geconcludeerd dat implantaatbehandeling in het geval van één of twee niet meer te behouden gebitselement(en) in de esthetische zone of reeds geëxtraheerde gebitselementen in de esthetische zone resulteert in gezonde peri-implantaire weefsels, gering peri-implantair botverlies en een hoge patiënttevredenheid, met uitzondering van de gecompromitteerde gingiva papillen die tussen twee implantaten vaak een duidelijk verlies van hoogte laat zien.

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Curriculum vitae

Wouter van Nimwegen was born on March 15th 1989 in Leeuwarden, the Netherlands. After finishing secondary in 2007, he started studying Dentistry in 2008 at the University of Groningen, Groningen, the Netherlands. During his study he was member of several student committees, treasurer of the board of medical student society Volonté and vice-president of the board of T.M.F.V. Archigenes, the dental student faculty association. After finishing his Master's thesis in implantology under the guidance of Prof. Dr. H.J.A. Meijer in 2014, he continued doing research in the field of implantology and completed a 5 month internship in 2015 in dentoalveolar surgery and implantology in Heerenveen, the Netherlands under guidance of oral and maxillofacial surgeons Dr. W. Kalk and Dr. A. Hoekema. After graduating as a dentist in 2015, he started his PhD-research project at the Department of Oral and Maxillofacial surgery of the University Medical Center Groningen, the Netherlands. Since then he combined his PhD research with his work as general dental practitioner in Buitenpost, Hardenberg, Wierden and Hengelo (the Netherlands). He currently lives in Borne, the Netherlands, with his wife Leonieke and son Wiebe and is planning to start with postgraduate training in implantology, periodontal surgery and prosthodontics.