Care and Aftercare Related to Implant-Retained Dental Crowns in the Maxillary Aesthetic Region: A 5-Year Prospective Randomized Clinical Trial

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ABSTRACT

Aim: To prospectively assess surgical and prosthetic care and aftercare related to the placement of implant-retained dental crowns after local bone augmentation in patients missing one tooth in the maxillary aesthetic region.

Methods: Ninety-three patients were randomly allocated to one of three local augmentation groups: (1) chin bone; (2) chin bone covered by a Bio-Gide® membrane (Geistlich, Wolhusen, Switzerland); and (3) Bio-Oss® covered by a Bio-Gide® membrane. After local augmentation, implant placement (ITI) and fabrication of an implant-retained dental crown (cemented metal-ceramic dental crown) was performed. Prosthetic and surgical care and aftercare was scored from the first visit until 5 years after the augmentation of the implant region.

Results: The need for care and aftercare was comparable between the local augmentation groups. Three implants were lost (5-year implant survival rate: 96.7%). Surgical aftercare was needed in 9% of patients and consisted of care related to peri-implant tissue problems. Prosthetic aftercare was needed more often: all patients needed periodic routine inspections; 63% needed supplemental oral hygiene support; and 16% needed additional prosthetic care, mainly consisting of fabricating new crowns (12%).

Conclusion: Placing an implant in the maxillary esthetic region after local bone augmentation is a safe and reliable treatment option not needing much specific aftercare other than periodic preventive routine inspections, routine oral hygiene care, and fabrication of a new crown in one out of every eight to nine patients in 5 years. The method used for augmentation was irrespective of the patients' need for aftercare.

KEY WORDS: Bio-Gide®, Bio-Oss®, care and aftercare, clinical trial, implant-retained dental crowns, local augmentation

INTRODUCTION

An implant-retained dental crown is often asked for by patients who are missing one or more teeth because of trauma, congenitally missing, or tooth extraction. Functional problems with a partial prosthesis and esthetic problems, especially if the tooth has been lost in the maxillary aesthetic region, are the main reasons for seeking help. Regarding the high implant survival rates in the anterior maxillary region (>95%,), single-tooth replacements by implant-retained dental crowns have evolved into a reliable treatment modality.[1–5] Also from a patients' perspective implant-retained dental crowns are favorable as studies with a follow-up of at least 5 years revealed favorable aesthetic results[2,6] and high patient satisfaction scores.[7–9] Such favorable results are not limited to standard cases, but also can be achieved in cases where space problems limit the use of standard

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or wide diameter implants.[10] Moreover, Brägger and colleagues[11] reported that implant reconstruction is accompanied by a favorable cost/effectiveness ratio when compared with conventional three-unit fixed partial dentures (follow-up 1–4 years). Thus, it can be stated – especially in clinical situations with either non- or minimally restored neighboring teeth and a sufficient volume of bone to allow for primary implant placement – that prosthodontic rehabilitation of a lost tooth by an implant-retained dental crown is to be recommended from both the patients' perspective and an economical point of view.[11]

Of all the published data on implant-retained single-tooth replacements, most studies report on surgical aspects,[12] osseointegration,[13] implant designs,[14] implant characteristics,[15,16] pain assessment,[17] early loading,[18] immediate loading and/or immediate placement,[5,19,20] surgical/augmentation techniques,[7,21] guided bone regeneration,[22] and (soft) tissue aspects.[23,24] To the best of our knowledge, there are no detailed studies focusing on the need for surgical and prosthetic care and aftercare related to implant-retained dental crowns. The few studies that reported on aspects related to aftercare, described the need for care and aftercare in rather general terms.[2,11,25–27] This observation is supported by the results of two recent systemic reviews of the literature focussing on implant-retained dental crowns.[28,29] Den Hartog and colleagues[29] noticed that data regarding complications other than implant loss and crestal bone resorption were not commonly reported in the studies they included in their systemic review of the literature. In addition, Jung and colleagues[28] concluded that implant survival rates for implant-retained dental crowns are high, but that such replacements were frequently accompanied by technical complications. Unfortunately, Jung and colleagues[28] were not able to provide (detailed) information about these technical complications in relation to treatment time needed for patients treated with implant-retained dental crowns, just because the papers they reviewed lacked such information. Also detailed information on the provided surgical and prosthetic care and aftercare was lacking. Therefore, the primary aim of this study was to provide an detailed assessment of the patients' need for surgical and prosthetic care and aftercare when being treated with an implant-retained dental crown. As placement of an implant in the aesthetic region of the maxilla often is preceeded with an augmentation procedure, the secondary aim of this study was to assess whether the need for care and aftercare was related to the specific augmentation procedure patients had been subjected to.

MATERIAL AND METHODS

Patient Selection and Treatment

Patients referred by their dentist or general medical practitioner to the Department of Oral and Maxillofacial Surgery and Maxillofacial Prosthodontics of the University Medical Center Groningen, the Netherlands, and to the Department of Oral and Maxillofacial Surgery of the Nij Smellinghe Christian Hospital in Drachten, the Netherlands, because of problems with missing or to-be-removed (profound caries, severe periodontal disease) upper anterior tooth were eligible for inclusion in the present study. A total of 93 patients with a single-tooth gap in the anterior region of the maxilla (P_1–P_1) were selected for the study, 44 men and 49 women (mean age 33 ± 13 years; median 31, range 18–63 years; Table 1).

Patients were included between 1999 and 2003 and selected on the basis of the following inclusion criteria (see also Meijndert and colleagues[30]):

- need for an implant supported dental crown to replace a maxillary lost tooth at the location of an incisor, cuspid, or first bicuspid;

TABLE 1 Group Characteristics at the Start of the Study

	Number of Patients at Start of Study	Mean Age in Years (Range)	Gender (Male/Female)
Group I: Chin bone augmentation	$n = 31$	34 (18–56)	13/18
Group II: Chin bone augmentation with membrane	$n = 31$	35 (18–63)	16/15
Group III: Bio-Oss® with Bio-Gide® membrane	$n = 31$	32 (18–59)	15/16
Total	$n = 93$	33 (18–63)	44/49

- single tooth diastema as a maximum;
- presence of a horizontal bone deficiency with an anatomy of local bone responding to a class 4 according to Misch and Judy[31], making a buccopalatinal local ridge augmentation necessary to obtain sufficient bone volume for reliable placement and sufficient initial stability of an endosseous dental implant;
- sufficient occlusal and mesio-distal dimensions for insertion of one implant with a functional prosthetic restoration;
- good oral hygiene and a healthy periodontal situation (see exclusion criteria) at the start of the treatment.

Exclusion criteria for this study were:

- presence of clinical active periodontal disease as expressed by the presence of periodontal pockets ≥ than 4 mm, gingival bleeding ≥ class 2 of modified bleeding index,[32] edema, glazing, and redness;
- presence of an acute inflammatory oral disease;
- smoking;
- diabetes;
- a history of pre-prosthetic or implant surgery at the same site as the planned augmentation and implantation.
- a history of radiotherapy in the head and neck region or current chemotherapy;
- disability (mental and/or physical) to maintain basic oral hygiene procedures.

To reconstruct the local bone defects, three treatment modalities were applied (for details see Meijndert and colleagues[30]):

- chin bone (group I, $n = 31$);
- chin bone in combination with a resorbable guided bone regeneration (GBR) membrane (Bio-Gide®, Geistlich, Wolhusen, Switzerland; group II, $n = 31$);
- Bio-Oss® spongiosa granules (0.25–1.0 mm, Geistlich) in combination with a Bio-Gide® GBR membrane (group III, $n = 31$).

A computer software program randomly placed the participating patients into one of these groups, using a balancing procedure aimed at an equal distribution of patients over the treatment groups regarding variables that may interfere with the outcome of the study (balancing criteria; Zielhuis and colleagues[33]) In this trial the balancing criteria were age, gender and the location of the single-tooth defect. With regard to these balancing criteria an equal distribution was found between the three treatment modalities (see Table 1). The study was approved by the Medical Ethical Committee; written informed consent was obtained from all patients.

Surgical Procedure

Surgical augmentation procedures were performed as described by Meijndert and colleagues.[30] All augmentation procedures were performed under local anesthesia. Antibiotic prophylaxis was given for 72 hours (amoxicillin 500 mg + clavulanic acid 125 mg [Augmentin®, SmithKline Beecham, Zeist, the Netherlands], 1 hour preoperatively and every 8 hours postoperatively). First, a buccal pedunculated and to the buccal side a reflected mucoperiosteal full-thickness flap was raised. From the top of the crest, a mesial releasing incision diverged to the buccolabial fold and was placed in such a way that the mucoperiosteal flap was 5 mm wider then the area to be augmented. The interdental papillae were included in the flap. The incision extended ± 5 mm palatinally from the top of the crest. The cortical bone on the receptor site was perforated with a small round bur in order to create a bleeding bone surface and to open the cancellous bone.

In groups 1 and 2, monocortical chin bone grafts were harvested using a bur and chisel and fixed on the perforated receptor site (cortical side to the buccal) with a 1.5 mm titanium screw (Martin, Tütlingen, Germany). Particulated chin bone was placed around the fixed block graft. In group 2, the chin bone graft was covered by a Bio-Gide® GBR membrane. The membrane was styled with a 3-mm extension over the bone margins of the defect and fixed with sutures (Vicryl 4-0, Ethicon, Johnson&Johnson, Amersfoort, the Netherlands).

In group 3, Bio-Oss® spongiosa granules were mixed with blood derived from the operation site and placed on the perforated cortical bone of the receptor site. A Bio-Gide® GBR membrane was applied to cover the grafts. The membrane was styled with a 3-mm extension over the bone margins of the defect and fixed with sutures (Vicryl 4-0).

Three months after augmentation of the anterior defect in the maxilla with chin bone (groups I and II) or 6 months after augmentation with Bio-Oss® (group III), the implants were placed. First, the screws used to fix the

bone grafts were removed. Next, the implants (ITI-Esthetic[Plus] dental implants, Institut Straumann AG, Waldenburg, Switzerland) were placed using a template (in all patients one implant was placed). The template design was based on a restoration driven approach with indications for a correct three-dimensional implant placement respecting the comfort zones. All implants had a standard body diameter of 4.1 mm. Before the surgical cover screw was placed and the mucosa closed an impression was taken to be able to fabricate a provisional acrylic crown, which was placed at uncovering of the implant. During the healing period of 6 months a partial denture was worn by the patient as a temporary prosthesis to cover the dental defect. If necessary during the healing period the partial denture was adjusted to fit to the defect for example with the application of a soft liner into the partial denture. After the healing period of 6 months uncovering of the implant and placement of a temporary suprastructure, being an acrylic crown, was performed. Patients were allowed to wear their partial denture during eating or to eat solid food during a period of 6 months between the insertion of the implants and the placements of the temporary crowns.

After abutment connection all patients were subjected to oral hygiene instructions. They visited the dental hygienist regularly for oral hygiene inspection. If necessary, oral hygiene instructions were given.

Prosthetic Procedure

A provisional acrylic dental crown with an adequate emergence profile was placed at the day of uncovering of the implant to guide and shape the peri-implant tissue prior to definitive restoration.[34] The provisional acrylic crowns were custom made in the laboratory by the dental technician and consisted of a titanium temporary post (RN synOcta® post, Institut Straumann AG, Basel, Switzerland) and veneering composite (Solidex, Shofu, Tokyo, Japan). The provisional crowns were screwed directly onto the implant and tightened to 15 Ncm using a torque control device. One month later a definitive crown was constructed. The definitive crowns were placed by an experienced prosthodontist and consisted of an abutment (RN synOcta® 1.5 mm abutment, Institut Straumann AG), a cast-on gold coping for contouring of an ideal emergence profile and adaption of the margin to the mucosal contour (gold coping, Institut Straumann AG) and a porcelain crown with a zirkoniumoxide core (Procera®, Nobel Biocare, Göteborg, Sweden). The synOcta® abutment was screwed directly into the implant with a tightening force of 35 Ncm; the gold coping was screwed onto the abutment with a tightening force of 15 Ncm; and the porcelain crown was cemented onto the gold coping. After crown placement careful oral hygiene instruction with emphasis on how to clean the implant region was given to all patients.

Clinical Analysis

From the first day patients visited our clinic until 5 years after the first surgical treatment session (augmentation), every visit to the clinic and all surgical or prosthetic therapeutic interventions were scored using a standardized score list. If a patient had to revisit the same day (e.g., small repair of porcelain crown in the dental lab), it was scored as one treatment session. The average treatment time allocated to a particular variable (indicated in Tables 2–5) was based on the average treatment time for that variable as indicated by three experienced prosthodontists and three experienced oral and maxillofacial surgeons. Only the dental chair time was counted. The received surgical and prosthetic care and aftercare was scored for five well-defined periods.

- Pretreatment period (diagnostic period): time between first appointment and start of the surgical treatment (local bone augmentation). The variables scored included consultation because of demands for implant-retained dental crowns in the maxillary aesthetic region (region of the missing tooth/cuspid/premolar) and reconsultation for treatment explanation and treatment planning.
- Surgical care period: time from start of the augmentation until 2 months after the dental crown was placed. The variables scored included augmentation with chin bone (either with or without Bio-Gide® membrane), augmentation with Bio-Oss® and Bio-Gide® membrane, placing the implant, postoperative care, abutment operation, reaugmentation with chin bone, reaugmentation with Bio-Oss®, replacement of an implant, minor surgical consults (e.g., dehiscence of cover screw, retightening of loose cover screw or healing abutment), surgical consult with treatment (e.g., exploration, abscesses), and fabrication templates (surgical guides).
- Prosthetic care period: time from start of surgical treatment (augmentation) until 2 months after the implant-retained dental crown was placed. The

TABLE 2 Surgical Care Period: Mean Number of Interventions (Mean and Standard Deviation) and Overall Treatment Time (Minutes) per Patient. Between Brackets the Average Treatment Time for a Particular Intervention is Given

	Group I $n = 31$	Group II $n = 31$	Group III $n = 30$	$n = 92$ Total
Augmentation with chin bone (60 minutes; with or without Bio-Gide® membrane)	1.00 ± 0.00	1.00 ± 0.00	0.00 ± 0.00	0.67 ± 0.47
Augmentation with Bio-Oss® (45 minutes; with Bio-Gide® membrane)	0.00 ± 0.00	0.00 ± 0.00	1.00 ± 0.00	0.33 ± 047
Placing implant (45 minutes)	1.00 ± 0.00	1.03 ± 0.18	1.03 ± 0.18	1.02 ± 0.10
Postoperative care (10 minutes)	5.38 ± 1.20	4.76 ± 1.64	5.61 ± 1.79	5.25 ± 1.60
Abutment operation (20 minutes)	1.00 ± 0.00	1.00 ± 0.00	1.03 ± 0.00	1.01 ± 0.10
Reaugmentation with chin bone (60 minutes)	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00
Reaugmentation Bio-Oss® (45 minutes)	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00
Replacement of an implant (45 minutes)	0.00 ± 0.00	0.00 ± 0.00	0.03 ± 0.18	0.02 ± 0.15
Minor surgical consult (10 minutes)	0.26 ± 0.63	0.26 ± 0.58	0.20 ± 0.48	0.24 ± 056
Surgical consult with treatment (20 minutes)	0.00 ± 0.00	0.00 ± 0.00	0.13 ± 0.35	0.04 ± 0.21
Fabrication surgical guide (15 minutes)	2.00 ± 0.00	2.00 ± 0.00	2.00 ± 0.00	2.00 ± 0.00
Total time needed	196 minutes	207 minutes	204 minutes	207 minutes

variables scored included adjustments of temporary partial prostheses (e.g., treatment related to the provisional acrylic crown, removable partial temporary prostheses or adjustments to existing single-tooth prostheses), fabrication of an implant-retained dental crown, oral hygiene support, occlusal adjustments after crown placement, consult without treatment (e.g., complaints of bad esthetics, fear for loose implants), and consult with treatment (e.g., sharp edges, gingivitis).

- Surgical aftercare: time from 2 months after placement of the implant-retained dental crown until 5 years after augmentation. The variables scored included removal of the implant, reaugmentation with chin bone, reaugmentation with Bio-Oss®, replacement of an implant in case a non-osseointegrated implant was lost (session implant added), palatal grafts, gingivectomy, flap treatment of triangle shaped bone deformities around the implant, consult without treatment

TABLE 3 Surgical Aftercare Period: Mean Number of Interventions (Mean and Standard Deviation) and Overall Treatment Time (Minutes) per Patient. Between Brackets the Average Treatment Time for a Particular Intervention is Given

	Group I $n = 31$	Group II $n = 31$	Group III $n = 30$	Total $n = 92$
Removal of implant (30 minutes)	0.00 ± 0.00	0.03 ± 0.18	0.00 ± 0.00	0.01 ± 0.10
Reaugmentation chin bone (60 minutes)	0.00 ± 0.00	0.03 ± 0.18	0.00 ± 0.00	0.01 ± 0.10
Session implants added (45 minutes)	0.00 ± 0.00	0.03 ± 0.18	0.00 ± 0.00	0.00 ± 0.00
Palatal grafts (45 minutes)	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00
Gingivectomy (15 minutes)	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00
Flap treatment (30 minutes)	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00
Consult without treatment (15 minutes)	0.06 ± 0.25	0.26 ± 0.77	0.13 ± 0.34	0.15 ± 0.53
Consult with minor treatment (20 minutes)	0.00 ± 0.00	0.06 ± 0.36	0.07 ± 0.25	0.04 ± 0.25
Session for postoperative care (15 minutes)	0.00 ± 0.00	0.29 ± 1.19	0.03 ± 0.18	0.11 ± 0.70
Session for placing abutments (30 minutes)	0.00 ± 0.00	0.03 ± 0.18	0.00 ± 0.00	0.01 ± 0.10
Removal hyperplasia (15 minutes)	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00
Local gingivaplasty (30 minutes)	0.00 ± 0.00	0.06 ± 0.36	0.00 ± 0.00	0.02 ± 0.21
Average time needed per patient	1 minute	15 minutes	4 minutes	6 minutes

TABLE 4 Prosthetic Care Period: Mean Number of Interventions (Mean and Standard Deviation) and Overall Treatment Time (Minutes) per Patient. Between Brackets the Average Treatment Time for a Particular Intervention is Given

	Group I $n = 31$	Group II $n = 31$	Group III $n = 30$	Total $n = 92$
Adjustments of temporary prosthesis (15 minutes)	3.19 ± 0.91	3.44 ± 1.68	4.41 ± 1.54	3.69 ± 1.47
Fabrication implant crown (90 minutes)	1.00 ± 0.00	1.03 ± 0.18	1.00 ± 0.00	1.01 ± 0.10
Oral hygiene support instructions (10 minutes)	2.22 ± 1.48	1.50 ± 1.34	2.17 ± 1.79	1.96 ± 1.55
Occlusal adjustments after crown placement (10 minutes)	0.00 ± 0.00	0.03 ± 0.18	0.00 ± 0.00	0.01 ± 0.10
Consults without treatment (15 minutes)	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00
Consults with treatment (20 minutes)	0.03 ± 0.18	0.03 ± 0.18	0.23 ± 0.50	0.10 ± 0.33
Average time needed per patient	161 minutes	160 minutes	182 minutes	168 minutes

(e.g., consults because of concerns related to the implant, for example gingiva recession), consult with minor treatment (e.g., problems related to gingivitis), session for postoperative care (removal of sutures, checking wound healing), session for placing abutments, removal hyperplasia, local vestibuloplasty.

- Prosthetic aftercare: time from 2 months after the implant-retained dental crown was placed until 5 years after augmentation. The variables scored included periodic/routine inspections, oral hygiene support, removal of calculus on the crown, recementing crown, repair fractured porcelain from the crown with composites, repair fractured porcelain from the crown in the dental laboratory, fabrication of a new crown, fabrication of a new abutment, consult without treatment (e.g., complaints about discomfort or aesthetics, fear of oral pathology, taste problems, etc), consult with treatment (e.g., smoothening sharp edges), routine inspection after treatment, retightening of loose screws, and adjustment of crown length.

TABLE 5 Prosthetic Aftercare Period: Mean Number of Interventions (Mean and Standard Deviation) and Overall Treatment Time (Minutes) per Patient. Between Brackets the Average Treatment Time for a Particular Intervention is Given

	Group I $n = 31$	Group II $n = 31$	Group III $n = 30$	Total $n = 92$
Periodic routine inspections (15 minutes)	3.59 ± 0.62	3.29 ± 0.89	3.56 ± 0.51	3.48 ± 0.67
Oral hygiene support (15 minutes)	0.71 ± 0.85	0.53 ± 0.87	0.39 ± 0.70	0.54 ± 0.80
Removal of calculus on crown (10 minutes)	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00
Recementing crown (15 minutes)	0.03 ± 0.18	0.00 ± 0.00	0.00 ± 0.00	0.01 ± 0.10
Repair dental crown composite (porcelain chipping; 15 minutes)	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00
Repair dental crown in laboratory (40 minutes)	0.03 ± 0.18	0.00 ± 0.00	0.03 ± 0.18	0.02 ± 0.15
Fabrication new crown (90 minutes)	0.13 ± 0.34	0.13 ± 0.34	0.10 ± 0.31	0.12 ± 0.33
Fabrication new abutment (30 minutes)	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00
Consult without treatment (15 minutes)	0.00 ± 0.00	0.16 ± 0.45	0.13 ± 0.43	0.10 ± 0.36
Consult with treatment (15 minutes)	0.10 ± 0.30	0.00 ± 0.00	0.10 ± 0.31	0.07 ± 0.25
Routine inspection after treatment (10 minutes)	0.03 ± 0.18	0.00 ± 0.00	0.00 ± 0.00	0.01 ± 0.10
Retightening of loose abutment screws (30 minutes)	0.03 ± 0.18	0.00 ± 0.00	0.03 ± 0.18	0.02 ± 0.15
Occlusal adjustment (10 minutes)	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00
Adjustments/fabrication temporary prosthesis (15 minutes)	0.00 ± 0.00	0.23 ± 0.96	0.00 ± 0.00	0.08 ± 0.56
Average time needed per patient	58 minutes	52 minutes	53 minutes	54 minutes

Statistical Analysis

The data were analysed using *t*-tests for the continuous data and Mann-Whitney tests for the ordinal data (SPSS for Windows, version 10.0, SPSS Inc., Chicago, IL, USA). In all tests a significance level of 0.05 was chosen.

RESULTS

Ninety two patients completed the 5-year follow-up; one patient was lost for follow-up because of implant loss during the osseointegration period (group III). Reimplantation in that particular patient was not done for patient-related personal reasons. For patient characteristics, see Table 1.

Pretreatment Period

On the average patients needed one session for consultation (20 minutes) and one session for reconsultation (15 minutes).

Surgical Care and Aftercare

Surgical care predominantly consisted of augmentation, fabrication of a surgical guide, placement of an implant, abutment connection, and postoperative care (see Table 2). In total three implants were lost (one in group II, two in group III), resulting in a 5-year survival rate of 96.7%. Two implants were lost during the osseointegration period and were removed during abutment connection. One of them was replaced successfully by a new implant; the other implant was not replaced for personal reasons of the patient. The third implant was removed after 3 years because the extended loss of buccal bone had resulted in bad aesthetics. The dark metal implant edge was visible when the patient smiled. After removal of the implant, the implant side was reaugmented with bone from the mandibular ramus region. After a healing period of 3 months, the implant was replaced. In group III, four minor complications occurred during the surgical care period requiring surgical intervention, namely, an abscess developed related to a loose cover screw, a fistula occurred because of a imperfect fit of the dental crown to the implant, and in two cases a local inflammation developed related to a dehiscent membrane or loose spongiosa granules, which recovered spontaneously after removal of the membrane or loose granules. On average, patients needed five sessions for postoperative care. Surgical aftercare was hardly needed and was limited to a local gingiva plasty to correct a gingiva retraction (group II) and a flap treatment for peri-implantitis (group III) (see Table 3). No significant differences were observed in the patients' need for aftercare among groups I, II, and III.

Prosthetic Care and Aftercare

Prosthetic care consisted mainly of adjustments of the temporary prosthesis (adjustments to or repair of existing temporary prostheses, loosening temporary acrylic crowns, etc), fabrication of an implant-retained dental crown, and sessions for oral hygiene support (see Table 4). Prosthetic aftercare was hardly needed and consisted of periodic routine inspections, supplemental oral hygiene support, and the fabrication of new dental crowns (see Table 5). In 12% ($n = 11$) of the patients in whom a new crown had to be made (four in group I, four in group II, and three in group III), the main reason (36%, $n = 4$) for making new crowns was related to the aesthetics of the crown (e.g., color, shape). Other reasons were explantation followed by reimplantation because of buccal bone loss ($n = 1$), fracture of porcelain as a result of drilling a hole in the crown to retighten a loose screw ($n = 1$), porcelain fracture ($n = 1$), imperfect fit ($n = 1$), and unknown ($n = 2$). No significant differences were noted between the groups.

Average Overall Treatment Time

During the 5-year period, the patients needed on average 24.7 ± 4.1 (range 18–34, median 23) treatment sessions and 436 minutes of treatment time (Table 6). Most sessions were needed during the care period (20.7 ± 3.7 sessions), whereas rather few sessions (3.6 ± 0.7 sessions) were needed during the aftercare period. No statistical differences were noted between the groups.

DISCUSSION

This study assessed the need for care and aftercare related to implant-retained dental crowns in the aesthetic maxillary region in patients who needed bone augmentation before placing the implant. Additionally, the differences between three treatment modalities for augmenting the implant area were compared. According to the results from this study, it is obvious that placing an implant in the maxillary esthetic region to retain a dental crown is a safe and reliable treatment option. Moreover, the need for surgical and prosthodontic

TABLE 6 Total Time Needed for Care and Aftercare (Minutes)

	Group I *n* = 31	Group II *n* = 31	Group III *n* = 30	Total *n* = 92
Surgical care period	196	207	204	208
Surgical aftercare period	1	15	4	6
Prosthetic care period	161	160	182	168
Prosthetic aftercare period	58	52	53	54
Total	416	433	443	436

(after) care was irrespective of the augmentation procedure applied.

Surgical Care and Aftercare

In many cases of a missing tooth in the maxillary aesthetic region, there is a need to perform a local augmentation of the alveolar ridge to enable reliable implant placement. In this study only patients needing pre-implant surgery before placement of the implant were included. By using this approach, we were able to evaluate the complete range of events that might occur when rehabilitating a patient with an implant-retained dental crown, that is, from local augmentation until the end of the 5-year follow-up. Moreover, in the current study, only calculations were made for dental chair time from the moment that the surgical treatment (local bone augmentation) was started. Other time investments and costs, for example, administration, treatment planning, (dental) technical labor, and making radiographs, were not included in this study. This was done to present the need for care and aftercare of an implant-retained dental crown as clear-cut as possible. As currently, for example, cone beam computer tomography (CBCT) is more commonly used during the diagnostic and planning phase, it becomes easier to select those cases in which no pre-implant placement augmentation procedure is needed or in whom even flapless surgery might be possible. Theoretically, this would have had an impact on total time needed for an implant-retained single-tooth replacement, for example, by needing more time in front of the computer for planning, but less time for surgery in a particular patient. However, in the current study no borderline horizontal bone deficiencies were included as all deficiencies had to be class 4 defects that, according to Misch and Judy,[31] need bucco-palatinal local ridge augmentation. As such, the application of CBCT, if available at the inclusion stage of this study, would not have shown to be a time sparing, but would have been a time consuming procedure.

The 5-year implant survival rate was 96.7%. One implant had been removed because of buccal bone loss, the other two implants were lost during the osseointegration period. This survival rate is in line with the implant-loss kinetics reported in the systemic review of the literature by Den Hartog and colleagues[29] showing that the far majority of the implants that failed were lost within the first 6 months after installation.

Although there is a minor tendency of more surgical complications in group III, there is no significant difference in overall treatment time between the three groups. This is caused by the fact that less treatment time is needed for augmentation with Bio-Oss® compared with chin bone.

Prosthetic Care and Aftercare

Prosthetic care was much more time-consuming than prosthetic aftercare. Regarding prosthetic aftercare it was noticeable that the need for aftercare was mainly related to routine inspections, oral hygiene support and occasionally to fabrication of new dental crowns. New crowns were predominantly needed in patients who disliked the aesthetics. This is not a surprising finding as in their systematic review of the literature on single-tooth implants in the aesthetic zone, Den Hartog and colleagues[29] mentioned that in the few studies that assessed the aesthetic outcome, a large subset of the patients judged the aesthetics of the implant-retained crown as poor.

In our study, loosening of abutment screws was negligible. This is in contrast to the common opinion in the literature as it is often mentioned that abutment screw loosening (and thus loose crowns) is an often seen complication (up to 48%),[2,13,26,35–37] but in agreement with Palmer and colleagues[38] who observed no cases of abutment screw loosening. In our study we used the

torque controller to tighten the screws as tight as possible as also suggested by Haas and colleagues.[39] In addition, we used the ITI Esthetic line implant that has internal abutment connection, the so-called internal octagon. The ITI Esthetic line implant has this internal abutment retention instead of external abutment retention as was applied in for example older conventional Brånemark implants (Brånemark, Nobel Biocare). The inner configuration of the ITI Esthetic line implant was designed to prohibit rotation that might reduce the risk of getting loose screws.

Although a loose screw did not occur frequently in our patient cohort, it has to be noted that the loosening of crowns can cause soft tissue problems.[13] In addition, regarding cemented crowns the abutment screw can only be reached by drilling a hole into the crown, which can weaken the crown or result in aesthetic problems in case the drilling hole is in the buccal area. Also fracture of the porcelain can occur. In our study, this was the reason a new crown had to be made in one patient. Retrievability is the main advantage with screw retention, whereas cementation may provide better aesthetics in situations with somewhat unfavorable implant placement.[40] Cicciù and colleagues[41] reported on the results of a study comparing screw retained implant prostheses with cemented-retained implant prostheses. The survival rate for cemented retained prostheses was 98.4 versus 100% for screw-retained prostheses.

Oral hygiene support was sparsely supplied in both the care and aftercare period. In the care period all patients were seen on average twice by an oral hygienist to give oral hygiene instructions. In the aftercare period on average one out of every two patients received one session for oral hygiene care. Moreover, removal of calculus on the implant crown was not needed. Referring to Visser and colleagues[42] this might be considered a remarkable result as they concluded from their study that prosthetic aftercare for patients provided with an implant-retained maxillary overdenture mainly consisted of intensive oral hygiene care. The good results in the current study might be related to the fact that only patients with a good oral hygiene and a healthy periodontal situation were included. On the other hand one can not deny that patients treated with an implant-retained dental crown in the aesthetic region of the maxilla are dissimilar from patients treated with an implant-retained maxillary overdenture. The latter group of patients is significant elder and most of them had lost their teeth because of caries and periodontal diseases in contrary to the former group who consisted mainly of youngsters who had lost their tooth in nearly two-thirds of the cases to a trauma. In general, these youngsters are probably keener with their dentition and are more used to maintain a good oral health. This is in agreement with the observation that oral hygiene support is hardly needed.

CONCLUSION

According to the results from this study it can be concluded that placing an implant in the maxillary esthetic region after local bone augmentation with or without the use of a Bio-Gide® membrane, to retain a dental crown is a safe and reliable treatment option not needing much specific aftercare other than periodic preventive routine inspections, routine oral hygiene care, and fabrication of a new crown in one out of every eight to nine patients in 5 years. Moreover, more then three-quarters of the overall treatment time was needed for surgical and prosthetic treatment and the need for care and aftercare was irrespective of the preimplant surgery procedure applied (chin bone with or without the use of a Bio-Gide® membrane and Bio-Oss® with the use of a Bio-Gide® membrane).

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